

# Energy Service Contracting: An Economic Perspective

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# Abstract

Energy service contracting consists in the outsourcing of energy-related services to a contractor, an Energy Service Company (ESCO), through a long-term contract. This business model has been deemed, in the literature, a promising market-based instrument to foster the deployment of renewable energy and energy conservation projects. This thesis examines empirically the determinants of adoption of energy service contracting and their underlying economic mechanisms. After a general introduction including a critical literature review, the first chapter focuses on adoption of energy supply contracting (ESC), while the second chapter examines the willingness to opt for energy performance contracting (EPC). The last chapter assesses how new energy policies could expand the supply-side of ESC and EPC. The analyses are based on three original datasets, including real contractual choices and two stated choice experiments targeted at the potential demand and supply of the energy service contracting market. The empirical evidence suggests that risk sharing is an important determinant of the client's adoption. Economies of scale and trust have also an impact, while the financing from the ESCO has a positive effect only for a minority of energy consumers. The transaction costs involved in these contracts are exacerbated by the number of decision-makers involved. On the supply side, only important changes in the energy market, such as the implementation of White Certificates or an increase in the demand of energy contracting from both public and private clients, have a significant impact on the willingness to enter the ESCO market. Using original empirical methods, this PhD thesis provides new insights in the mechanisms that could foster the diffusion of these contracts and exploit their potential in the energy transition and in business opportunities.

***Keywords: energy service contracting, energy efficiency, renewable energy, risk sharing, transaction cost economics, energy service company (ESCO)***

# Résumé

Les contrats de services énergétiques consistent à externaliser au travers d'un contrat de longue durée la provision et l'optimisation de services d'énergie à un contracteur, nommé ESCO (Energy Service Company). Ce modèle d'affaire est perçu dans la littérature comme un instrument de marché prometteur pour déployer des projets liant énergie renouvelable et économies d'énergie. Cette thèse étudie empiriquement les déterminants d'adoption des contrats de service énergétique et les mécanismes économiques sous-jacents. Faisant suite à une introduction générale contenant une revue critique de la littérature, le premier chapitre se concentre sur l'adoption des contrats de fourniture énergétique, alors que le second chapitre examine la volonté d'opter pour des contrats de performance énergétique. Le dernier chapitre explore comment de nouvelles politiques énergétiques pourraient étendre l'offre de ces contrats. Les analyses reposent sur trois bases de données inédites, découlant de choix contractuels réels et de deux expériences à choix (préférences exprimées) ciblant la demande et l'offre potentielles sur le marché des contrats de services énergétiques. L'analyse empirique montre que le partage du risque est un déterminant important dans le choix du client d'adopter de tels contrats. Les économies d'échelle et la confiance ont aussi un impact, alors que le financement par l'ESCO a un effet positif seulement pour une minorité. Les coûts de transactions de ces contrats sont exacerbés par le nombre de décisionnaires impliqués. Du côté de l'offre, seuls d'importants changements sur le marché de l'énergie, par exemple l'introduction de certificats blancs ou une augmentation de la demande de contracting de la part des clients privés et publics, ont un impact significatif sur l'offre. En se basant sur des méthodes empiriques inédites dans le domaine, cette thèse de doctorat offre de nouvelles perspectives sur les mécanismes susceptibles d'étendre la diffusion de ces contrats et ainsi exploiter leur potentiel dans la transition énergétique et les opportunités commerciales.

*Mots-clés: Contrats de service énergétiques, efficacité énergétique, énergies renouvelables, partage du risque, économie des coûts de transaction, ESCO*

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# Abbreviations

ESC	Energy Supply Contracting
EPC	Energy Performance Contracting
ESCO	Energy Service Company
ANA	Attribute non-attendance



# Introduction

## 1 Motivation

The Swiss authorities are considering to progressively abandon nuclear power while ensuring security of energy supply via a smooth transition to a sustainable and low carbon economy. In this context, it is crucial to attract sufficient investments in both renewable technologies and energy efficiency. The success of the energy policy programs will depend on the extent to which they can identify and overcome market barriers to investment. Thus, the potential of instruments such as energy contracting in Switzerland should be explored.

Energy service contracting is considered as a market-based instrument that can facilitate investments in renewable and efficient energy services and combines business opportunities with social benefits. These contracts have resulted in important energy savings (Soroye and Nilsson, 2010; Goldman et al., 2012) and investment in innovative renewable energy systems (Bleyl, 2011). In 2011, the aggregate revenues for the contractors were estimated to reach \$5 billion in the US (Gilligan, 2011), and 3.5 to 5 billion Euros in Germany in 2013 (Bertoldi et al., 2014).

Yet, the potential of energy service contracting does not seem to be fully exploited (Backlund and Thollander, 2011). In most countries indeed, these contracts have been applied only to large energy consuming buildings in specific market segments (Backlund and Thollander, 2011; Pätäri et al., 2016). In Switzerland, despite strong financial institutions and credit-worthy private and public institutions, the Energy Supply Contracting market has experienced a slow growth while Energy Performance Contracting has only recently started to emerge.

This PhD thesis intends to answer the following question: What are the determinants, and the underlying economic mechanisms, for adoption of energy service contracting? While the literature on energy contracting is wide and has benefitted from the contribution of experts coming from many fields such as engineering, business management, public policy, physics, law or finance, this thesis focuses on the economic perspective and uses econometric tools to answer this question. More

specifically, the determinants of energy service contracting are explored using economic theories on vertical integration, transaction cost economics, risk sharing, access to capital and economies of scale. This thesis uses empirical evidence from both the demand side and the supply side of the Swiss market of energy service contracting. The main contribution of this thesis relies on the original datasets and on the econometric methods used to explore energy service contracting adoption, namely discrete choice experiments.

This introductory chapter provides a critical review of the existing literature and exposes the contribution of the thesis.<sup>1</sup> The chapter is structured as follows: the next section reviews the definition and concepts of energy service contracting, as well as the technologies and contractual schemes involved. The interest of energy service contracting is exposed in section 3 and a presentation of the general tendencies on the markets is provided in section 4. A literature review of the determinants of adoption of energy service contracting is provided in section 5 for theoretical contributions and 6 for empirical evidence. The role of the government is discussed in section 7. The contribution of the PhD thesis is then exposed in section 8, and is followed by some concluding remarks.

## **2 Energy Service Contracting**

### **2.1 Definition and concept**

Energy service contracting involves the provision of energy services. Although many definitions of energy services exist in the literature, the relevant definition in the context of energy service contracting is provided by a directive of the European Parliament (Fell, 2017): “Energy service: the physical benefit, utility or good derived from a combination of energy with energy efficient technology and/or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to lead to verifiable and measurable or estimable energy efficiency improvement and/or primary energy savings.”

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<sup>1</sup> Substantial parts of this chapter are based on Klinke et al. (2017).

In this thesis, the conditions under which an activity is considered as energy service contracting, and under which a contractor is considered as an ESCO (Energy Service Company) follow Sorrell (2005): “A necessary feature of an energy service contract appears to be the transfer of decision rights over key items of energy equipment under the terms and conditions of a long-term contract, including incentives to maintain and improve equipment performance over time.”

Firms, public communities and house-owners usually outsource some of the activities related to the provision of energy services. However, these activities are considered as energy contracting only if the contractor has decision rights over the installations and/or the operation and an incentive to optimize equipment performance once the equipment is installed. As a result, conventional projects of construction or retrofit where the contractor or the engineer is paid at project delivery are not considered as energy service contracting, since the contractor is not involved in operating the installation and there is no long-term contract.

Energy service contracts involve at least two parties. The clients are typically the owners of the building. The contractors are called Energy Service Companies (ESCOs), which are typically energy utilities, energy equipment and appliances providers, facility managers or general companies.

The literature often refers to two different types of energy contracting: Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC) that are defined in the following sections.

## **2.2 Energy Supply Contracting (ESC)**

ESC, also called Delivery Contracting (DC) (Marino et al., 2011), covers usually one or more streams of useful energy (e.g. steam/hot water, coolant, electricity), but the contractor exerts no or little control over the demand of energy services (e.g. room heating, ventilation, lighting). In these contracts, the ESCO typically has no incentive to reduce energy service demand because it is usually paid by an indexed unit price for delivered energy plus a fix amount for the equipment. Helle (1997) presents the main characteristics of ESC: “The characteristics feature of that type of contracting is to be found in its shifting the interface between energy suppliers and energy

consumers by one (conversion) stage along the energy chain (primary energy - final energy -useful energy -energy services). While with the traditional energy market structure the interface between energy supplier and energy consumer is placed at the stage of supplying final energy, contracting from the energy supplier's point of view constitutes a forward integration."

The characteristics given by Helle (1997) imply that the adoption of ESC by the client consists in some way in outsourcing useful energy provision to an ESCO. This remark has been used by Sorrell (2007) to relate the decision to opt for ESC to the literature of vertical integration and transaction costs economics. This framework applied to the ESC choice will be reviewed in a following section.

Another general characteristic of ESC relies on the fact that the ESCO keeps the ownership of the installation during the contract's duration.

Energy supply contracting in Europe mostly promotes energy efficiency, renewable energy provision or innovative technologies for the delivery of heat (Bleyl, 2011). These types of contracts often involves technologies for the production of heating, hot water or cooling, such as heat pumps, biomass heating (pellets or woodchips), or solar (thermal).

### **2.3 Energy performance contracting (EPC)**

Energy performance contracting delivers energy savings to the building owner. The basic principle of EPC is that a contractor assesses, develops and finances energy efficiency measures. By monitoring the technical installations, the contractor provides its client with a reduction in energy costs in exchange for a fixed fee or part of the savings achieved. The contractor finances the equipment or guarantees energy savings to the building owner. EPC differs from ESC in the fact that the contractor does have an influence on the demand of energy services and delivers energy savings to the client. Typical measures proposed within EPC are efficient lighting, heating control systems, energy automation systems, and occasionally improved insulation of the building envelope and combined heat and power (CHP) systems (IEA-RETD, 2013). The two dominant EPC models are shared savings and

guaranteed savings (Hansen, 2006), which are mainly differentiated by the financing characteristic:

- *Shared savings*: the ESCO typically finances or receives financing by a third party in order to design and implement the project. Energy cost savings are then shared between the two parties.
- *Guaranteed savings*: In this model, the client carries the financing or gets financing by a third party. The ESCO guarantees that the energy saved will meet a certain threshold. Otherwise, the ESCO reimburse the difference. In these types of contracts, the ESCO is typically paid a fixed fee.

The fact that the ESCO is paid or provides guarantees according to the savings achieved obliges the two parties to agree on the measurement and verification methods of the outcome.

Other EPC schemes exist and can mix the characteristics of shared savings and guaranteed savings. The methods of financing are flexible and can involve a share of the actions financed by the ESCO while the rest is invested by the client. An additional actor such as an investor can also be part of the contract, as in the *forfeiting* scheme (swissesco, 2016). In this scheme, the investor finances partly or completely the installation and gets in return a corresponding predefined fixed share of the savings (from the client or the ESCO). As in the guaranteed-savings scheme, the client also pays a fixed fee to the ESCO which provides in return a guarantee on the energy savings achieved. In practice, it is also possible to see more comprehensive contracts that combine characteristics of both ESC and EPC. For instance, EPC can involve the financing of renewable energy technologies, such as solar photovoltaic systems, thermal collectors or heat pumps. ESC can also include quality insurance for energy efficiency measures as in the so-called Integrated Energy Contracting model (Bleyl, 2011).

## **2.4 ESC versus EPC**

ESC provides energy delivery while EPC provides energy savings. This results in the fact that ESC often includes renewable energy technologies while EPC rather focuses on equipment increasing energy efficiency. While the contractor is required to

decrease energy costs in EPC, there is no mean or incentive to reduce the energy consumption in ESC.

Despite this main divergence, the two types of contracts are closely related. First, both ESC and EPC provide risk sharing mechanisms. This is the case even if different risks prevail in each type: risk related to energy provision and renewable energy for ESC and risk related to energy savings for EPC.

Second, as both types of contracts can involve financing from the ESCO, they can both be seen as financing mechanisms.

Thus, the economic theory underlying the client's choice to opt for ESC or EPC is comparable (Sorrell, 2007). EPC and ESC are operating on the same supply chain of energy services, although EPC can be seen as a variant of ESC which goes deeper in terms of the ESCO's control on the energy distribution process.<sup>2</sup>

These similarities justify the interest of discussing the results in the contexts of both ESC and EPC in this PhD thesis. For instance, while chapter 1 focuses on ESC, EPC literature will still be discussed throughout the chapter. In this case, it is also relevant because the empirical literature on ESC adoption is inexistent while already wide on EPC, thus bringing insights into my empirical investigation.

A brief literature review on the interest of energy service contracting in the context of renewable and energy efficiency is further discussed in the next section.

### **3 The interest of energy service contracting**

#### **3.1 Renewable energy and the role of ESC**

Investment in the development and production of small scale renewable technologies has been seen earlier in the literature as sub-optimal, due to barriers such as lack of access to capital, missing information and awareness, and restricted access to technology at a reasonable price (Painuly, 2001).

In particular, many small-scale renewable technologies for heating and cooling are produced by SMEs that cannot reach the critical level to benefit from economies of

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<sup>2</sup> See Sorrell, 2007 for a diagram explaining the energy distribution process.

scale (IEA-RETD, 2013). Moreover, the uncertainty concerning new technologies may bias consumers' decision towards status quo or may imply that it is rational for consumers to delay investments. In this case, the literature calls this phenomenon irreversibility (Pindyck, 1991; Dixit and Pindyck, 1994).

Finally, any reasonable diffusions of renewable energy, let alone a mass-market development, depend also on the success of energy utilities to identify and exploit the potential market niches with a relatively high willingness to invest. However, the interested companies might be unable to identify and target the relevant potential customers. Indeed, although existing research shows positive willingness to pay for green energy (Borchers et al., 2007 among others), empirical evidence suggests that the estimates are highly heterogeneous across individuals and technologies (Borchers et al., 2007; Scarpa and Willis, 2010). As a result, while renewable technologies are significantly valued by consumers, for the vast majority of them this value is not sufficiently large to cover the capital costs of micro-generation energy technologies without any kind of financial or regulatory support.

ESC is typically used by customers to install new equipment that often involves renewable and/or innovative technologies such as co-generation systems (Bleyl, 2011). However, there has been no attempt in the literature to empirically prove that ESC promotes investments in renewable technologies. The impact of EPC, on the other hand, has been explored by Okay and Akman (2010) and Fang and Miller (2013), who analyse its influence on CO<sub>2</sub> emissions<sup>3</sup>. First, Okay and Akman (2010) use the ESCO markets' study of Vine (2005) on 38 countries to analyze pairwise correlations between ESCO indicators, such as the age of EPC market, the number of ESCOs and the total value of ESCO projects, and country indicators, such as GDP per capita, CO<sub>2</sub> emissions and energy consumption. They find positive correlations between ESCO indicators and CO<sub>2</sub> emissions and conclude that this suggests that ESCO projects are either not necessarily targeted to emission-reduction or that the market is unsaturated in most countries observed. Fang and Miller (2013) reach an opposite conclusion using a panel of 129 countries from 1980 to 2007. Using a GMM

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<sup>3</sup> Vine (2005), Okay and Akman (2010), Fang and Miller (2013) use the general term of ESCOs to refer to companies that are engaged in performance-based projects. Even if they also account for projects involving renewable energy, it is plausible to consider that they refer to EPC rather than ESC in their research.

estimation method, they find a negative impact of the existence of ESCO activities on CO<sub>2</sub> emissions that increase over time. Nevertheless, the results from both studies may still suffer from endogeneity problems and unobserved heterogeneity across countries.

As a result, there is no reliable empirical proof in the existing literature that energy contracting has a causal negative impact on CO<sub>2</sub> emissions and more precisely, that energy contracting promotes investment in renewable energy. This is the case even if many authors have argued that investments in renewable technologies are promoted because energy contracting, and especially ESC, can reduce some of the barriers aforementioned. For instance, Sorrell (2005) argues that ESC allows the client to transfer some risk onto the ESCO, thus reducing uncertainty linked for instance to the technical aspects of new technologies. Also, the customer can concentrate on core activities while finding a way to reduce his lack of technical knowledge or access to capital (Sorrell, 2005; Painuly, 2001; IEA-RETD, 2013). Moreover, the long-term contract and the incentive it creates for the ESCO to maintain equipment performance during the contract implies that ESC is an “instrument to minimize life-or project cycle cost, including the operation phase of the building” (Bleyl, 2011, p. 185). As a result, limited access to innovative and renewable technology at a reasonable price, as stated by Painuly (2001), may actually be overcome by ESC. This opinion is supported by Eikmeier et al. (2009) who explore the advantage of ESC over in-house energy provision, once an old heating system is replaced. Using query of contracting companies and telephone interviews with selected market participants, they find that “contracting enables to counter successive declines of the annual use efficiency over the heater lifetime roughly 4% better on average than in-house solutions”. Sorrell (2007) argues also that ESC can reduce significantly technologies’ prices since competitive bidding induces the ESCO to minimize production and operation costs. Conversely, when the energy supply is managed in-house, incentives of market competition are not present, unless such incentives are provided by an internal management mechanism (Irrek et al., 2005; Capelo, 2011). Then, Sorrell (2007) asserts that access to expensive, promising or new technologies can be achieved at reasonable price thanks to the economies of scale that ESCOs experience. Indeed,

while he observes that organizations usually lack the scale to implement large energy projects, the ESCOs, through specialization and contracting with multiple clients, can reach significant economies of scale.

While citing all these apparent advantages provided by ESC, it is to be kept in mind that a contract also incurs transaction costs. Indeed, while contracting is expected to reduce overall production costs as compared to in-house procurement, the overall transaction costs are also expected to increase (Capelo, 2011). Even if this argument has been used by Capelo (2011) about EPC, this also applies to ESC where the client must gather information about the ESCO and the implications of the contract, which comes at a cost (Sorrell, 2007).

Finally, no author has argued that ESCOs are more effective than conventional energy providers to target and reach customers with high willingness to pay for renewable energy.

To summarize, although the existing literature suggests that there may be several channels through which energy contracting may support and induce investment in innovative and renewable technologies, there is hardly any empirical attempt to support these conjectures. Nevertheless, the apparent success of the ESC markets in Europe to supply cost-effective projects with innovative and renewable technologies (see for instance Bleyl, 2011) suggests that the ESCOs attracted a significant part of the consumers interested in investing in these technologies.

In this context, exploring the relative importance of the mechanisms of ESC adoption would permit to propose contracting options that focus primarily on these important features, in order to develop further the ESC market and attract more customers who invest in promising renewable technologies. This represents the motivation of my first chapter of my PhD thesis, which assesses the mechanisms of ESC adoption.

### **3.2 Energy efficiency**

In order to understand how energy service contracting may have a role to play in energy efficiency, it is important to review the literature and the concepts underlying the energy efficiency gap. The literature in this domain is important because it gives insights on how the barriers to energy efficiency could be mitigated. These barriers

could also exist in the context of renewable energy. The objective is then to review the literature on the role of energy service contracting in this domain. Nevertheless, because this PhD thesis does not aim to explore in detail the concept of the energy efficiency gap, the present chapter proposes a summary of the literature, which does not pretend to be exhaustive.

Experts' interest in energy efficiency investments started with Hausman (1979). By comparing the capital costs with the expected operating costs, Hausman (1979) estimated an implied discount rate of approximately 20% - well above the rates at which most individuals borrowed or invested money. Hausman's observation that individuals do not seem to invest optimally in energy efficiency, or as stated by Jaffe and Stavins (1994), the existence of an *energy efficiency gap*, has given rise to an important literature (See Gillingham and Palmer, 2013). The potential reasons of this gap, among which market failures, have been analyzed in the literature, although its size remains unclear and the relative importance of its causes unknown.

The gap may take different definitions across studies. Engineering studies typically compare the amount of energy efficiency investments presenting positive net present values with the current level of investments (See for instance EPRI, 2009; McKinsey Company, 2009). On the other hand, economists define the gap as the difference between what is optimal from the consumer's perspective and what is actually invested (Gillingham and Palmer, 2013). A larger definition of the gap covers the difference between the socially optimal investment level in efficiency and the current level of investment. This chapter considers this wider definition, in order to analyze the role of energy service contracting in energy efficiency in general.

Several market failures can explain the energy efficiency gap as defined by the economists. While it has been argued in the literature that all these causes are playing a significant role in the energy efficiency gap, there has been hardly any attempt to compare the sizes of their impact on the sub-optimal investment.

- **Split incentives** may arise because the up-front costs are not paid by the individual who benefits from lower energy costs (IEA-RETD, 2013). Both theoretical models and

empirical evidence show that this results in under-investment in energy efficiency.<sup>4</sup> Split incentives can occur between landlords and tenants, as well as within a firm.<sup>5</sup> The landlord-tenants split incentives is of particular importance in the Swiss context where only 37% of the dwellings were inhabited by their owners in 2010 (OFS, 2013).

- **Imperfect information** may prevent the investor from appropriately assessing *ex ante* the potential of an investment (Tietenberg, 2009; Gillingham and Palmer, 2013). Gathering the necessary information about the differences in quality of these investments may also be too costly (Allcott and Greenstone, 2012; Sorrell et al., 2004).
- **Limited access to capital or credit constraints** has been cited as a market failure characterizing investments in energy efficiency, in cases where the lender cannot distinguish between good or bad credit risk borrowers (Gillingham and Palmer, 2013). This phenomenon is exacerbated if borrowers with a high energy savings potential have poor credit risk profiles (Palmer, Walls and Gerarden, 2012). Other constraints may prevent entities from investing in energy efficiency, such as debt ceilings (particularly affecting the public sector) or limited budget for non-core activities (in the case of private firms). In the latter case, firms may be reluctant to find external financing for investments that are not directly linked to the core-business (Hansen, 2006) and even if internal capital is available, the energy efficiency project may be considered less strategic than other investments (Cooremans, 2011). Finally, investors may be insufficiently informed about the financing options or subsidies available when making their decisions (IEA-RETD, 2013).
- **Regulatory failures** correspond to divergences between electricity prices and marginal costs, resulting from economic regulation of electricity markets, which may distort incentives to invest in energy efficiency and increase the gap when the price falls below marginal cost (Gillingham and Palmer, 2013). However, this effect may be only temporary since prices can also rise above the marginal cost, creating positive incentives to invest. Jaffe and Stavins (1994) argue that these potential distortions do not relate to the energy efficiency gap, since regulatory failures do not help in explaining non-adoption at current prices.

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<sup>4</sup> See Murtishaw and Sathaye (2006) and Davis (2010) for empirical evidence and the appendix of Gillingham et al. (2012) for a formal explanation.

<sup>5</sup> Within firms, split incentives may arise when the department which is in charge of investing in building technologies and the department who has to pay for the energy costs are separated and also have separated financial accounting.

- Finally, the energy efficiency gap has also been explained by the fact that consumers do not necessarily act according to the standard assumptions underlying the neoclassical economic theory. Gillingham and Palmer (2013) describe in detail the related behaviors that they call **behavioral anomalies**, such as loss aversion (Greene et al., 2009) or a systematic undervaluation of discounted future energy costs (Allcott and Wozny, 2012). Limited attention or non-standard decision-making processes lead individuals to simplify the decision by focusing only on certain attributes when making a choice or to stick to familiar or salient options.<sup>6</sup>
- Other insights may be brought into the energy efficiency gap literature by exploring how other **non-financial considerations** affect the decision to invest in energy efficiency (Cooremans, 2011; Cooremans, 2012), such as power relationships within the firms or the firm's strategy. The investment category in terms of analytical characteristics and scope is also likely to play a major role in the firm's decisions. The analytical characteristics of an investment include the impact, the level of risk, the financial return, the solutions available, the number of actors and the incentive to invest. The scope on the other hand defines whether the investment is related to the core-business or not. Therefore, not only the profitability matters in the investment decisions, but also its strategic component in terms of increasing the competitiveness of the core-business (Cooremans, 2011; Cooremans, 2012). One should also consider the fact that the firms are likely to have different criteria of decision depending on the type of investment. Investments related to the core-business may be typically evaluated using profitability criteria such as net present value. But, the decision-making process may be different in the case of investments that are not directly related to the core-business, such as investments in energy efficiency. In these cases, other requirements (rate of return) or other criteria (payback time) may apply.

Several other elements may explain why seemingly cost effective investments in efficiency are not undertaken. These elements represent the difference between engineering measures and the gap considered by the economists:

- First, the **heterogeneity across energy consumers** may imply that the net present value of an investment may be positive for the average consumer, but negative for a majority of individuals (Jaffe and Stavins, 1994; Allcott and Greenstone, 2012).

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<sup>6</sup> This has been studied in other contexts, such as consumption practices on eBay (Hossain and Morgan, 2006). Sensitivity to the framing of choices, whereby the presentation of choices can affect significantly the decision (Duflo et al., 2005), are also cited as having an impact on the energy efficiency gap (Gillingham and Palmer, 2013).

- Second, engineering studies fail to account for **hidden costs**, such as the discomfort linked to some technologies or the opportunity costs, which represent the return of any alternative investment that the consumer forgo when investing in energy efficiency. These opportunity costs may be particularly important for firms where the part of energy in production costs often represents a small share of 2-5%, implying that investments on the production process are well more interesting than energy efficiency (Hansen, 2006). Uncertainty about future energy prices and risk due to the irreversibility of the investment may also imply that it is rational for consumers to delay their investments in energy efficiency (Dixit and Pindyck, 1994) and thus lead to an overestimation of the energy efficiency gap in engineering studies.
- The **risk** inherent to energy efficiency investments reduces the number and amount of investments undertaken in energy efficiency (Anderson and Newell, 2004) and may explain the high implicit rates observed by Hausman (1979). Risk stems from financial or technical uncertainties. In the former case, it relates to unexpected realization costs or future energy price variations. The technical risk in energy efficiency investment relates to unexpected technical failures of the equipment, under-performance or uncertain energy savings. Based on 50 retrofitted residential multifamily buildings in Switzerland, Khoury and Hollmuller (2017) find that realized energy savings do not meet the expected savings, but are instead considerably lower due to a variety of reasons (mismatch between actual use and standards, uncertainty in facility managers and clients behaviour or poor input data quality).<sup>7</sup>
- Then, the estimations do not account for possible **interactions between technologies** if implemented together and often “assume perfect installation and maintenance” (Gillingham and Palmer, 2013). Moreover, the coordination of the different actors involved in energy efficiency projects is very important to guarantee an optimization of the system as a whole (Levine et al., 2007) and may imply significant transaction costs that are not included in these estimates.
- Finally, engineering studies may not account for the fact that expected energy savings can be reduced because of rebound effects, in which wealth effects following the implementation of energy-efficient installations lead the individuals to consume more<sup>8</sup>.

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<sup>7</sup> According to their model, 500MJ/m<sup>2</sup>/year expected savings translate in 310MJ/m<sup>2</sup>/year realized.

<sup>8</sup> See for instance Sorrell and Dimitropoulos (2008) for more details on the rebound effect.

Finally, the optimal level of investment from the consumer's perspective will still be lower than the socially optimal outcome because of externalities. Increasing the actual level of investment in energy efficiency will bring social benefits by decreasing negative externalities.

### **3.3 The role of energy service contracting**

#### *3.3.1 Split incentives*

There has been no attempt in the literature to determine whether and how energy service contracting reduces split incentives. One could argue that the ESCO, or the facilitator, can help tenants to coordinate in order to invest in energy efficiency. The ESCO may also assist potentially interested owners to redirect the costs of energy efficiency investments to the tenants. Nevertheless, I show in the first chapter of this thesis that having tenants is an important barrier to ESC adoption and suggest that the Swiss legal framework regarding the transfer of costs to the tenants should be clarified. In the UK (Nolden and Sorrell, 2016) as well as in the mature US and Canadian ESCO markets (Panev et al., 2014), commercial centers and office buildings represent untapped potential because of the involvement of tenants. While energy service contracting, in its standard form, does not seem to solve split incentives issues, it is possible that energy service contracts with alternative payment schemes are more effective in that sense. Nolden and Sorrell (2016) provide a list of these schemes, such as on-bill financing, in which repayments are typically tied to the property and not the owner or the tenant. However, because these schemes always involve a remuneration of the capital via the energy bill or an increased rent, they are not suitable for the current Swiss legal framework. Indeed, transferring to the tenants 100% of the retrofits capital costs via an increased rent is not possible, since only the value added can be transferred. The Swiss law explicitly mentions that retrofits capital costs cannot be transferred to the tenants in the ancillary costs either.<sup>9</sup> Hence, having

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<sup>9</sup> See art. 6 OBLF, concerning the ancillary costs ("charges accessoires"). One exception exists: district heating capital costs can be totally transferred to the tenant via ancillary costs. One should also note that the prohibition to transfer the capital costs via ancillary costs concerns by definition only capital costs of what is considered as an investment. If the EPC involves no investment on new equipment, but just energy equipment optimization (such as improved energy systems regulation), the costs for such optimization can be transferred to the tenants via the ancillary costs. Thus, on-bill financing has already been applied in some EPC contracts in Switzerland. But these contracts do not involve any capital investment. They just focus on energy systems optimization.

tenants is expected to decrease the likelihood of energy efficiency investment, with or without energy service contracting.

### *3.3.2 Imperfect information and risk*

In both ESC and EPC, the operation and maintenance is covered by the contractor during the whole contractual period. Thus, the client benefits from the technical knowledge of the ESCO in the long run, which may reduce imperfect information.

EPC is designed to give both the ESCO and the customer the incentive to reduce energy costs. ESC guarantees energy delivery at the same cost during the whole contractual period. These contracts therefore represent important risk sharing mechanisms. Even if the risk is not considered as a cause of the energy efficiency gap as perceived by the economists, it may still explain the low level of investment in energy efficiency as observed by engineers. Sharing the risk with the contractor, which is specialized in these types of equipment, may permit to reach a level of investment, which is closer to the socially optimal level.

Nevertheless, a guarantee comes at the cost of a risk premium paid to the ESCO. Respondents are likely to have heterogeneous preferences and perceptions towards the technological risk. Recent research from Polzin et al. (2016b) show that German municipalities underestimate the risks associated with street lighting LEDs retrofits and therefore do not value the risk-sharing advantage of EPC. But this result may be specific to the LED technology perceived as safe.

### *3.3.3 Limited access to capital*

ESCOs can facilitate access to financing, either by paying for the installation themselves, or by guaranteeing a third-party investment via the EPC “forfeiting” scheme (Swissesco, 2016). Li et al. (2014) find empirical evidence that ESCOs can partly relieve the clients of their financing need, using a sample of 140 EPC projects implemented in China.

However, these results may be challenged by the fact that the ESCO’s guarantee in the “forfeiting” scheme will provide added value only if the third party investor evaluates the ESCO with a better risk profile than the client. In ESC and in the shared-savings scheme, ESCOs may also have difficulties to find the necessary

capital (Nolden and Sorrell, 2016; Panev et al., 2014). Whether the facilitated access to capital provided by ESCOs is indeed valued by building managers depends on their actual credit constraints with respect to energy efficiency investments. These constraints might be relatively small in Switzerland especially in periods of low interest rate.

#### *3.3.4 Non standard behaviors and non-financial considerations*

To my knowledge no research has yet explored the impact of energy service contracting in this area. Because these contracts involve annual payments that are agreed upon at the signature of the contract, the underestimation of future financial flows as opposed to the initial investment may be reduced. Also, because the technical and financial risk is shared with the ESCO, the latter has an incentive to propose the investment which is the most relevant to the client. This may reduce the complexity of the choices the building owner has to make and thus may mitigate inattention or imperfect optimization.

Despite the lack of literature in this domain, the ESCO market actors seem aware of the importance of non standard behaviors: “We want to acknowledge the fact and raise awareness among Facilitators and other stakeholders [on the ESCO markets], that the identified needs for change require approaches beyond economic rationale based on a *homo oeconomicus* concept or environmental awareness. Instead psychological and organizational change processes need to be put on the agenda, even though this may be new territory for most energy efficiency professionals.” (Bleyl et al., 2012).

#### *3.3.5 Other empirical evidence on the role of EPC*

The extent to which EPC promotes energy efficiency has first been studied by Soroye and Nilsson (2010). Using data on EPC projects implemented in the public sector in Sweden between 2000 and 2010, they find that these projects led to an average of 22% energy savings for heating and hot water. They also observe that ESCOs helped to increase the awareness of firms about the usefulness of energy efficiency, although this could not be precisely measured. A few other studies attempted to measure the impact of EPC. Okay and Akman (2010) estimate pairwise correlations

between ESCO and country indicators in a sample of 38 countries and find that the volume and maturity of the EPC market is positively related to energy consumption. They conclude that this result stems either from the ineffectiveness or the non-saturation of the EPC market. However, this result could be due to reverse causality. Indeed, countries with higher energy use have a greater need for EPC solutions. Fang et al. (2012) reach an opposite conclusion using a panel of 94 countries over the period 1981 to 2007. They find that the existence of the EPC market has a negative impact on energy use and that the effect becomes stronger over time. However, these results may still suffer from endogeneity and/or unobserved heterogeneity across countries. Goldman et al. (2012) provide insights into the estimated amount of energy saved in the US thanks to EPC. Based on a sample of 2,484 projects implemented in the US over the period 1990-2008, they evaluate that EPC generated a net direct economic benefit of \$23 billion to their clients. While these studies provide illustrations of the potential size of energy savings induced by EPC, they do not provide empirical evidence that EPC induces investment in energy efficiency and thus reduces the energy efficiency gap. Indeed, it is possible that EPC simply facilitated the tasks of customers who would have invested anyway and as such, cannot be considered as a complete solution for the energy efficiency gap. Also, EPC projects may only involve optimization of the energy equipment and as such, do not directly imply an investment in energy efficiency, since they have no impact on the balance sheet. They will just affect the expenses, by providing energy savings, without any capital investment.

While the potential role of energy service contracting has been reviewed in this section, the next section explores whether these potentials are exploited in the current ESCO markets.

## **4 Diffusion of energy service contracting**

### **4.1 Foreign ESCO markets**

An important part of the relevant literature consists in assessing the evolution and the size of the ESCO markets around the world (see for instance Vine, 2005; Goldman et al., 2005; Painuly et al., 2003; Lee et al., 2003; Bertoldi et al., 2014; Bertoldi et al.,

2017; Marino et al., 2010; Marino et al., 2011; Xu et al., 2011; Goldman et al., 2012; Panev et al., 2014; Stuart et al., 2016; Nolden and Sorrell, 2016).

In 2014, the US was considered as the most mature ESCO market (Fang et al., 2012; Panev et al., 2014).<sup>10</sup> The US private industry has been developing since the 1970s as a response to the oil shocks and was mostly based on the shared-savings model (Langlois and Hansen, 2012). While the US was becoming a more mature market, the guaranteed-savings model has become predominant (Goldman et al., 2005). In a more recent report, Stuart et al. (2016) show that the US ESCO industry revenues have been stagnating between 2011 and 2014 and that ESCOs have tried to diversify. For instance, they are now proposing non-energy benefits within EPC, such as water conservation, emission credits or avoided operation and maintenance.

The initial Energy Contracting concept started in Western Europe more than 100 years ago (Hansen, 2006; Bertoldi et al., 2006; Adnot et al., 2002). However, it only re-emerged significantly in the European Union in the 1980s. In 2000, the estimation of the EPC market size in Western Europe was around 150 million Euros per annum (Bertoldi et al., 2003). Bertoldi et al. (2006) present the results of a survey conducted in the EU-25 countries and Romania and Bulgaria in the period 2003 to 2004 and show that there were important differences among the situation and evolution of the markets across countries. With 500 ESCOs and an estimated annual revenue of 3.5 to 5 billion Euros in 2013 (Bertoldi et al., 2014), Germany is the leading market in Europe (Eikmeier et al., 2009). It is followed by Italy and France (Marino et al., 2010; Bertoldi et al., 2014). The general trend in European countries shows stagnation or a slow growth for the 2010-2013 period (Bertoldi et al., 2014). Exceptions are France, Spain, Denmark and Ireland which experienced a strong growth in the same period. In 2013, the ESCO markets are still emerging or inexistent in a majority of countries<sup>11</sup> (Bertoldi et al., 2014), suggesting that the situation may significantly evolve in the EU in the next years (Bertoldi and Boza-Kiss, 2017).

The following tendencies have been noted on the foreign ESCO markets:

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<sup>10</sup> The US market may be now supplanted by the Chinese market, which was estimated to account for 55% of worldwide ESCO revenues in 2015 (IEA, 2016).

<sup>11</sup> Exceptions are Germany, France, Austria, Czech Republic, Denmark, Finland, Italy and UK, which show either moderate or good development of the ESCO market.

- **ESC projects dominate significantly the markets, as compared to EPC** in both European and US markets (Eikmeier et al., 2009; Bleyl, 2011; Bertoldi et al., 2006; IEA-RETD, 2013).
- The advantages of energy contracting are most **relevant beyond a certain scale**, mainly due to the transaction costs involved in the contracting process. For ESC, a Swiss ESCO uses typically bottom threshold of 50kW<sup>12</sup>, i.e. more than ten household units, while in Germany, Eikmeier et al. (2009) cites a thermal load of 100kW, i.e. around 20 000 € annual energy costs (Bleyl, 2011), as a minimum project size to cover all the transaction costs, based on empirical results from a market study. For EPC, which is expected to incur even higher transaction costs, the critical size for a viable project is even larger than under ESC. This has been showed by Goldman et al. (2005) who observed a median project cost of US\$1 million for EPC compared to US\$0.5 million for non-performance-based contracting projects. In Germany, the minimum energy cost for an EPC project is estimated at 100'000 euros per year (Bleyl, 2011).
- **Project financing varies across countries and seems to depend on the maturity of the ESCO market.** While the US ESCOs used to finance sometimes with their own funds the projects in the premises of contracting activities, this has drastically changed and projects are now financed with long-term debt or leases. Nowadays, US ESCOs prefer to serve as vehicle or facilitator to provide financing rather than directly finance themselves, in order to balance the risks (ICF, 2007; IEA-RETD, 2013). Conversely, shared savings is the dominant model used in Europe, while 90% of the contracts in the US are rather using guaranteed savings schemes. Since the European ESCO is a younger market, clients are likely to be less confident and aware about this new business model, and usually let the ESCO finance the investment and bear the financial risk as it is the case in the shared savings model (Hansen, 2006; Marino et al., 2011). In the US, on the other hand, confidence of the consumer leads them to invest in EPC projects, through guaranteed savings schemes (Goldman et al., 2005).
- Finally, while in practice **ESC is used in various market segments, such as housing, commerce industry or public buildings** (IEA-RETD, 2013), **EPC is practically limited to the public sector**, such as hospitals, swimming facilities or schools (Bleyl, 2011; Marino et al., 2011). The actors call it the “MUSH” market (municipal and state government, universities and colleges, schools and hospitals) (Satchwell et al., 2010).

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<sup>12</sup> For projects typically involving heat supply and hot water, sometimes coupled with passive cooling, cooling, ventilation, etc.

The abundance of public EPC projects in spite of private investments may be explained by several causes. First, public institutions often need third party financing and the ESCOs are not reluctant to provide the financing in such cases because public clients are credit worthy (Bleyl, 2011). Then, the size, the use and the age of public infrastructures typically represent high savings potentials that are attractive for the ESCOs (Bleyl, 2011). Moreover, regulations have forced public entities to implement energy policy goals in their own buildings (Langlois and Hansen, 2012). Finally, the public sector seems to accept longer payback period. Indeed, based on a sample of approximately 1 500 EPC projects, Goldman et al. (2005) find a median payback time of 10 years for public infrastructure as compared to 3 years for private projects.

## **4.2 The Swiss energy contracting market**

In Switzerland, detailed statistics on the energy contracting market are not available. The available data suggest a slow growth, due to lacking in-house expertise, limited flexibility for the industry, and financing barriers for small contractors (Marino et al., 2010; Bertoldi et al., 2014). In 1999, the Swiss Federal Office of Energy (SFOE) estimated the ESC market at 170 million Euros/year (Bundesamt für Energie, 1999). This number has reached 350 million Euros in 2009, according to Swiss Contracting<sup>13</sup>.

The EPC market, on the other hand, is still small and undeveloped with only a few ESCOs active and consequently only a few contracts per year signed. These projects encompass improvement of heating ventilation and air-conditioning (HVAC), lighting, pumps, automation, motors and inverters, with a relative dominance for industrial and non-residential buildings (Bertoldi et al., 2014). As opposed to other markets, a major part of EPC projects in Switzerland has been implemented with private clients.

Although interest from the supply-side for EPC exists, the concept is rather unknown among consumers<sup>14</sup>. The first call for tender applied to EPC has been published in 2016. The apparent delay of the Swiss EPC market as compared to other European ESCO market is not explained in the literature. Some experts argue that the main difference between the Swiss market and foreign ESCO markets lies in the fact that

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<sup>13</sup>Association that listed 76 energy contractors in 2010 which include local energy producers and distributors with some of them providing ESC. An estimation is that around 7-10 companies (mainly local energy utilities) have carried out energy contracting projects (Bertoldi et al., 2014).

<sup>14</sup> According to Jean-Marc Zraggen, EPC-expert of SIG, one of the few ESCOs offering EPC in Switzerland.

the Swiss potential clients do not need external financing, which has often been a trigger of adoption in foreign ESCO markets.

#### **4.3 Diffusion of energy service contracting and the energy service gap**

Despite the success of energy contracting in some countries, some authors have argued that the potential of this business model was not fully exploited in terms of both energy savings and business opportunities (Marino et al., 2010; Bleyl, 2011; Langlois and Hansen, 2012), which lead Backlund and Thollander (2011) to refer to this problem as the energy service gap. The main reason for the existence of the energy service gap, evoked by Backlund and Thollander (2011), relies on transaction costs that prevent the market to further develop. As a result, these contracts are mostly relevant beyond a certain scale and targeted at specific market segments, leaving out small energy consumers (Backlund and Thollander, 2011) and SMEs (Pätäri et al., 2016). Second, stagnation has been observed on some mature markets such as in the US (Stuart et al., 2016). Other authors observed that there is also an untapped potential of energy efficiency improvements in the public sector (Satchwell et al., 2010) as well as in the existing residential buildings (IEA-RETD, 2013).

Some authors claim that this is explained by the fact that low hanging fruits have already been harvested in most countries (Marino et al., 2010; Goldman et al., 2005). These attractive projects are typically represented by public buildings and simple technologies that reduce easily energy consumption, such as LED, HVAC, voltage optimization and building controls and rarely apply more comprehensive retrofits such as envelope enhancement (Bleyl, 2011; Nolden et al., 2016; Nolden and Sorrell, 2016). This observation could mean that the ESCOs have already exploited all their potentials and that other instruments than contracting must be found to cover other market segments or technologies.

One could also study the energy service gap under another perspective, i.e. indirect benefits. For instance, Goldman et al. (2005) state that customers in the US are no longer interested in cost/benefit ratios only, but are also increasingly valuing other indirect benefits, such as mitigating facility security or electric reliability of on-site

generation projects that are usually not taken into account in cost-benefit analyses. In this case, there may still be a potential untapped by the ESCOs.

Whether the energy service gap exists or not calls for a further investigation on the potential developments that remain for energy contracting. If these possibilities to grow further and target new market segments exist but are not exploited, then one should review the barriers that are hampering such an expansion. If these barriers happen to be non-existing or unbinding, then this could mean that ESCOs have already exploited the existing market niches. In this context, exploring the determinants of adoption of energy service contracting allows to assess whether and how its potential could be further exploited.

## **5 Theoretical review of the determinants of adoption of energy service contracting**

Only a few studies attempted to develop a theoretical framework applied to energy contracting. Yik and Lee (2004) and Li et al. (2014) provide a model for energy performance contracting viability and design based on net present values of future savings. Sorrell (2007) relies on economic theory, and more specifically on transaction cost economics (TCE), to assess contracts' viability, applicable for both energy performance and energy supply contracting.

Sorrell (2007) argues that energy contracting represents a shift from a hierarchical form of organization (vertical integration) to a more market-based form and thus can reasonably be related to the economic theory of the firm, i.e. the so-called "make-or-buy" decision.

Sorrell's model on the choice to invest in energy contracting rather than self-invest is summarized by Figure 1. The decision to opt for contracting draws upon the comparison of anticipated production costs (i.e. financing, distribution, control, maintenance, etc.) and transaction costs (i.e. consulting and legal costs, negotiations, costs associated with opportunistic behavior, etc.). Potential savings in production costs and aggregate production costs are key determinants in Sorrell's model to explain contracts' viability. Two other factors inspired from the TCE are added,

namely asset specificity and task complexity. Finally, he also incorporates two external variables specific to the context, i.e. competitiveness of the energy service market and institutional context (e.g. information, procurement, accreditation, consultancy, etc.).

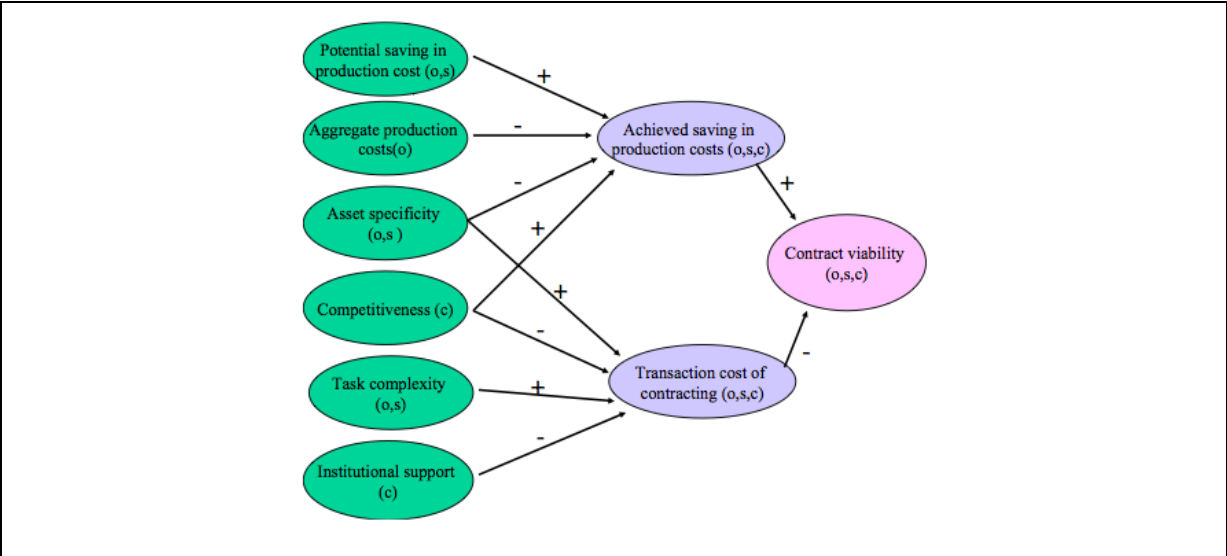


Figure 1 Sorrell's model of contracting decision (Sorrell, 2007; p. 519).<sup>15</sup>

The main determinants of adoption of energy service contracting considered in this thesis are transaction costs, risk sharing, economies of scale and financing. They are briefly developed in the next sections and further detailed in chapters I and II of this thesis.

**5.1 Transaction costs**

This PhD follows Sorrell's (2007) conjecture by identifying transaction costs as an important determinant of adoption of energy service contracting.

All investments in energy efficiency or renewable energy incur transaction costs. These may include consulting and legal costs, the cost of negotiations with the potential suppliers, as well as the burden of gathering information related to the available technologies, financing or subsidies opportunities. Energy service

<sup>15</sup> (o) refers to factors determining the contracting decision, (s) to determinants explaining why particular services are in or out of the contract, (c) for elements that clarify why contract's viability varies between comparable organizations in different contexts.

contracting may reduce part of these costs, since the ESCO benefits from its experience in the domain and accompanies the client in these processes.

On the other hand, because energy service contracting involves long term contracts, it incurs transaction costs in writing and negotiating the contractual clauses. The expected transaction costs that will occur after the contract's signature are also expected to have an impact on the client's decision to adopt energy service contracting. These costs include renegotiation and litigation costs, potential legal expenses and all the costs related to a modification of the technology or a transfer to another client or supplier. The transaction costs incurred in energy service contracts will depend on the technology specificity, the building and the client's type. The elements impacting energy service contracting adoption through transaction costs are developed in the first chapter of the thesis.

## **5.2 Risk**

When investing in renewable energy or energy efficiency, the client faces technological risks, such as unpredictable costs that arise in the construction phase of the project or any technological default that occurs in the equipment lifetime. A financial risk is also incurred in energy efficiency measures, due to the uncertainty surrounding energy savings. The ESCO can diversify the risk via a large portfolio of projects and other activities and benefit from higher technical knowledge than the client. It has also a better expertise in assessing a project's risk. As a result, it is optimal for clients with risky projects to share the risk with the ESCO in order to gain from a better control and mitigation of the risks. Thus, risk sharing is expected to be an important determinant of adoption of energy service contracting.

## **5.3 Economies of scale**

Many building owners cannot reach the critical level to invest in renewable energy or energy efficiency at reasonable costs. ESCOs may help the building owners to reach the critical size by pooling them together. This is typically the case in energy supply contracting involving district heating. Because the ESCO has a financial incentive to regroup the energy consumers, it will bear the costs of negotiating with the different potential clients to reach a viable size. This may also apply in the context of EPC, in

which the ESCO may help the clients to pool their buildings together in a single contract in order to benefit from economies of scale.

Transaction costs, risk and economies of scale are determinants that are likely to be interdependent in the client's decision to adopt energy service contracting. For instance, the client's size in terms of energy costs combines the effects of transaction costs and economies of scale. Sorrell (2007) argues that transaction costs for small consumers are likely to outweigh all ESC benefits, including economies of scale advantages. At the other extreme, very large consumers may benefit less from the ESCO's advantages such as economies of scale or risk sharing since they may benefit from in-house energy management. As a result, ESC contracts are likely to be the most viable for mid-size energy consumers.

Using different factors related to these concepts, the chapter I of this thesis intends to disentangle their effect in the willingness to adopt these contracts.

#### **5.4 Financing from the ESCO**

A building owner willing to implement energy efficiency measures or renewable technologies may have limited access to capital. This has been cited as a market failure characterizing investments in energy efficiency, in cases where the lender cannot distinguish between good or bad credit risk borrowers (Gillingham and Palmer, 2013). This phenomenon is exacerbated if borrowers with a high energy savings potential have poor credit risk profiles (Palmer, Walls and Gerarden, 2012). Taken together, these elements result in higher interest rates that can hamper consumers to invest. Building owners or managers may also be insufficiently informed about the financing options or subsidies available when making their decisions (IEA-RETD, 2013). Other constraints may prevent entities from investing in energy efficiency or renewable energy, such as debt ceilings (particularly affecting the public sector) or limited budget for non-core activities (in the case of private firms).

Both ESC and EPC can relieve the clients from their financing needs, since these contracts can include financing from the ESCO. Whether the facilitated access to

capital provided by ESCOs is indeed valued by building managers depends on their actual credit constraints with respect to energy efficiency investments.

## **6 Determinants of adoption from the client's point of view: empirical review**

While Sorrell's conjectures are available for empirical tests, there has been almost no attempt to determine econometrically whether these determinants are relevant.<sup>16</sup> This lack of empirical research is due to the problem of limited availability of data on contracts (Mathew et al., 2005). The existing empirical literature of the factors affecting the clients' decisions mostly consists of qualitative studies using a descriptive approach based on interviews and perception of various impacts. Here is a summary of the trends observed across the markets.

One of the most important barrier described in the literature is **low awareness, lack of information and skepticism** of the clients towards contracting options (Soroye and Nilsson, 2010; Vine, 2005; Xu et al., 2011; Marino et al., 2011; Hansen, 2006; Jensen et al., 2010; Capelo, 2011; Nguene, 2008; Pätäri et al., 2016).

A second important barrier relies on the **lack of commitment** from firms' top management (Thollander et al., 2013; Vine, 2005). Indeed, Hansen (2006) observes that EPC is hard to be implemented in business, especially industries, because "the horrible truth is that top management is not interested in energy". This is explained by the fact that the part of energy costs in the overall costs represents usually only up to 2-5% in industries. While these numbers can increase significantly for energy-intensive industries, up to 30% in chemical production (Hansen, 2006), clients may still be **reluctant to outsource** energy management to an ESCO, especially if in-house technical expertise exists (Marino et al., 2011). This reticence may be particularly important against EPC, if the production involves trade secrets, because the implementation of energy efficiency measures as well as the measures and verification of the savings, asks for a certain knowledge and control of the processes. Moreover, from the firms' point of view, transaction costs and financial risks incurred

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<sup>16</sup> An exception is Polzin et al. (2016).

by projects that are not related to their core business activities are regarded with caution. These projects need to bring high profitability in a limited period of time to be considered by the managers (Hell, 1997). As a result, Thollander et al. (2013) observe that only firms where the top managers have real ambitions for a long-term energy strategy tend to be interested in energy contracting. 50% of the firms surveyed in their study claim to have these ambitions. They also observe, together with Capelo (2011), that competition can increase the need to improve cash flows and subsequently increases the interest for EPC.

Finally, private clients (including firms) usually ask for small payback time periods (Goldman et al., 2005), which is sometimes hard or impossible to reach for the ESCOs. This is due to the fact that these clients want to limit the duration of the contract as much as possible (Hansen, 2006; Soroye and Nilsson, 2010; Lee et al., 2015). Iimi (2016) shows that competition between experienced ESCOs make EPC more attractive through shorter payment periods. This suggests that a potential solution is to foster the supply side of the ESCO markets. Iimi (2016) also demonstrates that the information disclosed in public calls for tenders affect the quality of the bids: by pre-announcing energy savings target, the collectivity is more likely to get bids with shorter contract duration.

Other barriers related to the contracts, such as administrative hurdles (Jensen et al., 2010), project complexity, repayment inability due to ESCOs default (Lee et al., 2015), complex procurement procedures (Nolden and Sorrell, 2016) or complex measure and verification processes (Xu et al., 2011) have been observed. Based on the transaction costs economics and on interviews with representatives of the UK ESCO market, Nolden et al. (2016) show how intermediaries, also called facilitators, can lower transaction costs and work as drivers for the clients. More specifically, they note that these intermediaries provide the client with specialization economies, scale economies and learning economies that reduce search costs, bargaining and opportunism costs. They can also pool small projects to reach a viable size and open EPC to smaller-size energy consumers.

It is finally worth noting that barriers hindering investments in energy efficiency may also apply in the decision to opt for EPC. This is the case for instance for split incentives, non-standard behaviors or non-financial considerations (cf. sections 3.2 and 3.3). Here again, there is no literature on how barriers to EPC and energy efficiency are cumulative or may substitute one another.

## **7 Is policy intervention needed?**

The rationale for government support has been emphasized in the literature by the observation, as explained earlier, that there exist an *energy service gap*. However, while the terminology has been used to bring a parallel with the *energy-efficiency gap*, one should note that it is not the same causes that are underlying these concepts. Indeed, as stated previously, the energy-efficiency gap eventually exists because of market failures that prevent energy customers to invest as it would be optimal. The energy service gap, on the other hand, is claimed to be due to high transaction costs, which represent a market barrier, but not necessarily a failure. And as stated by Jaffe and Stavins (1994) “unlike market failures, if market barriers are not market failures, they don’t call for policy responses”. In fact, one could argue that ESCOs are considered as market-based instruments to facilitate investments in renewable technologies and energy efficiency. And as such, they do not directly depend on, or should not rely on governmental support.

In the energy contracting literature, no study claims directly that there is no need for government support, to my knowledge. Yet, there is no evidence that an ESCO market cannot emerge and grow without any help from the authorities. Some authors argue in fact that energy contracting is likely to gain in importance in the future because of factors that are not linked to any policy instruments. For instance, Goldman et al. (2005) state that several trends, such as the increase in environmental concern, the need for technical system supply security, high fuel prices, and trend towards outsourcing energy procurement will induce growth on the ESCOs markets.

Switzerland provides an example where the government has stepped in only recently, but where contracting, yet only ESC, has been developed significantly.<sup>17</sup>

There is no proof either that without government support the main problem of ESCOs market will be overcome. Indeed, evidence seems to suggest that it is not possible for the ESCOs to target smaller customers if they do not get any policy support (Tietenberg, 2009). The appropriate question is to determine whether it is more efficient for the authorities to help the ESCOs to supply these smaller consumers with contracting options or to implement other policy instruments that are directly targeted to this market segment.

The instruments that directly target the energy efficiency gap and investment in renewable technologies include, for instance, the implementation of obligations and strengthening of building codes, the change of legal frameworks to allow to redeem the costs of investments onto the tenants and various incentive programs, such as subsidies or taxes. However, experience has shown that voluntary measures, enhanced by incentive programs, were not sufficient to foster significantly the development of renewable energy and efficiency measures (IEA-RETD, 2013). As a result, it seems that obligations will be needed to reach EUs 2020 energy savings goals, if the government choose to directly target energy consumers. However, IEA-RETD (2013) argue that energy contracting could be well more flexible, since it is a market-based instrument and can adapt to the customer's needs. Moreover, while obligations force the consumer and thus may overcome some behavioral issues, they do not solve limited access to capital or a lack of technical information. Hence, energy contracting could be seen as a promising complementary instrument to obligations in order to induce private investments in these market segments. One can then conclude that, not only energy contracting may need the support of the government, but the reverse could also be true. The extent to which energy contracting or obligations, together or alone, represent an appropriate policy tool, would need further research on what is really binding the potential private investors. Sorrell et al. (2004) argue that several limiting barriers are usually involved together in a single energy

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<sup>17</sup> See Klinko et al., 2017 (chap. II) for a comprehensive review of the energy policy instruments implemented in Switzerland and their direct or indirect link to energy service contracting.

efficient investment. This implies that using one single instrument may appear to be insufficient, “since it could simply cause another barrier to become the binding constraint” (Tietenberg, 2009).

## **8 Structure of the thesis**

Despite the abundant literature on energy service contracting, the lack of empirical evidence on the decision to adopt energy service contracting is striking. This PhD thesis intends to reduce this gap by exploring the economic mechanisms affecting the decision to adopt these contracts, both from the demand side and the supply side. The goal is to propose a positive analysis by focusing directly on the choices made by the clients or the suppliers, rather than relying on experts' perception. The three chapters of this PhD thesis are briefly described in the following subsections.

### **8.1 The determinants of adoption of Energy Supply Contracting: Empirical evidence from the Swiss market**

In order to identify the relevant determinants of adoption of energy service contracting, the first chapter analyzes the economic theories that can explain the customer's decision, i.e. outsourcing energy services or keeping them in-house. Because of the long term commitment of these contracts and the incentive provided to the ESCO to maintain the energy performance over the contractual time, risk sharing is expected to play a major role in the customer's decision. Since the ESCO has designed and implemented a large number of contracting projects, the perspective of economies of scale is also studied. These advantages, however, can be balanced by the fact that the long term contract is also assumed to increase transaction costs, i.e. search costs, bargaining, renegotiation and litigation costs, potential legal expenses and all the costs related to a modification of the technology or a transfer to another client or supplier.

This chapter also contains a simple formal model of ESC adoption based on transaction costs economics. This model shows that asset specificity and contract's

incompleteness, as well as the magnitude of expected transaction costs, affect negatively ESC adoption.<sup>18</sup>

The conjectures based on these theories are tested using an original dataset of 2,003 rejected and accepted ESC contracts proposed by two of the largest Swiss ESC suppliers. Since each client can receive several offers before accepting or definitively rejecting a contract, a probit model with random effects is used in order to account for possible correlation of the disturbances within an individual.

Due to confidentiality and competitive reasons, data collection on energy service contracts is rarely possible (Mathew et al., 2005). To my knowledge, the first chapter of my thesis is the first study to rely on actual contractual choices to analyze the adoption of energy service contracting. Focusing on the clients brings a new point of view, which can be compared to the market views of experts. The data are collected at the project level, which enables me to study aspects such as specificity, contract duration and economies of scale. Actual contractual choices allow me to derive revealed preferences that are not subject to biases which potentially affect surveys and stated choices.

The results show that the advantages of risk sharing and economies of scale brought by contracting, as well as trust in the supplier and technology reliability are important determinants of the client's choice to adopt ESC. Conversely, a large number of decision-makers, either through intermediary clients or tenants, has a negative impact on the likelihood of adoption. Finally, less specific contracts, involving residential or new buildings are more likely to be signed. This chapter also provides guidelines for the ESCOs to adapt their business model to better exploit the market.

Relying on revealed preferences nevertheless results in some limitations. First, as EPC is only emerging in Switzerland, the dataset includes offers of ESC only. The energy supply contracts in the sample are long term contracts, with a majority being entirely financed by the ESCO. The ESCO gets paid through a fixed fee and a variable fee for the useful energy consumed (room heating, cold, hot water,

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<sup>18</sup> While transaction costs economics can also be applied to analyze EPC adoption (Sorrell, 2007), the formal model developed in chapter one would probably be more complex in the context of EPC adoption in order to properly account for incentives on energy savings and risk sharing. See Yik and Lee (2004) and Li et al. (2014) for EPC adoption models. The latter however do not account for transaction costs economics.

ventilation, etc.). There is however no contractual incentive to reduce the client's energy costs. Nevertheless, although the empirical results of chapter one focus on ESC only, EPC is discussed throughout the chapter. This is justified by the fact that, as aforementioned, these two types of contracts are closely related (cf. section 2.4 of this chapter).

A second limitation related to actual contractual choices results from selection bias. The clients who received an offer are likely to be already interested in ESC. It can also come from the fact that only two ESC suppliers accepted to provide full information about their offers. Both are experienced ESCOs and may already be targeting the most viable projects. Thus, while my study can capture the determinants leading a client to reject or sign an ESC contract, it cannot analyze the determinants of adoption of the clients who never received an offer.

These limitations lead us to the motivation of the second chapter of this PhD thesis.

## **8.2 The mechanisms of Energy Performance Contracting adoption: Empirical evidence from a discrete choice experiment**

This chapter focuses on EPC adoption. The current state of the EPC literature lacks empirical evidence on the mechanisms driving the decision of a client to adopt EPC. This is explained by the difficulty to collect a sufficient number of EPC offers, especially in Switzerland where EPC is only emerging. Furthermore, in order to avoid the selection bias affecting the analysis in the first chapter, one has to use other methods.

The main contribution of chapter two relies on its methodology. Relying on a discrete choice experiment targeted at 297 potential clients, i.e. managers of large energy-consuming buildings in Switzerland, the impact of contractual attributes, such as a performance guarantee or financing from the ESCO, are assessed quantitatively. While such experiments have been used in other domains (e.g. Banfi et al., 2008; Rose et al., 2012; Blasch and Farsi, 2014; Caputo et al., 2014; Hole et al., 2016) they have, to my knowledge, never been employed in the context of energy service contracting. I use latent class models to analyze the stated preferences, in order to account for heterogeneity in the value attached to the benefits and costs of EPC. The

econometric models used also account for the heterogeneity and complexity of the decision-making, by considering possible attribute non-attendance, i.e. ignorance of certain attributes in the choice experiment. This allows me to account for the fact that consumers may not necessarily act according to the standard assumptions of neoclassical economic theory, especially in the context of energy efficiency (Gillingham and Palmer, 2013) and that they have heterogeneous preferences and decision-making mechanisms (Jaffe and Stavins, 1994, Allcott and Greenstone, 2012).

The choice experiment includes different types of energy performance contracts, i.e. with or without financing from the ESCO and with or without a guarantee on the energy savings. Different types of technologies are proposed within these contracts, such as building automation, exploitation optimizations, ventilation, envelope (walls and windows) refurbishment, or a new heating system (such as heat pumps, wood or solar panels).

The results show that the performance guarantee provided in EPC, and the resulting risk sharing mechanism, has a consistent positive impact on the likelihood to adopt these contracts. Conversely, the financing of the contractor is valued positively only by a minority of respondents. These are mostly public entities, presumably with debt ceilings. From the latent class analysis, this study provides insights into the complexity and heterogeneity underlying the decision to invest in energy efficiency. Finally, while its risk sharing mechanism is valued positively, EPC also faces a reticence from potential clients. We argue that this reticence could come from a misunderstanding of the concept and could therefore be mitigated by fostering greater awareness.

The methodology used in this chapter has also some drawbacks. First, the complexity of the survey leads to a low response rate and a limited sample size. Focusing only on Swiss potential clients in a specific time period also results in some limitations concerning the representativeness of the results, which may be specific to the current conjuncture in Switzerland. Finally, as in every survey with stated choices, I cannot

ascertain whether these clients, even if interested in EPC, will ever successfully implement such a contract in practice.

The last point is also likely to depend on the quality of the supply side. While the existing literature on energy service contracting typically focuses on market barriers concerning the demand side, little emphasis has been put on the market barriers and drivers on the supply side. This leads us to the last chapter of the thesis.

### **8.3 The provision of energy service contracting**

While the first two chapters of my thesis focus on the client's perspective and provide an overview of energy service contracting adoption, the third chapter intends to bring a new perspective on the potential of energy service contracting by focusing on the mechanisms that can foster the supply side of both ESC and EPC. This allows me to consider the potential of energy service contracting in terms of business opportunities and market innovation in the Swiss energy market.

This chapter assesses the extent to which changes in the energy market and energy policies can affect the firms' willingness to provide energy service contracting in Switzerland. Because the EPC market is only emerging and in order to study the choices of potential ESC and/or EPC suppliers, the methodology used is again a discrete choice experiment. The analysis is based on a survey among 208 energy utilities, gas providers, engineering firms, appliances and heating systems suppliers. The willingness to supply certain types of energy service contracts (shared-savings EPC, guaranteed-savings EPC and ESC) is empirically investigated in different hypothetical market and regulatory contexts.

The results show that an obligation for utilities to increase their clients' energy efficiency, as in a White Certificates scheme, has a positive impact on the willingness to provide energy service contracts from competitors and non-utilities. An exogenous and positive shock on the demand side positively affects the willingness to supply only if the shock stems from both public and private clients. Conversely, a total liberalization of the electricity market or an increase in tax levies on fuels and electricity, do not show significant impacts on the willingness to enter the market.

While these results may suffer from the hypothetical character of the policies presented and of the respondent's choices, this chapter still shows that focusing on the supply side brings new insights in the possibility to develop the market of energy service contracting and unlock business opportunities. Yet, further research is needed in order to fully understand the decision to enter the market of energy service contracting.



# 1 The determinants of adoption of Energy Supply Contracting: Empirical evidence from the Swiss market<sup>19</sup>

## **Abstract**

Energy supply contracting, the outsourcing of energy-related services, is considered a promising tool to induce investment in energy efficiency and renewable technologies. Yet, some energy contracting markets grow slowly and some segments remain untapped. This study investigates the determinants of energy supply contracting adoption, using a dataset of 2,003 accepted and rejected contracts offered in the Swiss market. The results show that the advantages of risk sharing and economies of scale brought by contracting, as well as trust in the supplier and technology reliability, are important determinants of the client's choice. A large number of decision-makers, inducing higher transaction costs, negatively impacts the likelihood of adoption. Less specific contracts involving residential or new buildings are more likely to be signed. If energy service contracting is proven to facilitate investment in energy efficiency, policy intervention may be needed to reduce the entailed transaction costs, for instance by clarifying the regulatory framework regarding tenants. Trust may be enhanced by the government's information campaigns on renewable technologies and certifications of the suppliers. The results of this chapter could be used to guide ESCOs to adapt their business models.

**JEL Classification:** L24, Q40

**Keywords:** Energy service contracting, transaction costs economics, risk sharing, renewable energy

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# 1 Introduction

Energy service contracting is considered as a market-based instrument that fosters investments in renewable and efficient energy services and combines business opportunities with social benefits. Indeed, these contracts have resulted in important energy savings (Soroye and Nilsson, 2010; Goldman et al., 2012) and investment in innovative renewable energy systems (Bleyl, 2011). They have also generated massive revenues for contractors. In 2011, the aggregate revenues were estimated to \$5 billion in the US (Gilligan, 2011), and 3.5 to 5 billion Euros in Germany in 2013 (Bertoldi et al., 2014).

Despite these advantages, the potential of energy service contracting does not seem to be totally exploited (Backlund and Thollander, 2011). In most countries indeed, these contracts have been applied only to large energy consuming buildings, leaving out small consumers and SMEs (Backlund and Thollander, 2011; Pätäri et al., 2016).

This study investigates the economic determinants driving the customer's choice to opt for energy service contracting. The empirical analysis is based on economic theories that can explain energy service contracting adoption, i.e. outsourcing energy services or keeping them in-house. Because of the long term commitment of these contracts and the incentive provided to the ESCO to maintain the energy performance over the contractual time, risk sharing is expected to play a major role in the customer's decision. Since the ESCO has designed and implemented a large number of contracting projects, the perspective of economies of scale is also studied. These advantages, however, can be balanced by the fact that the long term contract is also assumed to increase transaction costs, i.e. search costs, bargaining, renegotiation and litigation costs, potential legal expenses and all the costs related to a modification of the technology or a transfer to another client or supplier.

Existing empirical literature relies on descriptive studies based on interviews of experts and market analyses to assess the determinants of energy service contracting adoption (Vine, 2005; Marino et al., 2010; Backlund and Thollander, 2011; Xu et al., 2011; Bertoldi and Boza-Kiss, 2017). Polzin et al. (2016b) used stated preferences of German municipalities to quantitatively assess how stated obstacles,

drivers and municipality characteristics affect the willingness to consider EPC for LED retrofits. Due to confidentiality and competitive reasons, data collection on energy service contracts is rarely possible (Mathew et al., 2005). To my knowledge this is the first study to rely on actual contractual choices to examine energy service contracting adoption. More specifically, the results are based on a micro-econometric analysis of 2,003 rejected and accepted energy supply contracting projects proposed by two of the largest Swiss ESC suppliers over the period 1996-2011. Focusing on the clients brings a new point of view, which can be compared to the market views of experts. The data are collected at the project level, which enables me to analyze aspects such as specificity, contract duration and economies of scale. The quantitative analysis also permits to identify the determinants of ESC adoption. Actual contractual choices allow me to derive revealed preferences that are not subject to biases which potentially affect surveys and stated choices. Finally, this study provides insights into the Swiss ESC market, which has seldom been analyzed in the literature. Despite strong financial institutions, credit-worthy private and public institutions, the energy service contracting market is experiencing a slow growth in Switzerland.

Because EPC is only emerging in Switzerland, real contractual data on EPC could not be included in the analysis. Although focusing on ESC, this chapter provides a discussion on the closely-related and more abundant EPC literature. Relying on revealed preferences also comes at the cost of potential selection bias that might affect the estimation results, since only interested clients received an offer. I provide a discussion of this bias and potential solutions for further research.

This study provides quantitative evidence that economies of scale and risk sharing are indeed advantages of energy supply contracting. The data collected show that these projects include innovative renewable technologies. Adoption is however reduced by transaction costs, that are exacerbated by the number of decision-makers involved, such as tenants or intermediary clients. The results show that trust in the ESCO and technology reliability may mitigate part of these transaction costs. Policy intervention may also be required to clarify the regulatory framework regarding tenants. Adapting the ESCO's business model may also lead to an improved exploitation of the market potential. ESCOs should consider the underlying trade-offs

when targeting clients and could propose other forms of remuneration, such as on-bill financing (Nolden and Sorrell, 2016). They may also apply safeguard contractual clauses to reduce the risk of the client's bankruptcy or relocation in order to target non-residential buildings.

The chapter proceeds as follows. In the next section, I present the theoretical and empirical background as well as the hypotheses that will be tested empirically. The research context, data description and the econometric model are developed in section 3. Descriptive statistics and estimation results are presented in section 4 together with robustness checks, limitations and further research. Section 5 concludes.

## **2 Background and hypotheses development**

Energy service contracting consists in the outsourcing of energy-related services to a contractor, an Energy Service Company, through long term contracts. Two main types of energy service contracting exist: Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC) (Sorrell, 2005). ESC usually covers the financing, operation and maintenance of the energy equipment, while the contractor exerts no or little control over the demand for final energy services. ESC typically includes the delivery of useful energy such as steam, hot water or coolant. The technologies involved are typically new heating, cooling and hot water production systems such as biomass, air source or geothermal heat pumps. EPC differs from ESC in that the contractor has a financial incentive to reduce energy costs and supervises energy consumption by optimizing energy equipment operation, energy distribution or ventilation. In both types of contract, the client can share some of the risk, overcome her lack of technical knowledge or limited access to capital, and benefit from economies of scale and incentives from the ESCO to maintain performance over contractual time. As a result, energy contracting has been considered a promising market-based instrument to overcome barriers to energy efficiency (especially through EPC) and renewable energy investments (especially through ESC) (Sorrell, 2007; Yik and Lee, 2004; Soroye and Nilsson, 2010).

Several authors developed a theoretical framework for energy contracting. Yik and Lee (2004) and Li et al. (2014) provide models for EPC viability and design based on net present values of future savings. Sorrell (2007) relies on transaction cost economics to assess energy service contracts' viability. He argues that energy service contracting represents a shift from vertical integration to a market-based organization and thus can reasonably be related to a 'make-or-buy' decision. The present study follows Sorrell's idea to ground the determinants of ESC adoption into the theory of the firm. It does so by combining the factors predicted by transaction costs economics with risk-sharing and economies of scale considerations, in order to analyze the most important mechanisms underlying ESC adoption. The following subsections present the theoretical concepts that will be empirically tested in this study.

## **2.1 Transaction Costs Economics**

Transaction costs economics (Williamson, 1971; Lyons, 1996; Gibbons, 2005; Tadelis and Williamson, 2013) favors an interpretation of the 'make-or-buy' decision as a trade-off between reducing production costs through outsourcing or mitigating transaction costs through in-house provision. In the context of energy service provision, one can see energy contracting as an outsourcing decision, which reduces production costs and increases transaction costs. Appendix 6.1 provides a formalized simple theoretical model applied to energy supply contracting adoption rooted in transaction costs economics. This model predicts that the willingness to adopt ESC is inversely related to the probability that transaction costs will occur and their expected magnitude. In the following paragraphs, I explain which determinants are expected to have an impact on the probability of occurrence and the magnitude of the transaction costs and therefore on ESC adoption.

In a typical ESC contract, the supplier bears the costs of design, installation, operation and maintenance of the equipment. Engaging in ESC is different from hiring engineers to design the installation. First, because the ESCO typically finances the installation, it bears the risk related to unexpected costs in the realization phase. Then, it has an ex ante incentive to design an installation that will be efficient in terms

of operation and maintenance during the contractual period, which typically covers the equipment's lifetime.

This provides an incentive for the ESCO to minimize the overall production costs over the contract duration. This, however, can be balanced by the fact that the contract is also assumed to increase transaction costs, as compared to self-investment, if a disturbance occurs. Transaction costs consist in search costs, bargaining, renegotiation and litigation costs, potential legal expenses and all the costs related to a modification of the technology or a transfer to another client or supplier. The disturbances in ESC could typically be technical problems, financial issues on either the client's or the supplier's side or a change in the occupant's energy use. The viability of an ESC project from a client's point of view is determined by her expectations regarding the magnitude and the probability of occurrence of transaction costs as compared to the expected gains in production costs. Several elements are assumed to have an impact on this trade-off, such as asset specificity, trust, contract duration and the number of decision-makers. They are described in the following subsections.

### *2.1.1 Asset specificity*

Transaction costs might arise if it is costly to replace a contractor (or a client) when disturbances occur. In some cases, the project involves asset specificity, which increases the expected transaction costs when coupled with uncertainty.<sup>20</sup> Specificity in energy service contracting may relate to the physical asset, the human asset or the site (Sorrell, 2007). Physical asset specificity refers to the level of specialized equipment and the related importance of auditing and designing effort incurred before the implementation. Human asset specificity represents the degree of expertise and knowledge required to design the installation (Sorrell, 2007). If these forms of specificities are significant, they necessitate from the contractor an important investment, which will be lost if the contract is prematurely terminated by the client. This may result in an incentive for the ESCO to choose generic technologies in order to minimize the investment made before the client signs the contract (Backlund and

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<sup>20</sup> See Tadelis and Williamson (2013) for a theoretical background on the impact of specificity and Sorrell (2007) for a discussion on of the concept applied to energy service contracting.

Thollander, 2011). This may explain why EPC projects typically involve well-established technologies, such as LED, voltage optimization and building controls (Bleyl, 2011; Nolden and Sorrell, 2016). More comprehensive retrofits such as envelope enhancement or innovative technologies are however less frequent (Bleyl, 2011; Nolden and Sorrell, 2016). When clients ask for "cutting-edge" technologies, EPC suppliers are likely to contract without any performance guarantee (Hansen, 2006). This may however not apply to ESC projects, which often involve innovative technologies, such as combined heat and power systems (Bleyl, 2011). Nevertheless, once a specific technology is implemented and if the supplier does not deliver on its mandate, it may be costly for the client to find another supplier with the adequate level of expertise to take over. This results in bilateral dependency between the two parties and higher expected transaction costs. This is captured by the first hypothesis:

**H1a. The more specific and uncommon the technology, the lower the probability of opting for ESC.**

The equipment specialization demanded by the client may be dictated by her preferences or stem from particularities of the building (e.g. interior layout, proximity and access to potential energy sources such as groundwater for heat pumps). Technological constraints are typically weaker when the building and the energy equipment are designed at the same time. Conversely, human asset specificity is higher in existing buildings since it requires a relatively larger effort for the ESC supplier to design the most adapted technology. This results in the following hypothesis:

**H1b. ESC projects are more likely to be implemented in new buildings.**

Finally, site specificity relates to the difficulty to relocate the asset in case of a hurdle. This matters if the client moves out or goes bankrupt. The client's solvency risk is seen in the literature as an important barrier from the ESCO's perspective (Helle, 1997; Lee et al., 2015). In the case of a client's relocation or bankruptcy, the ESCOs are more inclined to search for another client to take over the building together with its equipment rather than relocate the installation, regardless of the technology. As a result, site specificity is determined by the probability of finding a client ready to take

over the energy technology. The relative ease to find a new client can be measured by the building type. For instance, when the building is used for residential purposes, it is likely that even though the initial occupant moves out, another resident will move in the building and reuse the energy technology. Similarly, if the initial client goes bankrupt, it is expected to be easier to find a new client to take over the ESC contract. Conversely, it can be harder to find a substitute client or occupant with the same use of a non-residential building (Helle, 1997). The following hypothesis reads:

**H1c. ESC projects are more likely to be implemented in residential buildings.**

#### *2.1.2 Trust and reliability*

Trust is likely to mitigate the client's fear of renegotiation, litigation, technical problems or financial issues undergone by ESCOs. As such it is expected to reduce the perceived probability that the contract will be renegotiated (represented by  $\rho$  in the formal model of Appendix 6.1). This relates to the fact that one of the most important obstacles in energy contracting markets described in the literature is low awareness, lack of information and skepticism of the clients towards contracting options (Soroye and Nilsson, 2010; Vine, 2005; Marino et al., 2011; Hansen, 2006; Jensen et al., 2010; Capelo, 2011; Pätäri et al., 2016; Bertoldi and Boza-Kiss, 2017). Trust in the supplier is expected to be as important as the reliability of the technology as perceived by the client. These observations lead to the following hypothesis:

**H2. Trust in the ESCO and technology reliability reduce the client's expected transaction costs and therefore increases the willingness to adopt ESC.**

#### *2.1.3 Contract duration*

The transaction costs model predicts that the longer the duration, the more difficult it is to design a contract that accounts for all contingencies that could occur in the long run. As a result, this increases the risk of renegotiation or litigation (represented by  $\rho$  in the formal model of Appendix 6.1). The reluctance to commit to an external firm during a long period of time has also been emphasized in the literature as a barrier to energy service contracting (Goldman et al., 2005; Hansen, 2006; Soroye and Nilsson, 2010; Lee et al., 2015). Hence, the following hypothesis reads:

**H3. The contract duration is expected to have a negative impact on ESC adoption.**

*2.1.4 Number of decision-makers*

The magnitude of expected transaction costs is likely to increase with the number of parties involved in the contract. Indeed, in the case of a disturbance, renegotiation and adaptation are expected to be costlier the greater the number of actors involved.

This is the case when the client is an intermediary, such as an architect, a general contractor or a real estate investor for instance, whose goal is to sell the building together with the energy supply contract. Therefore, the intermediary client who signs the contract is not the definitive owner or user of the building. Transaction costs may be expected at the time the building is resold and the energy supply contract passed onto the buyers, which results in the following hypothesis:

**H4a. Intermediary clients are less likely to opt for ESC.**

Transaction costs are also expected to be large if the building is rented, because the transfer of the costs of ESC to the tenants involves a risk of legal disputes.<sup>21</sup> Empirical evidence shows that this issue concerns all energy efficiency projects. Under-investment is indeed observed in rented buildings, which is explained by split incentives between the landlord, who owns the building and decides what investments to undertake, and the tenants who pay for the energy costs.<sup>22</sup> One could argue that energy contracting may actually mitigate this barrier. ESCOs may assist potentially interested owners in the legal process to redirect the costs of energy efficiency investments to the tenants. Market analyses show however that ESCOs in the UK (Nolden and Sorrell, 2016), in the US and in Canada (Panev et al., 2013) struggle to enter the rented buildings market, including commercial centers and office buildings. Hence, the following hypothesis reads:

**H4b. ESC projects are less likely to be implemented in rented buildings.**

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<sup>21</sup> See discussion in the results section.

<sup>22</sup> See Murtishaw and Sathaye (2006) and Davis (2010) for empirical evidence and the appendix of Gillingham et al. (2012) for a formal explanation.

## 2.2 Risk sharing

When investing in renewable energy or energy efficiency, the client faces technological risks, such as unpredictable costs that arise in the construction phase of the project or any technological default that occurs in the equipment lifetime. The ESCO, on the other hand, can diversify the risk via a large portfolio of projects and other activities and benefit from higher technical knowledge than the client. It has also a better expertise in assessing a project's risk. As a result, it is optimal for clients with risky projects to share the risk with the ESCO in order to gain from a better control and mitigation of technological risks. This results in the following hypothesis:

**H5. The larger the risk of the project, the higher the probability of ESC adoption.**

This hypothesis contrasts with the predictions from the incentive system theory (Gibbons, 2005) or moral hazard models (Lafontaine and Slade, 2007), which provide an alternative view of the 'make-or-buy' decision than transaction costs economics (Holmstrom and Milgrom, 1991, Holmstrom, 1999).<sup>23</sup> In these models, the principal (in our case the client) is expected to be less risk averse than the agent (in our case the ESCO). As a result, these models predict that the riskier the project, the smaller the likelihood to outsource. This may however not apply in the context of energy service contracting since the ESCO has typically a much larger economic size than the clients and therefore is likely to be less risk averse.

## 2.3 Economies of scale

The expected impact of a client's size on the decision to opt for ESC combines the effects of transaction costs and economies of scale.

On one hand, transaction costs imply that ESC is less viable for small consumers. Indeed, below a certain threshold of energy consumption, the transaction costs are

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<sup>23</sup> These models rely on principal-agent analysis to explain the trade-offs underlying the optimal choice regarding vertical integration. As in the model of transaction costs economics of Tadelis and Williamson (2013), increasing the supplier's cost share allows to address moral hazard and raises the supplier's unobservable amount of effort in reduction production costs. Moral hazard comes from the fact that the principal cannot design the optimal payment scheme for the agent as the latter's effort is not observable because of the presence of uncertainty. The difference between the transaction costs economics model of Tadelis and Williamson (2013) and moral hazard models lies in the fact that, as opposed to trading-off the effort incentive with transaction costs mitigation, it does so with risk sharing. Increasing the supplier's cost share not only raises its incentive, but also its risk share. Assuming the agent (i.e. the supplier) is more risk averse than the principal (the client), the moral-hazard models predict that as the level of risk borne by the agent increases, so does the agent's need for insurance, making in-house projects more desirable than externalization (cf. Lafontaine and Slade, 2007).

likely to outweigh the benefits of energy service contracting (Sorrell, 2017). The viability of ESC then increases with the client's size as the potential for energy production costs savings via ESC rises and offsets the transaction costs.

On the other hand, the economies of scale result in an attractiveness of ESC which decreases with size. The economies of scale brought by the ESCO are indeed relatively less interesting for large energy consumers who are more likely to benefit from in-house energy management.

The combination of these two effects may result in an ambiguous impact of size on ESC adoption. Sorrell (2007) however argues that transaction costs for small consumers are likely to outweigh all ESC benefits, including economies of scale advantages. At the other extreme, very large consumers may benefit less from the ESCO's advantages such as economies of scale or risk sharing since they may benefit from in-house energy management. As a result, ESC contracts are likely to be the most viable for mid-size energy consumers. This results in the following hypothesis, which, to my knowledge, has not been empirically tested in the literature:

**H6. The size of the client (in terms of aggregate production costs for energy service) has an inverted-U impact on ESC adoption.**

### **3 Empirical Methodology**

#### **3.1 Research context**

Although exhaustive statistics on the Swiss ESCO market are not available, the ESC market turnover was estimated at 170 million Euros/year in 1999 (Bundesamt für Energie, 1999) and at 170-350 million Euros/year in 2017 (Bertoldi and Boza-Kiss, 2017). Existing market analyses and expert interviews suggest a slow growth for ESC, while EPC is only emerging in Switzerland (Marino et al., 2010; Marino et al., 2011; Bertoldi et al., 2014; Bertoldi and Boza-Kiss, 2017). Nevertheless, some experts have observed an increased interest for ESC, which is partly attributed to the 2009 liberalization of electricity provision for large electricity consumers (>100,000 kWh/year) (Brunner, 2009).<sup>24</sup> This change in the regulatory framework has been seen

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<sup>24</sup> Liberalization of the electricity provision is planned to reach smaller energy consumers (<100,000 kWh/year) in the coming years (DETEC, 2017).

as an incentive for electric utilities, which beforehand were enjoying regional monopoly, to propose new business models such as ESC in order to attract large consumers (Brunner, 2009).

The Swiss context of limited growth in ESC is favorable to study the customer's decision. While experts identify the existence of barriers in Switzerland, such as low awareness, lack of trust and financing constraints for small contractors (Marino et al., 2010; Bertoldi et al., 2014), empirical evidence on ESC adoption from the client's perspective in Switzerland does not exist. The analysis of ESC adoption is particularly interesting in Switzerland, where the government decided in 2011 to progressively phase out of nuclear power. The need for market-based instruments such as energy service contracts to induce renewable energy and energy efficiency is all the more relevant in a context of reluctance of a share of the population towards policy intervention in the energy market. This can be seen in the recent referendum raised against the federal energy strategy, even though it has finally been accepted by a majority of the population (58.2%) on May 21, 2017.

This study relies on ESC projects offered by two large Swiss electric utilities. Both firms are controlled by a public entity and are mainly active in the canton in which they originally had a monopoly in the provision of electricity. While their estimated ESC market shares are unknown due to the uncertainty surrounding the overall size of the market, the number and the size of projects undertaken suggests these two firms to count amongst the four largest ESC providers in Switzerland. They pioneered the provision of ESC in Switzerland and have since gained an important experience in the market. These two firms are moreover representative of the majority of ESC providers in Switzerland in terms of the firm's type and size as shown by the answers to the survey conducted for the third chapter of this thesis. This survey, conducted in January 2017, includes answers from 208 energy utilities, gas providers, engineering firms, appliances and heating systems suppliers. Among them, 31 firms provide ESC and 9 firms are proposing EPC. A large majority of these ESC providers are electricity or gas providers controlled by public entities.

### 3.2 Data description

The empirical analysis relies on a unique dataset containing 2,003 rejected and accepted ESC offers<sup>25</sup> from two of the largest Swiss ESC suppliers between 1996 and 2011. The offers are targeted at 1,214 clients in 949 ESC projects. Each contract's offer is targeted at a single client, but an ESC project can include several clients, and thus several offers. This is typically the case when several building owners decide to group and have a centralized heating system installed and exploited by the ESCO. As can be seen in Figure 1.1, except from a peak in 2001, a minority of the offers in the sample have been accepted.<sup>26</sup>

One to eight offers were proposed to each client and almost 50% of the clients accepted a final offer. 37% of the clients obtained a single offer (cf. Table 1.1) and less than 10% of the clients received more than 4 offers. The dataset is unbalanced since the number of rejected offers is much larger than accepted offers (cf. adoption rate in Table 1.1). This stems from the fact that each client cannot accept more than one offer. This may result in estimation bias, which will be further discussed in the limitation section.

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<sup>25</sup>Initially, 2,506 offers were collected, up until 2013. However, contracts from 2012 on are excluded from the analysis since they were still under negotiation at the end of the data collection, which results in the impossibility to conclude whether the offers were rejected or not. After excluding observations with missing values on the main variables of interests, the sample results in 2,003 observations. The descriptive statistics shown in this section are based on the latter sample.

<sup>26</sup>Only 21 offers occurred in 2001 in the sample (average number of offers per year is 125), and 18 were accepted.

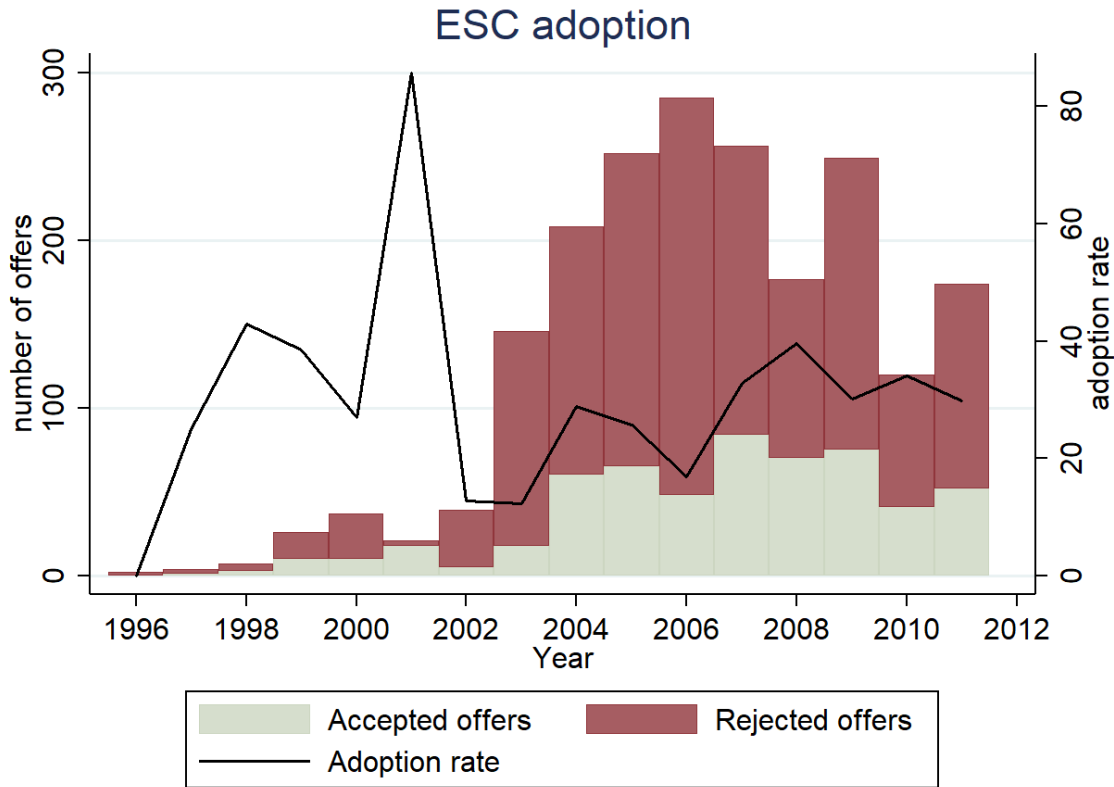


Figure 1.1 ESC adoption

**Table 1.1: Number of offers per client and adoption rate**

Number of offers per client	Adoption rate (%)	Frequency	Percent
1	37.26	740	36.94
2	24.16	594	29.66
3	27.49	291	14.53
4	19.12	204	10.18
5	14.44	90	4.49
6	10.00	30	1.50
7	14.29	14	0.70
8	10.00	40	2.00
Average:	27.96	Total: 2,003	100

While it is known when an offer has been or not rejected, the outside option is unknown. In some cases, the customer might have chosen an ESC contract of a competitor, in which case it would be wrong to consider the observed rejection as an actual dismissal by the client of the ESC option. This may results in biased estimates of the determinants of ESC adoption. However, this bias may be limited by the fact

that the customer is likely to choose a less comprehensive energy service when rejecting an ESC offer. This assumption is supported by the fact that conventional turnkey projects in Switzerland are much more frequent in practice than ESC.

Another issue related to the data is its iterative process, which results from the negotiation between the first offer and the subsequent ones. This may also result in estimation bias due to endogeneity and will be further discussed in the limitation section.

On average, 5 months separate the first offer from the last one. The minimum duration between the first and the final offer equals zero for several offers or variants proposed at the same time and the maximum is 7.5 years. The increase in offers since 2003 stems from a change in business strategy of one of the ESC suppliers, which opted to drastically increase prospection for ESC.

ESC suppliers typically prospect by sending e-mails and letters to large and mainly private energy consumers. Private clients indeed represent 97.8% of the offers. All the offers are prepared by the contractors to reply to a client's request. Therefore, there may be a certain selection bias in the sample, since it includes only primarily interested clients. As a result, the results of this study regarding ESC adoption may suffer from selection bias.

It is worth describing the characteristics of the clients targeted by the ESCOs in the sample.<sup>27</sup> A majority of the clients (44%) are architects and general contractors. Then, 40% are private owners and 15% real estate investors or investment funds. Firms (6.6%) and public collectivities (3%) represent a small share of clients.

Table 1.2 provides descriptive statistics of the cost components in the offers. Each offer typically includes an annual fixed cost covering capital, operation and maintenance costs and a variable cost for primary energy purchases which depends on the client's energy consumption. When the client participates to the initial financing, the fixed cost is consequently reduced. The variable cost is usually determined by the price in CHF/kWh for each energy service (e.g. heating, hot water,

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<sup>27</sup>The characteristics are represented as the percentage of occurrence in non-mutually exclusive groups. Many projects combine several types of clients. This is why the total is more than 100%.

ventilation, etc.) multiplied by the annual consumption of that service (kWh/year). The heating and hot water consumption levels described in Table 1.2 relate to consumption estimates before the implementation of the contract. The variable cost for the remaining energy services consumptions (*variable cost other cons.*), may include ventilation, cooling, passive cooling or other energy services' costs. Table 1.2 shows that the projects are relatively heterogeneous in costs, which is mostly due to differences in the customer's size (c.f. surface in table 1.3).

**Table 1.2: Costs**

Variable		mean	std. dev.	min.	max.	N
Fixed cost	(CHF/year)	31,988	67,516	0	992,906	2,002
Client's initial financing	(CHF)	16,355	293,342	0	6,910,000	2,002
Price heating	(CHF/kWh)	0.06	0.02	0.02	0.34	1,999
Heating consumption	(kWh/year)	178.817	392.991	7,955	7,000,000	1,719
Price hot water	(CHF/kWh)	0.07	0.02	0.02	0.28	1,959
Hot water consumption	(kWh/year)	65,505	110,717	2,000	2,045,120	1,351
Variable cost other cons.	(CHF/year)	469	5,955	0	180,990	2,003

### 3.3 Econometric model

An energy service customer ( $i = 1, \dots, n$ ) can either decide to sign an offer for ESC ( $j=1, \dots, J$ ), to ask for another bid  $j+1$  or to choose an outside option. Customer  $i$ 's choice is supported by a comparison of the utility obtained with the ESC offer  $j$ ,  $U_{ij}(ESC)$ , and the outside option's utility, which is normalized to zero. The customer will opt for contract  $j$  if and only if  $U_{ij}(ESC) > 0$ . I observe the binary variable  $y_{ij} = \mathbf{1}[U_{ij}(ESC) > 0]$ .

$$U_{ij}(ESC) = \alpha + X_{ij}\beta + Z_i\delta + \text{year dummies}_{ij}\Gamma + u_i + \varepsilon_{ij} \quad (1)$$

$X_{ij}$  represents a vector of offer characteristics, such as the technology or contractual terms. The vector  $Z_i$  includes the characteristics of the client and the building. Year dummies are included to control for unobserved external factors specific to each year.  $u_i$  are random effects and  $\varepsilon_{ij}$  represent the idiosyncratic errors.

The choice of explanatory variables is supported by the hypotheses proposed in Section 2. Table 1.3 presents descriptive statistics of the covariates included in  $X_{ij}$  or  $Z_i$ , the corresponding hypotheses developed in Section 2, and the predicted direction of the effects of the covariates on the probability of adopting ESC.

**Table 1.3: Descriptive statistics of ESC adoption determinants**

	<i>Variable name</i> Proxy for empirical testing	Predicted impact on adoption		mean	std dev.	min.	max.	N
<b>Transaction cost Economics</b>								
H1a	<i>specificity index</i> A hundred minus the share of this technology in all building types in Switzerland that year	negative	%	93.19	3.58	38.22	99.99	2,003
H1b	<i>new building</i>	positive	dummy	0.83				2,003
H1c	<i>residential building</i>	positive	dummy	0.93				2,003
H2	<i>canton ESCO</i> trust in ESCO: same canton as ESCO	positive	dummy	0.82				2,003
H2	<i>oil backup</i> reliability of technology: heating system with oil as a backup	positive	dummy	0.05				2,003
H3	$\ln(\textit{duration})$ duration of the contract	negative	years	26.54	6.31	10	60	2,003
H4a	<i>intermediary client</i>	negative	dummy	0.47				2,003
H4b	<i>rented building</i>	negative	dummy	0.81				2,003
<b>Risk sharing</b>								
H5	<i>interest rate</i> Project's real interest rate set by the ESCO	negative	%	4.55	1.20	2.26	6.66	633
<b>Economies of scale</b>								
H6	$\ln(\textit{total cost/year})$ Client's yearly total energy costs	inverted U-shape	CHF/year	51,153	100,138	32,901	1,983,200	1,577
<b>Control</b>								
	Surface		x 1000m <sup>2</sup>	3.27	7.91	0.105	190	1,608

The degree of asset specificity, as described in hypothesis H1a, is measured by an index which negatively depends on the diffusion of the technology proposed. More precisely, I measure how frequently the technology included in the offer<sup>28</sup> is present in existing buildings in Switzerland (OFS, 2015). The proxy *specificity index* is computed as the complement to the share, in percent, of the Swiss buildings having the same

<sup>28</sup> Either for heating and/or hot water

technology as the one proposed in the offer at the same period.<sup>29</sup> This proxy assumes that the less frequent the technology is implemented in existing buildings, the higher the difficulty to find another supplier with sufficient knowledge to take over the installation or maintenance in the case of litigation with the original ESCO. This increases expected transaction costs and decreases the desirability of ESC with respect to in-house projects.

In order to account for increased flexibility in technology design in new buildings (hypothesis H1b), the model includes a dummy (*new building*) equating one if the technology of the ESC contract is installed as the building is under construction. The dummy *residential* equals one if the building is destined for residential use and relates to hypothesis H1c.

Trust in the ESCO (hypothesis H2) is measured by a variable capturing probable historical relationship between the contractor and the client. The dummy variable *canton ESCO* equates one when the customer is located in the same canton as the supplier. This is supported by the fact that, until 2009, the ESC suppliers in the sample had cantonal monopolies for the supply of electricity, which is still the case for small consumers. Therefore, I assume pre-existing interactions between the ESCO and the clients located in the same canton. The use of this proxy is also supported by the testimony of an ESC expert, who observed difficulties gaining market shares in other cantons because of the customers' reluctance to deal with a utility originating from another canton. Descriptive statistics show that a majority of offers (82%) are proposed to clients within the same canton as the ESCO, which reflects that the suppliers retain a comparative advantage in terms of proximity.

In some offers, the clients have requested for an oil heating system to work as a backup. A dummy *oil backup*, which equals 1 if oil backup is included in the offer, is a proxy for the perceived reliability of oil heating systems as opposed to the main technology in the contract. Having oil as a backup may also be seen as a flexible solution to uncertain future uses and energy consumption. In either case, these

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<sup>29</sup> The buildings census is available in 1990, 2000, 2009-2014. Thus, data from the 2000 census is used for offers from years 1996-2004 and 2009 census for years 2005-2009.

backup systems can be seen as a safeguard technology aimed at reducing expected transaction costs and therefore increase the viability of ESC projects (hypothesis H2). Only 5% of the projects proposed include oil as a backup technology, so that empirical results should be interpreted cautiously. These backup systems are used in similar proportions in old and new buildings, mainly in support to renewable technologies such as heat pumps (58%) and wood heating systems (23%). A simple logistic regression informs that these backups are more likely to be used in buildings with large energy consumption and non residential uses, such as industries or schools.

In order to account for increased expected transaction costs due to longer contractual periods, the model controls for the contract duration (hypothesis H3). The average contract lasts more than 26 years, and a large majority of offers are either 15 or 30 years contracts. The distribution of duration is highly skewed to the right, with only a few offers representing longer contractual periods, which supports taking the natural logarithm of duration in the regression model.

The dummies for *intermediary clients* and *rented buildings* are related to hypotheses H4a and H4b and capture the fact that negotiation and adaptation are expected to be more costly when several actors have interests at stake.

The proxy used in the model to measure the risk (hypothesis H5) is the real interest rate applied by the ESCO to compute the client's annuities.<sup>30</sup> The ESC suppliers apply different rates depending on the technology installed, the client's type, the building's characteristics and size. Ranging from 2.26 to 6.66%, the rate offered to a specific client captures the ESCO's ex ante risk assessment of the project. Due to the expertise of the ESCO in these projects risk assessment, this is a good proxy of the project's risk. Nevertheless, it may also capture other risks perceived by the ESCO, such as financial risk (e.g. client's relocation, change in energy use, or bankruptcy) and risk of litigation and renegotiation in the course of the contract. This represents a limit of this proxy, which may however be mitigated by the fact that I control for most of the determinants that the ESCO considers to evaluate the client's risk. For

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<sup>30</sup> Real interest rates were computed with the following formula:  $\text{real rate} = (1 + \text{nominal rate}) / (1 + \text{inflation rate}) - 1$ . Monthly data on annual IPC inflation rate come from OCDE (2017).

instance, I control for the specificity index of the technology, the size and the type of building (new or residential).<sup>31</sup> Concerning risk sharing, other determinants, such as the ESCO's efforts, the risk aversion of both the client and the ESCO, are also likely to affect ESC adoption. Nevertheless, the impact of these elements is difficult to assess empirically. Thus, the analysis focuses primarily on the project's risk.

The client's aggregate production costs of energy services  $s = 1, \dots, S$  are used to test the combined impact of economies of scale and transaction costs (hypothesis H6).

The following proxy is computed:

$$\frac{\text{total cost}}{\text{year}} = \sum_s^S (p_s \times \text{consumption}_s) + \text{fixed cost} + \frac{\text{client initial financing}}{\text{duration}} \quad (2)$$

The measure for aggregate production costs is the annual cost and includes the variable cost, computed as the yearly consumption of each energy service multiplied by the corresponding energy price ( $p_s$ ). When primary energy purchase is not included in the contract, and thus no price is specified, an approximation of the market price is used to specify  $p_s$ .<sup>32</sup> The yearly fixed cost typically includes the amortization of the investment financed by the ESC supplier, the design, the operation and the maintenance. In some contracts the client participates to the initial financing by an amount represented by *client initial financing*, which is divided by the contract duration to account for the participation in the yearly total cost. Aggregate production costs are expressed in natural logarithm in the regression in order to mitigate the effect of outliers and heterogeneity.

Finally, the variable *surface* represents the squared meters heated surface dedicated to the client<sup>33</sup> and is used as a control for size effects.

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<sup>31</sup> In appendix 6.3, I also added a control for private or public clients.

<sup>32</sup> EICOM (2014), *Surveillant des prix* (2014) and OFS (2016) data on monthly or yearly energy prices are used for the estimation of energy prices, and depend on either the month or the year of the offer, and the size of energy consumption per year. When the energy is electricity and data is available, the electric supplier and the technology also has an influence on the variable cost. Following Phillips (2010), I assume that geothermal, groundwater and lake-water heat pumps use 35% and air-water heat pump 25% of final energy. Ventilation or cooling is assumed to be present in the building only when it is specified in the ESC contract. However, each customer is assumed to consume at least space heating and hot water.

<sup>33</sup> In most of the cases, the offer is for one client and one building. In some cases however, there may be several clients in a same building.

### 3.4 Estimation method

As each client faces one or several offers, the dataset is treated as an unbalanced panel. I apply a random effects probit model, in which idiosyncratic errors are assumed to be independent across offers and individuals, and are assumed to follow a standard normal distribution,  $\varepsilon_{ij} \sim N(0; 1)$ .  $u_i \sim N(0; \sigma^2)$  are client-specific random effects, which vary across clients and are assumed to be unrelated with the regressors and independent across individuals. As opposed to a pooled estimation, random effects allow the disturbances  $v_{ij} = u_i + \varepsilon_{ij}$  to be correlated within an individual. The Log-Likelihood function is approximated using the Gaussian quadrature with Hermite integration formula suggested by Butler and Moffitt (1982). In addition, project-clustered robust standard errors are used to allow for correlation within the projects. In order to evaluate the magnitude of the impact of each variable on the probability of signing the ESC contract, the average marginal effects<sup>34</sup> of each variable on the prediction that  $y_{ij} = 1$  are computed.<sup>35</sup>

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<sup>34</sup> i.e. marginal effects averaged over the sample

<sup>35</sup> These results obtained by estimating the random effects will be compared with the average marginal effects obtained when assuming  $u_i = 0$ , i.e. imposing the random effects to equal zero.

## 4 Results and discussion

### 4.1 Descriptive analysis

Figure 1.2 shows how frequently each technology appears in the accepted offers of the sample.<sup>36</sup> To underline the technology diffusion, Figure 1.3 provides the shares of technologies based on data covering all Swiss buildings (OFS, 2015).

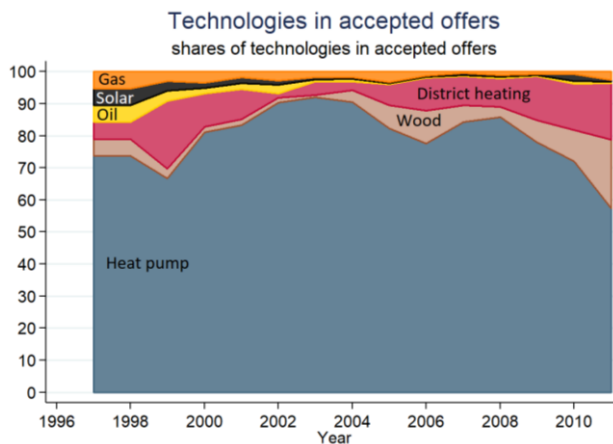


Figure 1.2 Technology in accepted offers

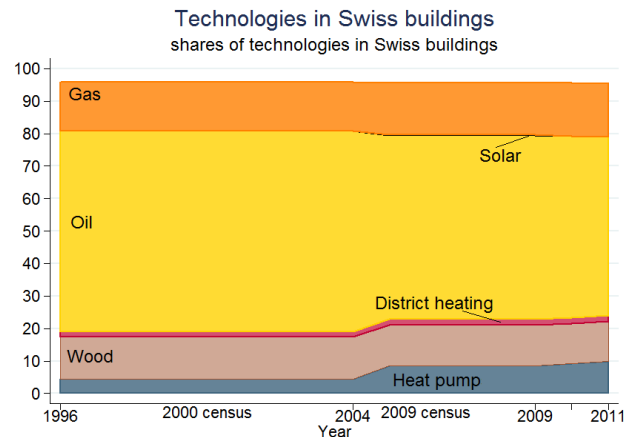


Figure 1.3 Technology in Swiss buildings

Heat pumps (mostly geothermal), included in 88% of the offers, are largely predominant in the sample. They are followed by district heating (9%) and wood, either woodchips or pellets (7.3%). Oil heating systems, mostly used in combination with another technology, are present in 5% of the cases while gas represents a share of 2.5% and solar panels 1.9%.<sup>37</sup> Except in the first years of the sample, the diffusion of the technologies in accepted offers (Figure 1.2) is very similar to the one in the complete sample. Figures 1.2 and 1.3 show that the technologies most often proposed by the ESC suppliers are very uncommon as compared to the one

<sup>36</sup> For illustration reasons in 1.2 and 1.3 and in order to represent the relative shares, the technologies have been classified in mutually exclusive groups corresponding to OFS (2015). Because many offers in the sample include a combination of technologies, the main technology in terms of power is illustrated in the figure. An exception is made for oil, which is always used as a back-up in the sample. I still decided to show separately the group of offers including these oil back-ups. District heating is also a special case as it represents a separated group while it can use the same energetic agents as the other groups (e.g. wood, electricity for heat pumps). In the econometric analysis however, each combination of technologies has its own specificity index.

<sup>37</sup> These numbers are the percentage of occurrence in non-mutually exclusive groups. Since many projects combine several technologies, the total exceeds 100%.

implemented in Swiss buildings. This translates into a high specificity index (average 93.1 in Table 1.3). The specificity index is also high in existing buildings, with an average for the specificity index equal to 93.9% among old buildings in the sample. Several innovative technologies appear among the offers, such as groundwater, lake-water, air or residual heat pumps and co-generation. A small share of observations (236 offers) includes data on the technology used before the ESC project. Out of these, 93.4% relied on oil, 3.5% on electricity, and 3% on gas at the moment of the offer. These observations suggest that ESC favors renewable energy technology.

Table 1.3 informs that new and residential buildings concern a large majority of the offers (83% and 93% respectively). This suggests that the barriers mentioned earlier for old and non-residential buildings imply an *ex ante* selection. In the survey lead for the chapter 3 of this thesis, we find that Swiss firms interested in providing ESC favor targeting residential buildings, together with education facilities and industries.

The descriptive statistics do not suggest, however, the *ex ante* selection against rented buildings as these represent 81% of the offers. Likewise with intermediary clients who represent a considerable share of the offers (47%). Table 1.4 provides the share of accepted offers contingent on whether an offer relates to a rental building or if an intermediary client is involved.

**Table 1.4: Accepted, rejected offers by rented buildings and intermediary client**

	not rented	all or partly rented
rejected offer	184 (49%)	1,259 (77%)
accepted offer	194 (51%)	366 (23%)
total	378	1,625
	direct client	intermediary client
rejected offer	655 (62%)	788 (83%)
accepted offer	398 (38%)	162 (17%)
total	1,053	950

The table informs that a higher share of rejected offers occurs when the building is either completely or partly rented (77%) and when the client is an intermediary (83%), which is in line with the predictions based on higher expected transaction costs. This leads to the following question: Why these two ESC suppliers target rented buildings and intermediary clients, despite these being associated with a higher rate of rejected offers? A possible explanation lies in the fact that the contractors primarily target residential buildings and especially multi-family houses, which represent less specific clients that can easily be replaced in the case of a relocation or a bankruptcy. However, this comes at the cost of an increased risk of legal disputes with tenants, since residential buildings consist in rental housing in most cases<sup>38</sup> (85% in this sample). A similar dilemma occurs with intermediary clients. ESC is mostly targeting new buildings, and the primary interlocutors for new buildings in the sample are intermediary clients (54%) who will resell the building with the contract. These represent additional interlocutors and increase expected transaction costs. These two dilemmas are analyzed further in the next section.

## **4.2 Estimation results**

The estimation results based on equation 1 are provided in column 1 of Table 1.5. Due to the small sample size resulting from missing values for the interest rate, the yearly total cost and the surface, the regression in column 2 omit these variables. To capture the impact's magnitude of each determinant on ESC adoption, the average marginal effects are provided beside the coefficients.<sup>39</sup>

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<sup>38</sup> This is also the case in general in Switzerland. According to the federal census of the population from the Swiss federal statistics Office, 66% of the Swiss housing were rented in 2000.

<sup>39</sup> The estimated average marginal effects are similar if we estimate random effects or if we set them to equal zero.

**Table 1.5: Estimation results**

Random Effects Probit dependent variable: offer accepted ( $y=1$ )		(1)		(2)
	coefficient	Average marginal effect	coefficient	Average marginal effect
<i>specificity index</i>	-0.007 (0.029)	-0.002	0.009 (0.013)	0.002
<i>new building</i>	0.966*** (0.293)	0.220***	1.050*** (0.159)	0.226***
<i>residential</i>	1.385** (0.622)	0.316**	0.997*** (0.214)	0.203***
<i>canton ESCO</i>	0.073 (0.199)	0.017	0.550*** (0.127)	0.135***
<i>oil backup</i>	- -	-	0.541*** (0.203)	0.160**
<i>ln(duration)</i>	0.836 (0.582)	0.190	0.262 (0.198)	0.070
<i>intermediary client</i>	-0.633*** (0.165)	-0.144***	-0.553*** (0.086)	-0.153***
<i>rented</i>	-1.183*** (0.416)	-0.270***	-1.224*** (0.197)	-0.382***
<i>interest rate</i>	0.276* (0.156)	0.063*		
<i>ln(total cost/year)</i>	-0.493*** (0.162)	-0.112***		
<i>surface (x1000m<sup>2</sup>)</i>	0.055*** (0.017)	0.013***		
observations		529		2,003
groups		321		1,214
year dummies		yes		yes
		y=0 y=1		y=0 y=1
$\hat{y}=0$		407 84		1,368 353
(%)		(97.84) (74.34)		(94.80) (63.04)
$\hat{y}=1$		9 29		75 207
(%)		(2.16) (25.66)		(5.20) (36.96)

Notes: Upper part of the table: Project-clustered robust standard errors in parentheses. Average marginal effects (AME) on  $\Pr(y=1)$  are estimated based on estimated coefficients. \*\*\*  $P < 0.01$  \*\*  $P < 0.05$  \*  $P < 0.1$  Lower part of the table: See Appendix 6.2 for details on year dummies.  $y=0$  (resp.  $y=1$ ) indicates observed values of  $y$ ,  $\hat{y}=0$  (resp.  $\hat{y}=1$ ) indicate predicted values of  $y$  using estimated random effects and set to 1 if  $P(y=1|x) \geq 0.5$ , 0 otherwise.

The proxy for asset specificity, i.e. the specificity index (hypothesis H1a), has no significant impact on ESC adoption. This could be explained by the fact that ESC represents an instrument for the owner to benefit from the ESCO's technical expertise and risk sharing, which promotes the implementation of innovative technologies. ESCOs may also have an incentive to target these technologies because they represent lower operating costs.

The hypothesis (H1b) that adoption is more likely in projects involving new buildings is favored here, with a probability of adoption 22 to 23 percentage points greater. ESC projects are also more likely to be signed (20 to 32 percentage points) in residential buildings, favoring hypothesis H1c.

The importance of trust (hypothesis H2), as observed by Xu et al. (2011), is favored in the larger sample (column 2)<sup>40</sup>, with a 14 percentage points increase in the probability of signing the contract if a former relationship exists between the ESC supplier and the client (which is the case if the client lies in the ESCO's canton).

The probability of adopting ESC increases by 16 percentage points if the technology includes an oil heating system backup. This variable could however not be included in the model of column 1, since oil backup is only present in rejected offers in this smaller sample. In the larger sample, interacting the variable *oil backup* with a trend shows that its impact does not change through time, suggesting that the need for reliable technologies is likely to be as important for clients in 2011 than it was in the 1990s.<sup>41</sup> This in turns suggests that renewable energy heating systems may still be perceived as unsure or insufficient.

The coefficient on contract duration (hypothesis H3) has no significant impact on ESC adoption, while a negative impact is suggested by both transaction cost economics theory and observations of the ESCO markets (Goldman et al., 2005; Soroye and Nilsson, 2010; Lee et al., 2015). The absence of a significant result may stem from the fact that contract duration often equals the technology's lifetime. Therefore, the negative impact predicted may be outweighed by the positive perception on long lasting technologies.

As expected, a greater number of decision-makers taking part in the ESC contract, as it is the case when the client is an intermediary (hypothesis H4a) or when the building is rented (hypothesis H4b), decreases the probability of opting for ESC. The results confirm the observation of untapped potential in rented buildings (e.g. Nolden and Sorrell, 2016; Panev et al., 2013). Renting the building is the most important obstacle

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<sup>40</sup> The variable canton of the ESCO is however not significant in the smaller sample of 529 observations.

<sup>41</sup> In the larger sample, this was tested by using a time trend interacted with the variable oil backup, which had no significant impact.

considered, with a negative impact on adoption ranging from 27 to 38 percentage points. The negative effect seems to come from the risk of legal disputes with tenants, rather than from landlord-tenants split incentives. Indeed, a dummy variable capturing the fact that the owner lives in the building has no significant impact on ESC adoption, once the fact of having a tenant is controlled for. The perceived risk of legal disputes stems from the legal framework of transferring the costs of ESC to the tenants, which remains unclear in Switzerland.<sup>42</sup>

The average marginal effects provide some answers to the aforementioned dilemmas concerning residential - and often rented - buildings as well as new building frequently involving intermediary clients. The results show that the negative impact of rented buildings more than offsets the positive effect of residential buildings.<sup>43</sup> The contractor would get a larger rate of adoption by targeting non-residential buildings such as industries or non-rented administrative buildings. The barrier related to tenants may also explain why ESCOs are struggling to reach the residential sector in Finland (Suhonen and Okkonen, 2013). On the other hand, the cost implied by the involvement of intermediary clients seems to be compensated by the positive impact of a new construction on ESC adoption.<sup>44</sup>

The real interest rate, measuring the project's risk (hypothesis H5), has a significant positive impact on ESC adoption. A one percentage point increase in interest rate raises by 6 percentage points the probability of signing the contract. This means that the riskier the project, the higher the client's probability of signing the contract. This result differs from Polzin et al. (2016b), who showed in the context of EPC adoption that collectivities tend to ignore the advantage of risk-sharing brought by the outsourcing of energy services to an ESCO.

Finally, while the client's size in terms of squared meters (*surface*) has a small significant positive effect, the measure for aggregate production cost, *ln(total*

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<sup>42</sup> When the energy equipment is external to the building, as for district heating, the owner is legally allowed to transfer the costs of operation, maintenance, energy purchase and investment amortization into the renting charges (ancillary costs). Theoretically, the owner could do the same when the energy equipment is within the building but owned by a third party, as in ESC. However, this has never been subject to a legal precedent. Thus, the risk of legal dispute remains high.

<sup>43</sup> In regression 2, a Wald test on the marginal effects of the variables rented and residential rejects the null hypothesis of marginal effects being identical in absolute value: the impact of rented is significantly greater (99% confidence level).

<sup>44</sup> A Wald test on the marginal effects of new and intermediary client in regression 2 rejects the null hypothesis of marginal effects being identical in absolute value: the impact of new is significantly greater (99% confidence level).

*cost/year*), displays a significant and negative impact on ESC adoption. The predicted inverted-U shape relationship between the client size and ESC adoption (hypothesis H6) is not confirmed, since the squared term of  $\ln(\text{total cost/year})$  is not significant (cf. Appendix 6.3). The fact that transaction costs render ESC undesirable for small energy consumers is not confirmed here. This result must however be viewed cautiously since the dataset is characterized by a selection of relatively large clients: 85% of the offers are targeted at clients with yearly energy costs greater than CHF 15,000, which corresponds to the consumption costs of buildings with half a dozen apartments. Another proxy for economies of scale has been tested, i.e. the size of the installations in terms of power (kW). The latter has no significant impact on ESC adoption, even when interacted with technology dummies such as heat pumps.<sup>45</sup>

### **4.3 Limitations, robustness checks and further research**

The limitation of this research relies first on the possible selection bias. First, this results from the fact that the sample includes only interested clients since they requested an offer. This may prevent the analysis to capture all the determinants of ESC adoption. The selection bias is also likely to affect the types of technologies involved in these contracts. This also comes from the fact that only two ESC suppliers accepted to provide full information about their offers. Both are experienced ESCOs and may already be targeting the most viable projects, e.g. large-size new residential buildings. Because non-residential buildings and ESC solutions with oil are under-represented in the sample, this may result in estimation biases. Further research would need to compare this study's results with analyses based on offers made from other contractors and on clients who never received an ESC offer, such as small energy consumers. The latter could be done using a survey with stated preferences.

Then, the dataset is characterized by a larger number of rejected, as opposed to accepted, offers. This, according to King and Zeng (2001), may lead to an underestimation of the predicted probability of signing the contract. This can also be

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<sup>45</sup> The empirical analysis does not include technology-specific dummies as they have no significant impact on ESC adoption (cf. appendix 6.4).

seen at the bottom of Table 1.5, in which fitted values of  $y$  are better at predicting  $y = 0$  than  $y = 1$  in both regressions.

A first strategy to check the validity of the results is to perform a bootstrap without replacement, i.e. to randomly select a subsample of rejected offers, which are equal in number to the accepted offers. Average marginal effects for both regressions are computed with balanced samples, using random subsamples of rejected offers, with 113 rejected offers for regression (1) (respectively 561 for regression (2)). The average marginal effects results, after 500 random draws, are presented as histogram plots in appendix 6.5. The results show that the average marginal effects are close to the values of Table 1.5. A few variables show a more important impact in the larger sample (regression (2)), such as canton ESCO, new building, residential and intermediary client. This however does not affect the conclusion of tenants offsetting the advantages of residential building and new buildings being interesting to target despite the frequent involvement of intermediary clients.<sup>46</sup> One can also note that average marginal effects computed this way are characterized by the presence of many outliers in the smaller sample (regression (1)), for residential and rented variables for instance. This is probably explained by the small sample, which is consequently reduced to 226 observations.

This bootstrap strategy may however not be sufficient to properly account for the problem of an unbalanced sample. The number of rejected offers is also larger within the clients. This may result in a bias towards picky clients, since these are over-represented by the number of offers they have rejected. In other words, the number of offers to a client may be endogenous, i.e. related to the probability of adoption. A strategy to test this possibility consists in performing a bootstrap without replacement, in this case by selecting a subsample of rejected offers within each client with more than one rejected offers. The results are shown in appendix 6.6 with 500 random draws, keeping a maximum of one rejected offer per client. The histograms suggest that, although all marginal effects keep the same sign and significance, some of the

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<sup>46</sup> Indeed, the distribution of the average marginal effects (AME) of intermediary clients lie between -0.15 and -0.25 and new buildings AME from 0.26 to 0.36. Rented buildings lie between -0.31 and -0.41 while residential lie between 0.20 to 0.35.

coefficients may be slightly biased. This is the case for canton ESCO<sup>47</sup>, duration, new and residential building, rented buildings and intermediary clients. In fact, except for rented buildings in the large sample, the magnitudes of the marginal effects are larger in absolute value when using the bootstrap strategy. Thus, the impacts presented in the results section are robust although they may be somehow underestimated in their strength. An exception is rented building which may have an impact that may be slightly overestimated in the large sample.<sup>48</sup> One can also note that the results about the tradeoffs are robust. Indeed, rented buildings negative impact still compensate the positive effect of residential buildings and the positive impact of new buildings offset the negative effect of having an intermediary client. Finally, one can note that this bootstrap strategy results in a significant positive impact of specificity and contract duration on adoption,<sup>49</sup> which contradicts the literature.

Third, the dataset is characterized by an iterative process between the first offer and the subsequent ones, which results from negotiation between the two parties. The first implication lies in the fact that the offers made to a client are not independent. Using the random effects to account for this issue may not be sufficient if the random effects correlate with the regressors. Relaxing the random effects assumption of uncorrelated effects, by using fixed effects or correlated random effects for instance (Wooldridge, 2009), is not suitable to this dataset. Within variation of the variables of interest is indeed insufficient, i.e. the offers to each client do not change sufficiently from one another. Another result of this issue lies in the possible endogeneity. Indeed, the contractual attributes of the accepted offers will be determined by the client's negotiation. Therefore, the explanatory variables may not be exogenous. An additional robustness check consists in including only the final offer for each client. The results are shown in Appendix 6.7. Except for the interest rate, which becomes insignificant, all other variables gain in magnitude and exhibit the same significant sign. The specificity index and the contract duration also have a significantly positive impact on ESC adoption, but only in the larger sample. Further research may consider other methods to deal with this issue. One could for instance model this

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<sup>47</sup> In the big sample only.

<sup>48</sup> AME= -0.38 in the basic regression and ranges from -0.33 to -0.37 in the bootstrap.

<sup>49</sup> Only in the large sample for specificity.

negotiation process using dynamic games. Using discrete choice experiments is also another method to make sure that the regressors are exogenous.

Another limitation lies in the proxy used to measure asset specificity, i.e. the specificity index. The proxy is imperfect because most existing Swiss buildings were built before the 1990s (OFS, 2015), while 82% of the buildings in the sample have a construction date that coincides with the timing of the project (therefore after the 1990s). A better proxy would compare the offers' technology with Swiss buildings of the same age. The construction year is however unavailable in my sample. In order to account for this potential problem, the specificity index is interacted with a dummy equating one for existing buildings. I find no statistical difference of the specificity proxy's impact on ESC adoption between old and new buildings. The fact that the specificity index has no significant impact may also come from a reverse causality bias between ESC adoption and specificity (Masten, 1996; Saussier, 2000). Indeed, the client may choose the level of asset specificity, given her choice to adopt ESC or not. This could be tested in future research using an instrumental variable for asset specificity, such as the proximity to energy sources, e.g. lakes or groundwater for technologies such as heat pumps. Finally, one should note that the proxy for asset specificity used here may also reflect market power, as it measures the difficulty to find another supplier. The effect of market power on ESC adoption is ambiguous and may also suffer from reverse causality. Hence, further research should focus on alternative measures for asset specificity.

Several other robustness checks were performed to test whether relaxing the assumptions underlying the random-effects probit model and changing the approximation method affects the results.

First, relying on a random-effects logit model, rather than on a random-effects probit model, results in quantitatively similar average marginal effects.<sup>50</sup>

The quality of the quadrature approximation of the random-effects probit model has been checked and confirmed.<sup>51</sup>

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<sup>50</sup> Differences lie at the hundredth.

<sup>51</sup> This has been done by changing the number of integration points and assess how it affects the results. The relative differences between the coefficients when changing integration points from 8 to 16 (instead of 12 in table 4) were very

The results are also robust to an increase in sample size resulting from an estimation of missing values in energy consumptions based on the buildings' type and size.<sup>52</sup>

Finally, I showed that the project's risk has a positive effect on adoption. This suggests a need for clients with projects including larger risk to shed it onto the ESCO. Further research concerning risk would be needed to study the client's and the ESCO's risk aversion. Plausible proxies for risk aversion are difficult to find. I tested whether the offer being targeted at a private vs. a public client has any impact - either directly or through the interest rate - on adoption. The use of this determinant is supported by the fact that public entities are often considered in the economic literature as being risk neutral.<sup>53</sup> This variable has nevertheless no significant impact (see Appendix 6.3).<sup>54</sup> Then, I analyze other measures for the project's risk as perceived by the client. In ESC, the client typically bears the risk of energy prices variations<sup>55</sup>. Their impact was tested using several measures. First, I used a ratio of fixed cost on total cost which measures the part of the energy cost that is not subject to uncertainty. Then, a measure of prices variability (namely the standard deviation)<sup>56</sup>, was tested. These have no impact on adoption (cf. appendix 6.3).

## 5 Conclusion and policy implications

This study examines the economic determinants of adoption of energy supply contracting (ESC). Conjectures based on economic theories and observations of ESCO markets are tested quantitatively using an original dataset of rejected and accepted ESC offers from two Swiss ESC suppliers over the period 1996-2011. These ESC projects involve a large share of renewable energy technologies.

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small (of the order of  $\times 10^{-6}$  to  $\times 10^{-8}$ ), suggesting a quadrature approximation of quality.

<sup>52</sup> Hot water consumption was assumed to be 75MJ per squared-meter heated surface (i.e. 75/3.6 kWh per m<sup>2</sup>) in residential building and 50MJ in non-residential buildings. New buildings (respectively old buildings) were attributed a heating consumption of 100MJ/m<sup>2</sup> (respectively 250MJ/m<sup>2</sup>). This method permits to increase the sample to 575 observations.

<sup>53</sup> See for instance McAfee and McMillan (1986).

<sup>54</sup> This may come from the fact that public clients represent a very small share in the sample (2.25%), making it difficult to test it properly.

<sup>55</sup> When primary energy supply is included in the contract, as in a standard ESC contract, the variable cost determined into the contract is indexed each year to the corresponding energetic agent's index, as set by OFS (2014). There exists however some contracts called "light contracting", where the client keeps on buying the primary energy to her initial energy supplier. In this case, the variation in variable cost is determined by the variation in the market prices of the corresponding energetic agents with data from OFS (2016).

<sup>56</sup> Price volatility was computed with 2000-2014 data on monthly energy prices (OFS, 2016) for "light contracting" and of monthly energy indices (OFS, 2014) for standard ESC contracts.

The results suggest that clients with risky projects are willing to share the risk with the ESCO, who can diversify via a large portfolio of projects and other activities, and have a better control of technological risks. Economies of scale also appear to be a determinant of ESC adoption. This result should, however, be taken cautiously with regard to the insufficient share of small clients in the dataset. Asset specificity does not display a negative effect on ESC adoption as predicted by economic theory. While this must be confirmed by future empirical research, this would be good news for policy makers. Indeed, if asset specificity is proven to have no impact on customer choice, it may be non-strategic for the contractors to propose generic technologies as it has been observed on EPC markets (Mills, 2003; Sorrell, 2007).<sup>57</sup>

This study also provides quantitative evidence that ESC adoption is smaller in rented buildings. This can be related to the perceived legal issue linked to rented buildings caused by a lack of clear legislation on the transfer of the contract costs to the tenant. Having an intermediary client, who plans to sell the building with the ESC contract, also increases expected transaction costs and thus reduces ESC adoption. On the other hand, if the project relates to a new or a residential building, the probability of contract adoption increases. This suggests low penetration of ESC in more complex buildings such as industrial facilities, office buildings and commercial centers, which represent higher risks for the contractor if the client relocates or goes bankrupt.

If energy service contracting is proven to foster investment in renewable technologies and energy efficiency, the priority for policy makers would be to address market failures, such as the lack of clear legislation in Switzerland regarding the transfer of energy contracting costs to the tenants. This study shows that ESC suppliers cannot reach several market segments because of the transaction costs involved. According to transaction costs economics, these costs can be mitigated by the ex ante effort to design as complete a contract as possible with respect to future uncertainty. National and international ESCO associations propose general guidelines and standard contracts to reduce transaction costs (Polzin et al., 2016a). The impact of these top-

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<sup>57</sup> Non-strategic here is considered as a decision that may not contribute to the competitive advantage of the firm (cf. Cooremans, 2011). This point may however be challenged by the fact that the risk may offset the gain in value resulting from proposing innovative technologies. Therefore, proposing generic technologies may still be strategic for ESCOs. This point merits further research.

down approaches has however been limited in practice (Nolden et al., 2016). The knowledge required to design such contracts calls for the intervention of facilitators, working as intermediaries between the clients and the ESCOs, who provide technical and administrative support (Bleyl et al., 2012; Nolden et al., 2016; Polzin et al., 2016a). This study provides rationale for encouraging these bottom-up and tailor-made solutions provided by facilitators, for instance through subsidies on their start-up costs as suggested by Nolden and Sorrell (2016). I show that the perceived reliability of the technology and a pre-existing relationship with the ESCO may also reduce the client's expected transaction costs. Trust may also be enhanced by government campaigns raising public awareness and certifying the ESCOs.

I argue that the potential could be better exploited by the ESCOs, were they to adapt their business model. First, the ESCOs must fully account for the trade-offs underlying the type of clients they are targeting. Residential and new buildings present the advantage of less specific investments and more flexibility in the technological installation. Yet, these advantages must be balanced with disadvantages of involving tenants and intermediary clients. While advantages related to new constructions offset the expected transaction costs incurred by intermediary clients, this is not the case for residential buildings destined for rental use. Second, were the legal situation to be clarified, ESCOs could use other repayment schemes such as on-bill financing (Nolden and Sorrell, 2016). This may significantly reduce transaction costs for rented buildings as well as for buildings with large risks of relocation. Finally, in order to target other types of clients, such as old or non-residential buildings, ESCOs may consider safety nets or contractual clauses regarding the client's risk of relocation or bankruptcy. These may include real estate liens or guarantee fund among several ESCOs.

## 6 Appendix

### 6.1 A simple model of ESC adoption rooted in transaction costs economics

The model described here uses a simplified version of the formal model developed by Tadelis and Williamson (2013). In Tadelis and Williamson's model, a buyer optimizes over both the degree of externalization ( $z$ ) and the mode of governance. In the model presented here, the energy customer optimizes over the degree of externalization only. I argue that in the context of energy service contracting, this is sufficient to distinguish between the different types of energy service provision to capture the trade-offs underlying energy service contracting adoption in the context of transaction cost economics.

The limitation of this model lies in the fact that it does not properly account for risk sharing<sup>58</sup> and economies of scale.

#### 6.1.1 Basic Setup

A customer willing to acquire an energy service, such as heating, lighting or cooling faces a multitude of options in terms of organizational structure and outsourcing degree. First she can opt for full in-house provision, which is akin to vertical integration of the energy service. In that case, the supplier is an employee such as an energy manager, who takes care of each necessary activity  $k=1,\dots,K$  in order to provide energy services. These include the analysis of the adequate equipment needed, its purchase and installation, the operation and maintenance as well as the energy purchase. The employee is allocated with a fixed wage ( $F_1$ ) and the corresponding amount needed to pay each activity's cost ( $C = \sum_k^K c_k$ ). Hence, the total cost for the client is  $F_1+C$  and the cost's share ( $z_1$ ) borne by the employee is null.

The customer can also opt for energy supply contracting, where the supplier, i.e. the ESC contractor, is paid a fixed price ( $F_2$ ) to take care of the whole process including operation and maintenance. In addition the customer pays a variable cost corresponding to her energy consumption. In this kind of contractual relationship, the cost share borne by the supplier ( $z_2 = (C_d + C_p + C_m)/C$ ) is large and includes design and

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<sup>58</sup> See McAfee and McMillan (1986) and Lafontaine and Slade (2007) for formal models of risk sharing.

engineering costs ( $c_d$ ), purchase and installation costs ( $c_p$ ) and operation and maintenance costs ( $c_m$ ).<sup>59</sup> Hence, the total cost for the client<sup>60</sup> is  $F_2+(1-z_2)C$  and the cost borne by the ESC supplier is  $z_2C$ .

The main difference between the various organizational structures of energy provision can be summarized by the supplier's cost share  $z$ , which can also be seen as an externalization's degree. Any combination of fixed and variable payments is a possible option. Thus,  $z$  is considered as a continuous variable that can take any value between 0 and 1. The customer's final choice for energy service provision will depend on her optimal choice for  $z^*$ , which results in ESC adoption if and only if:

$$z^* \geq z_2 \Leftrightarrow U_{ij}(ESC) > U_{ij}(other\ provision) \Leftrightarrow y_{ij} = 1 \quad (1)$$

where  $z_2$  is the ESCO's cost share ratio, which includes all necessary energy service activities costs except energy purchase.<sup>61</sup>  $y_{ij}$  takes the value 1 if individual  $i$  signs the ESC contract  $j$  proposed, and equals zero otherwise. The following subsection describes how the cost share ratio  $z$  is optimally chosen by the customer in the transaction costs economics framework.

### 6.1.2 Production costs

Production costs are given by:

$$C(e) = \bar{c} - e \quad (2)$$

and represent the total costs for all the activities necessary to provide useful energy, i.e.  $C(e) = C = \sum_k^K c_k$ .  $0 \leq e < \bar{c}$  represents the endogenously chosen amount of supplier's effort put into the project, which depends on  $z$ . The supplier's opportunity cost of effort is  $y(e)$ , assuming  $y'(e) > 0$ ,  $y'(0) = 0$ ,  $y''(e) > 0$ ,  $y'''(e) = 0$ . As in Tadelis and Williamson (2013) and in agency theory, it is further assumed that it is not possible to contract directly on unobservable effort.

<sup>59</sup> A priori, ESC seems to be very close to a conventional turnkey project, where the only difference in the former is that the operation and maintenance costs are borne by the supplier. However, in practice, this represents an important difference since this provides the ESCO with the incentive and the mean to control and optimize the equipment performance during the entire contract's time. In the majority of the ESC contracts considered in this chapter, the contract's time corresponds to the expected lifetime of the equipment.

<sup>60</sup> In ESC,  $(1-z_2)C$  typically equals the variable cost corresponding the client's energy consumption,

<sup>61</sup> Since a higher degree of externalization than  $z_2$  is not observed in my sample, the choice can without loss of generality been simplified to opting for ESC if and only if  $z^* = z_2$ .

### 6.1.3 Transaction costs<sup>62</sup>

Transaction costs  $K(z) > 0$  are incurred ex post<sup>63</sup> in the case that an exogenous disturbance occurs and that adaptations are needed in order to obtain the same utility value  $v$  from the energy service. Depending on the kind of disturbances, transaction costs can in practice be borne either by the ESCO or the client. However, assuming perfect competition ex ante, i.e. at the time of the tendering process, any ESCO's expected transaction cost will be incorporated into its bid and will consequently be transferred to the client (Bajari and Tadelis, 2001; Bajari et al., 2014). It is assumed that  $K'(z) > 0$ , i.e. the higher the supplier's cost share the higher the transaction costs. Furthermore,  $K''(z) \geq 0$  is assumed so that the gain from adaptation when a higher share is borne by the supplier is evolving at a non-decreasing rate. Since transaction costs are incurred ex post, at the time the customer must choose whether to adopt ESC, it is the expected value of the transaction costs that matters. And a disturbance is not sufficient in itself to incur transaction costs. Transaction costs are expected to occur with a probability  $\sigma\rho$ , i.e. only if the interaction of two components take place.<sup>64</sup> First, contract's incompleteness will appear in  $\rho \in [0,1]$  which corresponds to the probability that the contract will be renegotiated due to a disturbance. Second, asset specificity will be represented by  $\sigma \in [0,1]$ , which is the probability that the supplier (or the buyer) cannot be replaced by a competitor when disturbance occurs.

#### a) *Ex post versus ex ante transaction costs*

Tadelis and Williamson (2013) emphasize that ex post adaptation is the main problem of organization under focus in the transaction costs economics (TCE). According to them, it is even the main difference between TCE, focusing on ex post adaptation, and agency-based theories or property rights theory, which focus on ex ante alignment of incentives.

The model presented here follows Tadelis and Williamson (2013) and thus considers only ex post transaction costs, i.e. renegotiation costs after the contract is signed, which simplifies significantly the mathematical model. This assumption does not

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<sup>62</sup> In Tadelis and Williamson, 2013, transaction costs are defined as the sum of the production costs and ex post adaptation costs. I however changed the denomination and named transaction costs what Tadelis and Williamson named adaptation costs.

<sup>63</sup> See section 6.1.3.a).

<sup>64</sup> As a result, expected adaptation costs are given by  $\sigma\rho K(z)$

mean that ex ante transaction costs do not occur. But they are considered as exogenous as they are expected to be captured in the contract's incompleteness  $\rho$ .

Ex ante transaction costs relate to the costs incurred before the contract is signed, such as contractual design costs, the time needed to choose the technology, the ESCO and possible intermediary agents, and to monitor the quality of service. Of course a less restrictive assumption would consider that the customer can choose to invest time and money before signing the contract, i.e. increase ex ante transaction costs and reduce the probability of ex post renegotiation  $\rho$ .

A more comprehensive model would consider this trade-off between ex post adaptation costs and ex ante design costs. This has been done by Bajari and Tadelis (2001) who develop a model where the buyer can endogenously choose the degree of design completeness in response to the project complexity. They find that in more complex projects, the effort invested ex ante will result in contracts that are weakly less complete, *ceteris paribus*. This does not mean that in case of very high task complexity the buyer will put no effort in trying to define additional possible contingencies in the contract. But even if she does provide this effort, it will not reduce the probability of ex post renegotiation  $\rho$ . This result justifies the choice of Tadelis and Williamson (2013) to consider only ex post transaction costs and treat contract's incompleteness as an exogenous variable.

Testing empirically the importance of ex post vs. ex ante transaction costs is out of the scope of this study. However, my empirical analysis is aligned with this theoretical model since the determinants of the hypotheses H1 to H4 can be captured by the asset specificity ( $\sigma$ ), the contract's incompleteness ( $\rho$ ) or the magnitude of expected ex post adaptation costs ( $K'(z)$ ). My empirical analysis complement this model by adding risk (hypothesis H5) and economies of scale (hypothesis H6) as other determinants of ESC adoption.

#### 6.1.4 Optimization and results

The supplier's profit maximization and the first order condition are given by:

$$\max_e \Pi(e, z) = F - z(\bar{c} - e) - y(e) \quad (3)$$

$$FOC : y'(e) = z \quad (4)$$

The first order condition implies, following  $y''(e) > 0$ , that  $\partial e / \partial z > 0$ . Thus, a relatively higher supplier's cost share provides him with an incentive to increase effort and hence, reduces production costs.

The customer's optimization is presented by:

$$\begin{aligned} \max_z U(e, z) &= v - \sigma\rho K(z) - F - (1 - z)(\bar{c} - e) \\ \text{s. t. } e &= y'^{-1}(z) \end{aligned} \quad (5)$$

where  $v - \sigma\rho K(z)$  is the expected gross benefit from the transaction and is positive because it is assumed  $v - K(z) > 0$ , i.e. the energy service's value is such that it is always worth taking the risk of ex post transaction costs. The customer optimizes expected gross benefit minus payment, given the supplier's optimal amount of effort provided, which is represented in the incentive compatibility constraint.

The customer's first order condition is:

$$FOC : F(z, \sigma, \rho) = \bar{c} - [y'^{-1}(z)] + (1 - z)[(y'^{-1})'(z)] - \sigma\rho K'(z) = 0 \quad (6)$$

Using the implicit function theorem, I find:

$$\frac{\partial z}{\partial \sigma} = \frac{\frac{\partial F(z, \sigma, \rho)}{\partial \sigma}}{\frac{\partial F(z, \sigma, \rho)}{\partial z}} = - \left( \frac{-\rho K'(z)}{-2[(y'^{-1})'(z)] + (1 - z)[(y'^{-1})''(z)] - \sigma\rho K''(z)} \right)$$

Because  $y'^{-1}(z) = e \geq 0$  and I assumed  $y''(e) > 0$ , it is then possible to show that:

$$(y'^{-1})'(z) = \frac{1}{y''(y'^{-1}(z))} > 0$$

Furthermore, Since,  $y'''(e)=0$ :

$$(y'^{-1})''(z) = \frac{-y'''(y'^{-1}(z)) (y'^{-1})'(z)}{(y''(y'^{-1}(z)))^2} = 0$$

And because I assumed  $K'(z) > 0$  and  $K''(z) \geq 0$ , I find:

$$\frac{\partial z}{\partial \sigma} = \frac{\rho K'(z)}{-2[(y'^{-1})'(z)] - \sigma \rho K''(z)} < 0$$

Thus,  $\sigma$  (similarly  $\rho$ ) has a negative impact on the solution of the customer's optimization, and thus on the customer's optimal choice  $z^*$ . Finally, the client signs the ESC contract if and only if  $z^* \geq z_2$ . As a result, asset specificity  $\sigma$  and contract's incompleteness  $\rho$  have a negative impact on the probability of opting for ESC. Furthermore,  $K'(z)$ , which can be related to the magnitude of expected transaction costs, also positively affects the impacts of  $\sigma$  (respectively  $\rho$ ) on ESC adoption.

## 6.2 Estimation results with year dummies

**Table 1.6: Estimation results with year dummies**

Random Effects Probit	(1)	(2)
dependent variable: offer accepted ( $y=1$ )		
<i>specificity index</i>	-0.007 (0.029)	0.009 (0.013)
<i>new building</i>	0.966*** (0.293)	1.050*** (0.159)
<i>residential</i>	1.385** (0.622)	0.997*** (0.214)
<i>canton ESCO</i>	0.073 (0.199)	0.550*** (0.127)
<i>oil backup</i>		0.541*** (0.203)
<i>ln(duration)</i>	0.836 (0.582)	0.262 (0.198)
<i>intermediary client</i>	-0.633*** (0.165)	-0.553*** (0.086)
<i>rented</i>	-1.183*** (0.416)	-1.224*** (0.197)
<i>Interest rate</i>	0.276* (0.156)	
<i>ln(total cost/year)</i>	-0.493*** (0.162)	
<i>Surface (x1000m2)</i>	0.055*** (0.017)	
<i>year: 1998</i>		0.975 (0.752)
<i>year: 1999</i>		0.606 (0.662)
<i>year: 2000</i>		0.270 (0.619)
<i>year: 2001</i>		1.810*** (0.676)
<i>year: 2002</i>		-0.811 (0.791)
<i>year: 2003</i>		-0.323 (0.634)
<i>year: 2004</i>		0.119 (0.627)
<i>year: 2005</i>		0.105 (0.602)
<i>year: 2006</i>		-0.178 (0.603)
<i>year: 2007</i>	-0.813** (0.351)	0.395 (0.605)
<i>year: 2008</i>	0.434 (0.456)	0.564 (0.615)
<i>year: 2009</i>	-0.577 (0.404)	0.524 (0.605)
<i>year: 2010</i>	0.103 (0.349)	0.762 (0.610)
<i>year: 2011</i>		0.588 (0.625)
observations	529	2,003
groups	321	1,214

Notes: Project-clustered robust standard errors in parentheses. \*\*\*  $P < 0.01$  \*\*  $P < 0.025$  \*  $P < 0.1$ . In column two, Base: years 1996 and 1997. In column 1, several years dummies are omitted because of collinearity

### 6.3 Other tests

**Table 1.7: Other tests**

Random Effects Probit dependent variable: offer accepted ( $y=1$ )	(1) Squared term for $\ln(\text{total cost}/\text{year})$	(2) Public building	(3) Fixed cost/total cost	(4) Std.dev of energy prices
<i>specificity index</i>	-0.001 (0.029)	0.002 (0.024)	-0.000 (0.028)	-0.010 (0.028)
<i>new building</i>	0.962*** (0.294)	1.186*** (0.256)	0.949*** (0.949)	1.016*** (0.316)
<i>residential</i>	1.483** (0.651)	1.016** (0.442)	1.440** (0.673)	1.549** (0.699)
<i>canton ESCO</i>	0.057 (0.200)	0.210 (0.185)	0.098 (0.199)	0.089 (0.199)
$\ln(\text{duration})$	0.607 (0.571)	0.125 (0.403)	0.979 (0.610)	1.010* (0.579)
<i>intermediary client</i>	-0.632*** (0.166)	-0.641*** (0.167)	-0.652*** (0.165)	-0.663*** (0.162)
<i>rented</i>	-1.248*** (0.423)	-0.980*** (0.346)	-1.248*** (0.424)	-1.323*** (0.426)
<i>interest rate</i>	0.287* (0.157)	0.370** (0.015)	0.316* (0.162)	0.289* (0.156)
<b><i>interest rate x public building</i></b>		<b>-0.288 (0.362)</b>		
$\ln(\text{total cost}/\text{year})$	2.026 (3.234)		-0.591*** (0.181)	-0.604*** (0.177)
<b><math>\ln(\text{total cost}/\text{year})^2</math></b>	<b>-0.126 (0.161)</b>			
<i>surface (x1000m<sup>2</sup>)</i>	0.082** (0.032)		0.053*** (0.017)	0.057*** (0.017)
<b><i>public building</i></b>		<b>0.788 (1.721)</b>		
<b><i>Fixed cost/total cost</i></b>			<b>-1.958 (1.448)</b>	
<b><i>Std-dev of monthly energy prices</i></b>				<b>0.068 (0.041)</b>
observations	529	614	529	529
groups	321	380	321	321
year dummies	yes	yes	yes	yes

Notes: Project-clustered robust standard errors in parentheses. \*\*\*  $P < 0.01$  \*\*  $P < 0.05$  \*  $P < 0.1$ .  $\ln(\text{total cost}/\text{year})$  and surface omitted in (2) in order to avoid public variable to be omitted because of collinearity.

## 6.4 Estimation results with technologies dummies

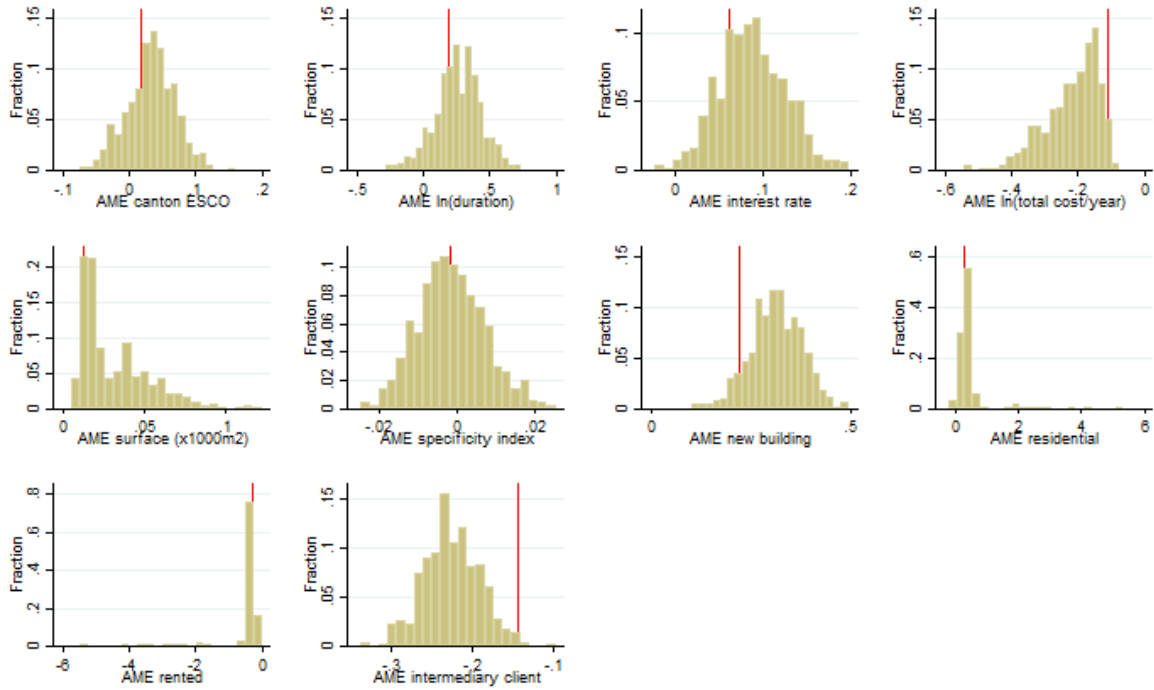
**Table 1.8: Estimation results with technologies dummies**

Random Effects Probit	(1)	(2)
dependent variable: offer accepted ( $y=1$ )		
	coefficient	Coefficient
<i>heat pump</i>	-0.089 (0.570)	0.094 (0.450)
<i>wood</i>	0.703 (0.549)	-0.245 (0.287)
<i>gas</i>	0.604 (0.743)	0.798 (0.847)
<i>district</i>	0.354 (0.731)	0.190 (0.504)
<i>solar</i>	1.031 (0.681)	-0.126 (0.487)
<i>specificity index</i>	-0.082 (0.068)	-0.008 (0.025)
<i>new building</i>	1.074*** (0.326)	1.081 (1.683)
<i>residential</i>	1.844** (0.694)	1.005 (1.110)
<i>canton ESCO</i>	0.111 (0.208)	0.521 (0.954)
<i>oil backup</i>	.	0.613 (0.946)
<i>ln(duration)</i>	1.818** (0.741)	0.255 (0.783)
<i>intermediary client</i>	-0.689*** (0.164)	-0.550 (0.949)
<i>rented</i>	-1.478*** (0.438)	-1.260 (1.463)
<i>interest rate</i>	0.278* (0.163)	
<i>ln(total cost/year)</i>	-0.666*** (0.169)	
<i>surface (x1000m<sup>2</sup>)</i>	0.067*** (0.017)	
observations	529	2,003
groups	321	1,214
year dummies	yes	yes

Notes: Project-clustered robust standard errors in parentheses. Oil backup omitted in (1) because there is no accepted offers with oil backup in the model of column (1). \*\*\* P<0.01 \*\* P<0.05 \* P<0.1

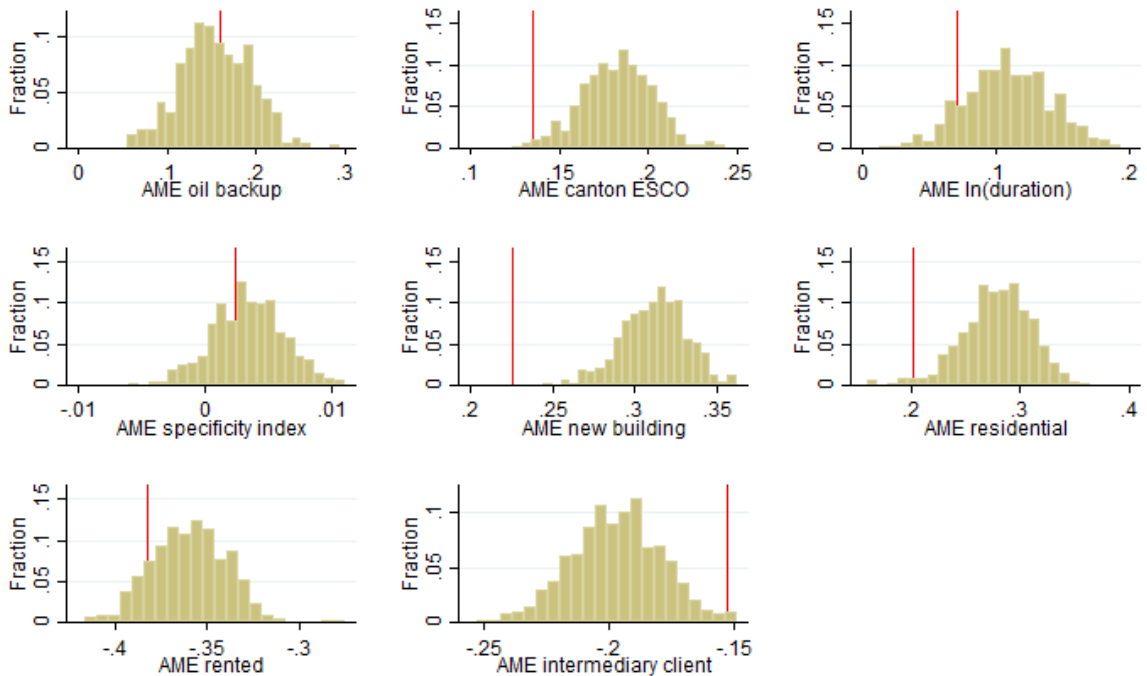
## 6.5 Robustness check: random draws of balanced subsamples

Average Marginal Effects with  $y$  as balanced, regression (1) from Table 1.5



(500 random draws with 113  $y=0$  (randomly chosen) and 113  $y=1$ )

Regression (2) from Table 1.5



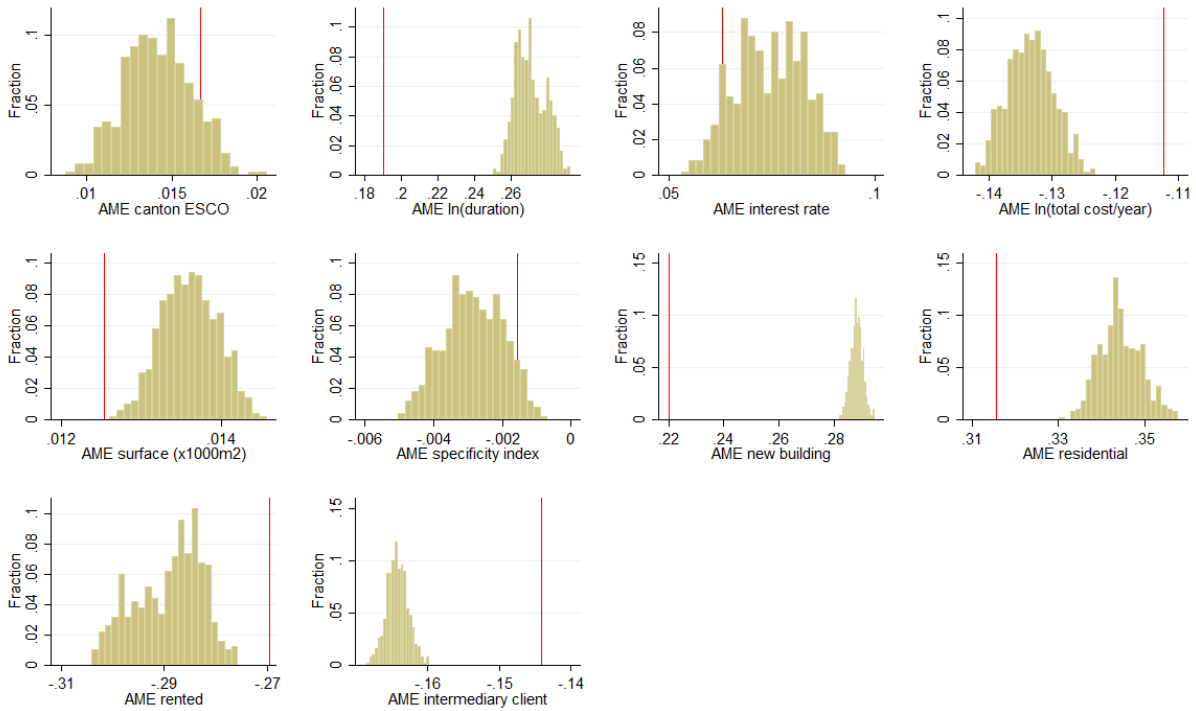
(500 random draws with 113  $y=0$  (randomly chosen) and 113  $y=1$ )

## 6.6 Robustness check: random draws of rejected offers within each client

**Table 1.9: Bootstrap**

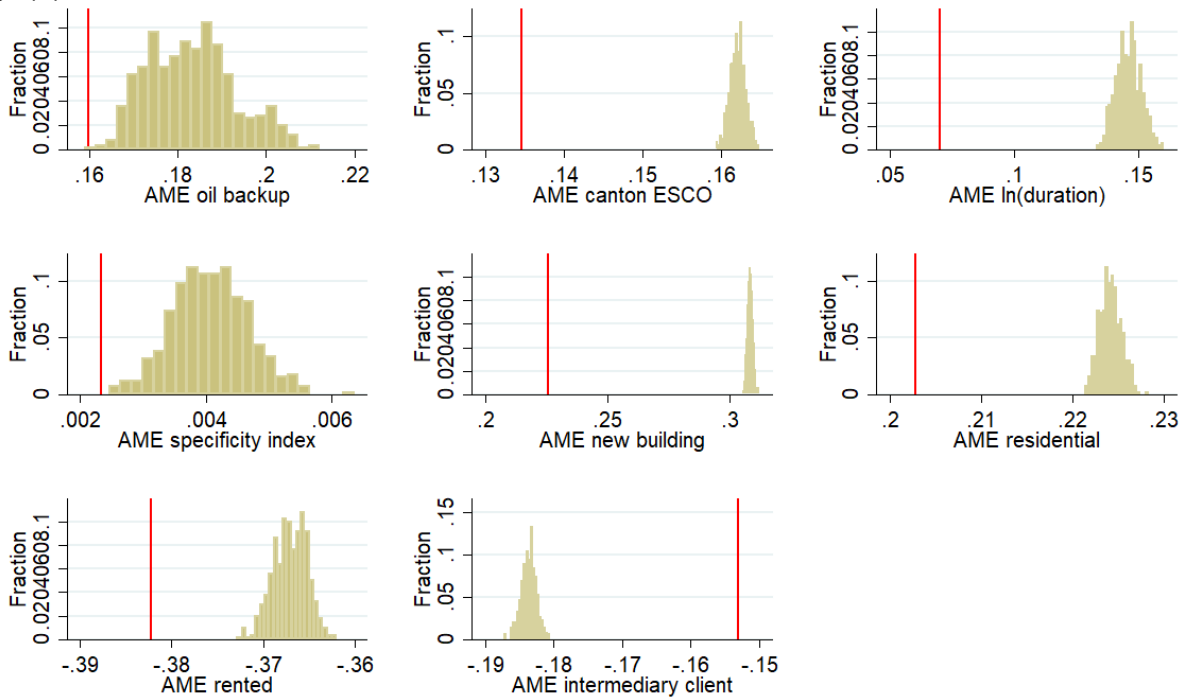
	Small sample (reg. 1 of Table 1.5)	Big sample (reg. 2 of Table 1.5)
Total clients	321	1 214
<b>Total observations</b>	<b>529</b>	<b>2 003</b>
Clients with one observation (not affected by bootstrap)	180	740
Clients with two observations: one accepted and one rejected (not affected by bootstrap)	39	140
Clients with one accepted and several rejected (affected by bootstrap)	22	141
Clients with none accepted and several rejected (affected by bootstrap)	80	193
Total number of clients in the bootstrap strategy	321	1 214
<b>Total number of observations in the bootstrap strategy</b>	<b>382 (180+39×2+22×2+80)</b>	<b>1495 (740+140×2+141×2+193)</b>

Bootstrap: Average Marginal Effects with max. 1 rejected offer per client  
reg. (1) from Table 1.5



(500 random draws of rejected offers for clients with more than one rejected (n=382))

Bootstrap: Average Marginal Effects with max. 1 rejected offer per client  
reg. (2) from Table 1.5



(500 random draws of rejected offers for clients with more than one rejected (n=1495))

## 6.7 Regressions with the final offers only

**Table 1.10: Estimation results with the final offers only**

Probit	(1)	(2)
dependent variable: offer accepted ( $y=1$ )		
	coefficient	Coefficient
<i>specificity index</i>	0.039 (0.037)	0.048** (0.022)
<i>new building</i>	1.598*** (0.352)	1.863*** (0.186)
<i>residential</i>	2.313*** (0.699)	1.007*** (0.252)
<i>canton ESCO</i>	0.084 (0.248)	0.854*** (0.170)
<i>oil backup</i>		0.577** (0.285)
<i>ln(duration)</i>	0.099 (0.524)	0.577** (0.237)
<i>intermediary client</i>	-1.058*** (0.215)	-1.124*** (0.127)
<i>rented</i>	-1.540*** (0.417)	-1.283*** (0.217)
<i>interest rate</i>	0.146 (0.193)	
<i>ln(total cost/year)</i>	-0.899*** (0.195)	
<i>surface (x1000m<sup>2</sup>)</i>	0.078*** (0.021)	
observations	321	1,214
year dummies	yes	yes

Notes: Project-clustered robust standard errors in parentheses. Oil backup omitted in (1) because there is no accepted offers with oil backup in the model of column (1). \*\*\*  $P < 0.01$  \*\*  $P < 0.05$  \*  $P < 0.1$ . In the case of the final offers being proposed the same date (e.g. several variants of the contract), the accepted offer is kept. If all last offers of the same date are rejected, the least expensive is kept for the regression. In column (2), all 18 offers of 2001 are accepted and are therefore dropped together with the year dummy 2001.



## 2 The determinants of adoption of Energy Performance Contracting: Empirical evidence from a discrete choice experiment<sup>65</sup>

### **Abstract**

Energy Performance Contracting (EPC) consists in outsourcing the design, the operation, and possibly the financing of an energy-efficiency project. The contractor provides the client with a reduction in energy costs in exchange of a fixed fee or part of the savings achieved. This study analyzes the mechanisms underlying EPC adoption and how particular contractual clauses are valued by potential clients. The analysis is based on a discrete choice experiment among 297 managers of large private and public buildings in Switzerland. In order to analyze heterogeneity in preferences and decision-making processes, I compare conditional logit models with latent class models accounting for attribute non-attendance. The empirical analysis shows that the performance guarantee, and the resulting risk sharing mechanism, consistently improves the willingness to adopt EPC. The financing of the contractor is valued positively only by a minority of respondents. These are mostly public entities, presumably with debt ceilings. This study provides insights into the complexity and heterogeneity underlying the decision to invest in energy efficiency. While its risk sharing mechanism is valued positively, EPC also faces a reticence from potential clients, which may partly stem from a misunderstanding of the concept and could therefore be mitigated by fostering awareness.

**Keywords:** Energy efficiency, transaction costs, risk sharing, Energy Service Company (ESCO)

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<sup>65</sup>Based on Klinke et al. (2017), chapter III. This research has benefited from financial support from the Swiss Federal Office of Energy and from the Swiss Competence Center for Energy Research SCCER CREST funded by the Commission for Technology and Innovation (Grant KTI. 1155000154).

# 1 Introduction

Energy Performance Contracting (EPC) belongs to the set of instruments available for reaching the objectives defined by the Swiss Energy Strategy 2050. Indeed, these contracts typically involve energy conservation, energy efficiency or renewable energy. They also represent market-based solutions that do not necessarily require the government's intervention, and as such, are expected to be less costly for the government.

Switzerland's building sector satisfies *a priori* many of the prerequisites of a developed EPC market: strong financial institutions, a significant number of credit-worthy private and public companies with limited budget, an increasing need for building renovation and finally, the policy context of ambitious energy efficiency and CO<sub>2</sub>-reduction objectives. However, the actual situation differs from this expectation. Although a limited but growing interest seems to exist on the supply side and a few contracts have been initiated, the concept remains unknown to many potential clients, including public entities (Bertoldi et al., 2014). The first Swiss EPC call for tenders has been launched in 2016 and the market is still in its infancy, lagging behind neighboring countries, such as Germany or France (Bertoldi et al., 2014).

In this context and in order to fully exploit the benefits of EPC, one should review the mechanisms driving the decision of a client to adopt these contracts. The main channels that can foster EPC adoption, such as risk sharing, access to capital, technical expertise and enduring performance have been highlighted in the literature (Sorrell, 2007; Capelo, 2011; IEA-RETD, 2013). However, quantitative evidence in support of these conjectures is scarce and is rarely based on the customer's perspective, but rather on interviews of experts. A recent exception is Polzin et al. (2016b) who surveyed 1,298 German municipalities. Using stated choices, they assess the determinants of the probability of considering EPC for street lighting LED retrofits. They find that municipalities do not value the risk-sharing advantages of EPC. However, when constrained by budget or human resources capacity, they are more likely to consider EPC options.

The current state of the EPC literature however lacks empirical evidence on the decision mechanisms of EPC adoption and how they are affected by the contractual terms. Relying on a discrete choice experiment targeted at managers of large energy-consuming buildings in Switzerland, I assess quantitatively the impact of contractual attributes, such as a performance guarantee or financing from the ESCO. While such experiments have been used in other domains (e.g. Banfi et al., 2008; Rose et al., 2012; Blasch and Farsi, 2014; Caputo et al., 2014; Hole et al., 2016) they have, to my knowledge, never been employed in the context of energy service contracting. Second, I use latent class models to analyze the stated preferences, in order to account for heterogeneity in the value attached to the benefits and costs of EPC. The econometric models also account for the heterogeneity in the decision-making process, by considering possible attribute non-attendance, i.e. ignorance of certain attributes in the choice experiment. The fact that consumers do not necessarily act according to the standard assumptions underlying the neoclassical economic theory has been cited as a specificity of energy efficiency investments decision-making (Gillingham and Palmer, 2013). Heterogeneity in preferences and in decision-making is also characterizing the decision to invest in energy efficiency (Jaffe and Stavins, 1994, Allcott and Greenstone, 2012). Being aware of the existence of these behaviors in the case of energy efficiency and EPC (Bleyl et al., 2012) is of considerable importance as they explain why policy instruments such as information campaigns are insufficient to induce investment (Tietenberg, 2009).

The next section develops a series of hypotheses concerning the contractual attributes and how they may affect the choice of a potential client to adopt EPC. Section 3 presents the research context and the methodology, and in particular the survey design and the econometric framework. A description of the data and summary statistics are provided in section 4. The results are presented in section 5, followed by robustness checks and guidelines for further research. A conclusion is provided in the final section.

## 2 Background and hypotheses development

The basic principle of EPC consists in a contractor designing, installing, exploiting and sometimes financing energy efficiency measures in a client's building. EPC differs from ESC in the fact that the contractor does have an influence on the demand for final energy services. By monitoring secondary conversion equipment, the contractor provides its client with a reduction in energy costs in exchange for a fixed fee or part of the savings achieved. Typical measures proposed within EPC are efficient lighting, more efficient heating production and distribution systems, heating control systems, energy automation systems, and occasionally improved insulation of the building envelope and combined heat and power (CHP) systems (IEA-RETD, 2013). The two dominant EPC models are shared savings and guaranteed savings (Hansen, 2006):

- *Shared savings*: the ESCO typically finances or receives financing by a third party in order to design and implement the project. Energy cost savings are then shared between the two parties.
- *Guaranteed savings*: In this model, the client carries the financing or gets financing by a third party. The ESCO guarantees that the value of energy saved will meet a certain threshold. Otherwise, the ESCO covers the gap. In these types of contracts, the ESCO is typically paid a fixed fee.

Other energy performance contract's schemes exist. For instance, the *forfeiting* scheme involves a third-party investor. The investor finances partly or completely the installation and gets in return a corresponding predefined fixed share of the savings (from the client or the ESCO). As in the guaranteed-savings scheme, the client also pays a fixed fee to the ESCO which in return provides a guarantee on the energy savings achieved.

The shared savings model tends to be favored in younger EPC markets, while the guaranteed-savings scheme is more developed in mature markets. For instance, the US EPC market, which is considered as one of the most mature ones (Fang et al., 2012; and Panev et al., 2014), has been developing since the 1970s and was initially based on the shared-savings model (Langlois and Hansen, 2012). This has

drastically changed and projects are now financed with long-term debt or leases. Nowadays, US ESCOs prefer to serve as facilitators to provide financing rather than directly financing themselves (ICF, 2007; IEA-RETD, 2013). This can as well explain the differences between the types of EPC schemes used in Europe as compared with those in the US. Indeed, shared savings is the dominant model used in Europe, while 90% of the contracts in the US are rather using guaranteed savings schemes. Since the European ESCO is a younger market, clients are likely to be less confident and aware about this new business model, and usually let the ESCO finance the investment and bear the financial risk as it is the case in the shared savings model (Hansen, 2006; Marino et al., 2011). In the US, on the other hand, confidence of the consumer leads them to invest in EPC projects, through guaranteed savings schemes (Goldman et al., 2005).

These market analyses provide insights on the reasons why an EPC contractual scheme may be more efficient at attracting customers depending on the market situation. However, empirical evidence based on the customer's perspective is lacking. The present study assesses how potential clients value the contractual clauses and how it affects their decision to adopt EPC. The focus is particularly placed on the two contractual clauses that distinguish the main EPC schemes, i.e. the financing from the ESCO and the performance guarantee. The mechanisms through which these contractual clauses may affect EPC adoption are described in the following subsections.

## **2.1 Financing from the ESCO**

A building manager willing to implement energy efficiency measures may have limited access to capital. This has been cited as a market failure characterizing investments in energy efficiency, in cases where the lender cannot distinguish between good or bad credit risk borrowers (Gillingham and Palmer, 2013). This phenomenon is exacerbated if borrowers with a high energy savings potential have poor credit risk profiles (Palmer, Walls and Gerarden, 2012). Moreover, energy efficiency investments usually cannot be guaranteed by a collateral and the returns rely upon uncertain future energy cost savings (Hansen, 2006). Taken together, these elements result in higher interest rates hampering consumers to invest. Building owners or

managers may also be insufficiently informed about the financing options or subsidies available when making their decisions (IEA-RETD, 2013). Other constraints may prevent entities from investing in energy efficiency, such as debt ceilings (particularly affecting the public sector) or limited budget for non-core activities (in the case of private firms).

ESCOs may facilitate access to financing, either by paying for the installation themselves through the shared-savings EPC scheme, or by guaranteeing a third-party investment via the *forfeiting* scheme (Swissesco, 2016). Li et al. (2014) find empirical evidence that ESCOs can partly relieve the clients of their financing need, using a sample of 140 EPC projects implemented in China. This is captured by the first hypothesis:

***H1: Financing from the ESCO has a positive impact on EPC adoption***

This hypothesis may be challenged by the fact that the financing from the ESCO in the *forfeiting* scheme will provide added value only if the third party investor evaluates the ESCO with a better risk profile than the client. In the shared-savings scheme, ESCOs may also have difficulties to find the necessary capital at favorable costs (Nolden and Sorrell, 2016; Panev et al., 2014). Whether the facilitated access to capital provided by ESCOs is indeed valued by building managers depends on their actual credit constraints with respect to energy efficiency investments. Given the context prevailing in Switzerland at the time of this study, and in particular the low level of interest rates, the financing of ESCOs may be unattractive as compared to bank credits. Also, public entities may be able to circumvent debt ceilings *via* the financing of ESCOs only if the EPC project is off-balance sheet.<sup>66</sup> As a matter of fact, expert interviews reported in Klinke et al. (2017) suggest that the financing flexibility of EPC is not considered as a decisive advantage by Swiss ESCOs.

## **2.2 Energy savings guarantee and risk sharing**

The risk reduces the number and amount of investments undertaken in energy efficiency (Anderson and Newell, 2004). Risk stems from financial or technical uncertainties. In the former case, it relates to unexpected realization costs or future

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<sup>66</sup> As reported in Klinke et al. (2017), the off-balance sheet financing of EPC is not always feasible.

energy price variations. The technical risk in energy efficiency investment relates to unexpected technical failures of the equipment, under-performance or uncertain energy savings. Based on 50 retrofitted residential multifamily buildings in Switzerland, Khoury and Hollmuller (2017) find that realized energy savings do not meet the expected savings, but are instead considerably lower due to a variety of reasons, such as a mismatch between actual use and standards, uncertainty in facility managers and users' behaviour or poor input data quality.<sup>67</sup>

Imperfect information may also intensify the apparent risk of energy savings investments if the lack of technical knowledge prevents the investor from appropriately assessing *ex ante* the potential of an investment (Tietenberg, 2009; Gillingham and Palmer, 2013). Gathering the necessary information about the differences in quality of these investments may also be too costly (Allcott and Greenstone, 2012; Sorrell et al., 2004).

EPC is designed to give both the ESCO and the customer the incentive to reduce energy costs. ESCOs either provide a performance guarantee or get paid a share of the achieved energy savings. In either case, the client benefits from the technical knowledge of the ESCO and shares some of the performance risk. This leads to the second hypothesis:

***H2: Performance guarantee<sup>68</sup> and the resulting risk sharing mechanism has a positive impact on EPC adoption***

A guarantee comes at the cost of a risk premium paid by the client to the ESCO. Respondents are likely to have heterogeneous preferences and perceptions towards the technological risk. Recent research from Polzin et al. (2016b) show that German municipalities underestimate the risks associated with street lighting LEDs retrofits and therefore do not value the risk sharing advantage of EPC. Because this result may be specific to the LED technology with relatively low risk on the energy savings achieved, this study seeks to further analyze the impact of the performance

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<sup>67</sup> According to their model, 500MJ/m<sup>2</sup>/year expected savings translate in 310MJ/m<sup>2</sup>/year realized.

<sup>68</sup> We refer here to the general understanding of performance guarantee, which can either be provided indirectly through the shared-savings scheme or directly via the guaranteed-savings or the "forfeiting" scheme. Although for simplicity, in the choice experiment analysis, we consider the direct guarantee only, it is assumed to capture the general effect of direct and indirect performance guarantees provided by EPC.

guarantee on EPC adoption. It does so by considering the technical risk and the provision of a guarantee on the energy savings.<sup>69</sup> Because the technology involved in these contracts is likely to have an impact, the empirical analysis of the present study controls for the different kind of technologies proposed, e.g. envelope enhancement, heating production or building automation.

### **2.3 The costs of EPC**

The financing and performance guarantee of ESCOs give rise to transaction costs. For instance, protocols for the measure and verification of the energy savings must be contractually agreed upon in order to mitigate the potential moral hazard that may occur from the consumer's side or asymmetry of information regarding the ESCO's effort. These transaction costs, as well as the risk premium, are included in the client's annual payment to the ESCO. The latter is expected to have a negative impact on EPC adoption.

Energy performance contracts also imply long contractual periods. The impact of the contract duration is ambiguous *a priori*: on the one hand, duration is valued negatively by the respondents reluctant to a long-term commitment. On the other hand, a longer contractual period increases the duration of the performance maintenance and also unlocks more comprehensive refurbishments. Private entities may be more responsive to the first argument while public entities are likely to attach greater value to the second.

Finally, EPC adoption may be hampered because of other reasons (Backlund and Thollander, 2011; Pätäri et al., 2016; Stuart et al., 2016). In the Swiss context where the concept remains relatively unknown, the lack of awareness is likely to translate into reluctance towards EPC solutions. Empirically, this reticence may appear in the way costs and energy savings are valued depending on whether they are presented in an EPC or not, once all other contractual clauses are controlled for. It may also appear through the fact that some respondents never choose EPC, regardless of the

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<sup>69</sup> The uncertainty on future energy prices is voluntarily excluded from the performance guarantee in the analysis in order to decrease the complexity of the choice experiment. In Switzerland in practice, the performance guarantee typically covers both technical and price variation risks since the energy price is often fixed for the contractual period and the guarantee is expressed in CHF saved. In the choice experiment, we voluntarily presented the guarantee as kWh saved in order to disentangle the technical and financial risk.

attributes presented. Follow-up questions on the reasons why EPC is disregarded by the potential clients provide additional guidelines for ESCOs and policymakers.

## **3 Methodology**

### **3.1 Research context**

EPC is a market niche in Switzerland, which has started to develop only recently. The first public tender for EPC was published in Fall 2016. In Spring 2017, to our knowledge, 5 to 10 ESCOs had implemented EPC projects in Switzerland with a total of around 25 EPC contracts signed. The clients are hotels, industries, education and health facilities, private office buildings, residential buildings and shopping centers. In addition to the ESCOs which have implemented EPC projects, 5 to 10 additional ESCOs are active on the Swiss EPC market without having signed any contracts yet. Based on the survey lead for chapter 3 of this thesis, I estimate around 40 contracts under negotiation in Spring 2017, mainly with private entities.

The market being only at its infancy in Switzerland, we would expect the shared-savings scheme to be favored, as in other emerging EPC markets. However, some Swiss EPC experts refute the need of financing from the ESCO. They even explain the delay of the Swiss EPC market by the sufficient availability of financing for investments into energy efficiency measures (Klinke et al., 2017, chapter II). While financing from the ESCO might have been a trigger to the EPC market in other countries, this may not be the case in Switzerland.

In the Swiss context, it is crucial to understand how potential clients indeed value the different contractual clauses of EPC. Focusing on the client's point of view allows me to bring objective insights into the contractual mechanisms that can attract new clients and develop the Swiss EPC market.

### **3.2 Survey design**

#### *3.2.1 Target group*

The survey is targeted at the potential demand side of EPC in Switzerland. It includes participants from both the public and the private sectors. The selection of private

buildings is performed by a bottom-up approach<sup>70</sup> focusing on the technical energy savings potential, with an emphasis on relatively complex and therefore non-residential buildings. In total, around 2,200 addresses are collected including representatives of public entities, building owners and managers in charge of public or private education and health facilities, shopping centers, hotels, sport facilities and offices (public administration, banks, and insurance companies). Industries are not targeted to avoid large heterogeneity across respondents. The list of participants includes institutions from all regions of Switzerland. The survey exists in the two main national languages (French and German). More details about the position of the participants within the organization and their role in decision making are provided in section 4.2.2. The letter sent to respondent is provided in appendix. It was aimed to motivate potential respondents to participate to the survey while minimizing at the same time the potential sample selection issues. The mention of the support of the Swiss federal office of energy was aimed at providing the necessary neutrality to mitigate sample selection.

### 3.2.2 *Survey structure and choice experiment*

The survey divides into five main parts described in the appendix. The methodology for the choice experiment is described in the next subsections.

#### a) *Introductory elements to the choice experiment*

Four choice tasks are presented to each respondent in the choice experiment. The respondents have to imagine the situation in which revisions in the building were soon to be necessary. In each task, they are invited to decide if they would opt for energy efficiency measures, with or without contract, or if they would choose a simple overhaul. As illustrated in Figure 2.1, each choice task is presented as a two-step process in which the respondent first has to choose between simple overhaul and investing in energy efficiency measures without contract. In a second step, an EPC proposition is added to these 2 alternatives.

**Assume your building will soon require a revision. Which option would you consider?**

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<sup>70</sup> The addresses collection and mailing has been performed by TEP Energy GmbH, an energy consultancy. The majority of addresses come from lists of addresses publicly available on websites of specific domains (high schools and universities, health care facilities, hotels, banks and insurance institutions, municipalities, cantonal and federal administrative buildings). For other affectations (e.g. sport facilities), no website was available so that addresses come from google research.

Choice task 1/4

	Investment without contract	Simple overhaul
Measure	<u>Building automation</u>	Wall and windows painting
<u>Total cost</u>	120CHF/m <sup>2</sup> heated surface (120'000 CHF)	80CHF/m <sup>2</sup> heated surface
<u>Energy savings</u>	Expected 5% (can vary from 4% to 6%)	No energy savings
	<input type="checkbox"/>	<input type="checkbox"/>

Now a contractor offers you a contract. Which option would you consider?

	Energy Performance Contract	Investment without contract	Simple overhaul
Measure	<u>Building insulation + automation</u>	<u>Building automation</u>	Wall and windows painting
<u>Total cost</u>	200CHF/m <sup>2</sup> heated surface (200'000 CHF), from which the contractor finances 60% and you 40%	120CHF/m <sup>2</sup> heated surface (120'000 CHF)	80CHF/m <sup>2</sup> heated surface
<u>Energy savings</u>	39% guaranteed savings (but can reach 48%)	Expected 5% (can vary from 4% to 6%)	No energy savings
<u>Contractual terms</u>	21.55CHF/m <sup>2</sup> heated surface (21'550 CHF) per year during 10 years		
	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 2.1 Choice task example<sup>71</sup>

The simple overhaul alternative has a cost but no energy savings, while investments without contract include a cost, predicted energy savings and an interval for the extent of energy savings. Energy performance contract adds the possibility of the ESCO financing part of the upfront cost, the possibility to have a guarantee on the savings (therefore, reducing the energy savings variation presented) an additional payment fee to the ESCO and a contract duration.

Shortly before starting the choice experiment, two kinds of information are randomly presented to the respondents. First, additional information is provided on energy efficiency measures regarding their non-monetary benefits such as comfort, safety and CO<sub>2</sub> emissions mitigation. Second, the respondents are informed that EPC also provides the client with guarantee on the upfront cost of the installations. Depending

<sup>71</sup> The total costs in parentheses (200'000 CHF) and total annual costs of the contract (21'550 CHF) were directly computed in the experiment, using the respondent's former indication on the building's heated surface in squared meters. It was left blank for respondents who did not provide this information. The elements with a dashed-under-line provided further information to the respondent in a pop-up if she moved the mouse over these.

on a random distribution, respondents can see both information, one of them or none. This strategy is aimed at determining whether these additional features of EPC and energy efficiency measures have an impact on the decision process. Ideally, this information would have been added as attributes in the choice experiment. However, due to the complexity of the choice tasks, this information was randomly provided before the choice experiment in order to assess their impact without further increasing the information burden within the choice tasks. These two additional pieces of information, if provided to the respondent, are expected to increase their willingness to opt for EPC.

*b) Choice experiment design*

The choice experiment is designed so that the types of energy efficiency measures proposed are relevant to the respondent. In order to do so, information regarding the realized retrofits in the building of interest is obtained from a prior question of the survey. The respondents are then accordingly distributed in different types of choice experiments, as illustrated in Figure 2.2. For instance, for a building in which the only refurbishment realized since the year 2005 relates to its envelope, the respondent is directed towards type 2's choice experiment, which includes measures such as new heating systems (with or without building automation) or building automation. The simple overhaul alternative (without energy efficiency measure) is, in this case, a revision of the boiler.

The final designs are elaborated using the Ngene software, which determines the combinations of attributes levels seen by the respondents in each choice task. Attributes and levels are presented in Table 2.1.

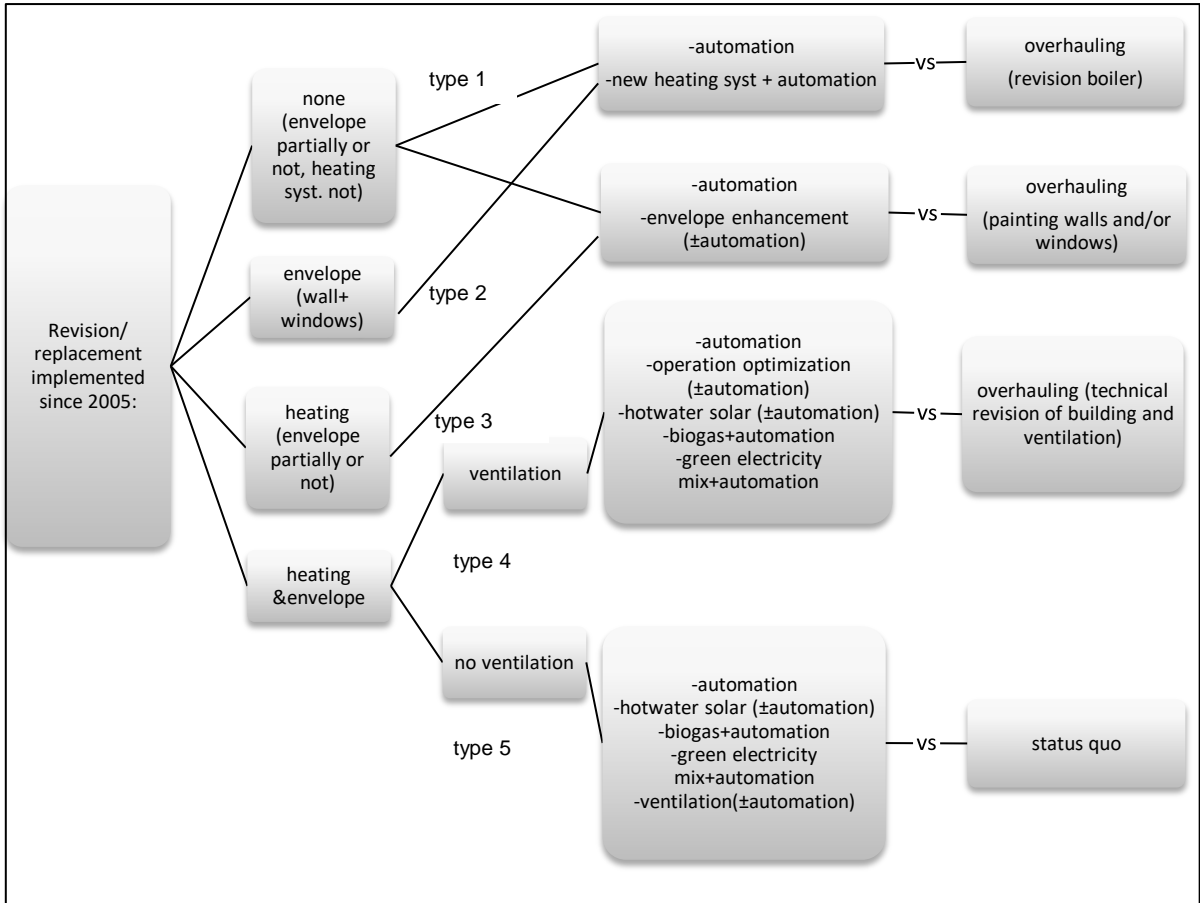


Figure 2.2 Choice experiments allocation

**Table 2.1: Attributes and levels in the choice experiment design**

Attributes	Energy efficiency investments levels	Overhauling levels
Total up-front cost <b>(includes realization cost but not payment to ESCO)</b> <b>CHF/m2 heated surface</b>	Types1+3	Types 1-4
	80–100–120–150–180–200–250–300	20–40–60–80
	Types2+4+5	Type 5
	80–100–120–150	0
Energy efficiency measure <b>Allocation determined according to the upfront cost</b>	Type 1 BA,HP+BA,Wood+BA,Envelope,Envelope+BA	Type 1 Revision boiler,painting wall and/or windows
	Type 2 BA,HP+BA,Wood+BA	Type 2 Revision boiler
	Type 3 BA,Envelope,Envelope+BA	Type 3 painting wall and/or windows
	Type 4 BA,Nebo+,solar+BA,biogas-green elec.+BA	Type 4 technical revision of building and ventilation
	Type 5 BA,ventil.,solar+BA,biogas-green elec.+BA	Type 5 do nothing
Expected Energy savings <b>% kWh saved</b>	Types 1+3	0
	5–10–20–30–40–50–60–70	
	Types 2+4+5	
	5–10–20–30	
Energy savings variation <b>% of expected energy savings</b>	Types 1-5	-
	20–40–50–60	
Part of up-front cost financed by ESCO <b>%</b>	Types 1-5	
	0–30–60–100	
Guarantee from the ESCO	Types 1-5	
	1-Expected energy cost savings guaranteed	
	2-guaranteed savings at 0.5*upper bound determined by the savings variation level	
	3-guaranteed savings at upper bound determined by the savings variation level	
	4-No guarantee	
Annual Payment to ESCO <b>(interest rate (r) and ESCO's value added (VA) in equation (1))</b> <b>CHF/m2 surface heated</b>	Types 1-5	
	(0%; 0%)	
	(5%; 5%)	
	(10%; 10%)	
	(15%; 15%)	
Contract duration <b>Years</b>	Types 1-2-3	
	5–10–15–20	
	Types 4-5	
	5–10	

**Notes:** BA: building automation and control system (BACS class B): This includes automatic detection for lighting and daylight control, combined light and heating automatically controlled, control and optimization of operations, alarming and monitoring functions. HP: heat-pump. Wood: woodchips or pellets. Nebo+: durable energy operation optimization of ventilation and air conditioning, adaptation of operation durations, reduction of air volumes, optimization of air humidity, reduction of electric needs for air transportation, control of air purification. Ventil: installation of a controlled ventilation.

The 5 types of design are performed using D-efficient Bayesian designs<sup>72</sup> in which the signs of the priors are based on economic theory. Cost, risk on savings and payment to the ESCO are assumed to have a negative effect on adoption, while expected savings and guarantee on savings are expected to have positive impacts. A prior of value zero is set on duration and the financing of the ESCO.<sup>73</sup> Since no priors exist on the size of the impacts, the magnitude of the coefficients is set so that each attribute has a similar impact on the profit maximization function. This assumes that no attribute is more important than another in the decision process. While being potentially restrictive, this hypothesis presents the advantage of hampering an attribute to become artificially important in the estimation. Several constraints are applied to the design elaborations in order to avoid irrelevant or dominated alternatives.<sup>74</sup>

In a second step, the types of energy efficiency measures are allocated to the alternatives with respect to the upfront cost according to estimations derived from Jakob et al. (2014).<sup>75</sup> Typically, measures such as envelope enhancing are assigned to the highest costs (120-300 CHF/m<sup>2</sup>) and building automation to the lowest costs (80-120 CHF/m<sup>2</sup>). Details of measures-costs allocation for each design type are provided in appendix 7.3.

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<sup>72</sup> 5 designs with 48 rows divided into 12 blocks of 4 choice tasks were elaborated.

<sup>73</sup> Contract duration may be negatively valued by entities for whom outsourcing operation and maintenance may be constraining, while it may be positively valued by entities who perceive guarantees and maintenance benefits in a longer run. The impact of the financing of the ESCO is positive for credit constrained entities, but may be negative for entities with access to credit at good conditions.

<sup>74</sup> Constraints were for instance implemented to avoid dominated strategies when considering only cost and savings. Also, if the level for the payment to ESCO attribute was zero, then the financing of the ESCO was constrained to be larger than zero, in order to make sure that the payment was always positive in the EPC alternative. Finally, the risk on savings was set to be smaller for very large amount of expected savings in order to avoid energy savings upper bounds larger than 85%.

<sup>75</sup> Jakob et al. (2014) provide the costs for façade insulation enhancement (fig. 8, p.48) and window insulation enhancement (fig. 10, p.50) as CHF/m<sup>2</sup> of wall or window. In order to translate these costs into CHF/heated m<sup>2</sup>, we used building geometries data (keeping only offices, hospitals, hotels, schools, commerce) and wall surface/heated surface, windows surface/heated surface ratios provided by TEP Energy GmbH. We estimated the ranges of cost for walls and windows enhancement in CHF/heated surface from 50 CHF/m<sup>2</sup> (for a large (>30'000m<sup>2</sup>) new building school) to 930 CHF/m<sup>2</sup> (for a small (330m<sup>2</sup>) new office building with a large share of windows and a high ratio wall surface/heated surface). Because the 1<sup>st</sup> quartile was at 120CHF/m<sup>2</sup> and the 3<sup>rd</sup> quartile was at 345 CHF/m<sup>2</sup>, we conclude that a range lying between 120-300 CHF/m<sup>2</sup> is plausible. We proceeded similarly for overhauling costs assuming painting cost of 80-140CHF/wall m<sup>2</sup> and 50-200CHF/window m<sup>2</sup>. Building automation costs are also provided in Jakob et al. (2014) in table 11 as price per room and we estimated a range assuming rooms of 50-60m<sup>2</sup> for schools, and 15-20m<sup>2</sup> for residential buildings, p. 54. New heating systems (wood and heat pumps) always proposed with building automation are estimated to have an upfront cost of 100-180CHF/heated m<sup>2</sup> and operation optimization, solar panels and biogas/green electricity mix of 80-150CHF/heated m<sup>2</sup>.

The yearly payment to the ESCO in CHF/m<sup>2</sup> is computed from the levels determined by Ngene according to the following formula:

$$\text{Annual payment to ESCO} = \frac{\text{ESCO financing share} \times \text{cost} \times r}{1 - (1 + r)^{-\text{duration}}} + \frac{\text{cost} \times \text{added value}}{\text{duration}} \quad (1)$$

Where *ESCO financing share* is the percentage of upfront cost (*cost*) financed by the ESCO, *duration* is the contract duration, *r* is the interest rate and *added value* is expressed as a share with the levels presented in Table 2.1. The first term on the right-hand side is thus the typical annuity computation resulting from the credit made by the ESCO. The second term represents a value added captured by the ESCO, which is set to be proportional to the upfront cost and the contract duration.

c) *Follow-up questions*

After responding to the four choice tasks, a question assesses the certainty with which the respondent makes her decision. Then, depending on the choices made by the respondents, several follow up questions appear. If, for instance, the respondent always choose the simple overhaul alternative, the fourth choice task is again presented but excluding the overhaul option. The respondent has to state which one of the 2 options (Investment without contract or EPC) she would choose or if she would be indifferent between the two. This additional choice task ensures that sufficient data is collected to estimate the attributes' coefficients, even in the case a large share of the respondents always choose the overhaul option.

Specific questions are asked to respondents who never invest in energy efficiency measures and/or never opt for EPC. Special emphasis is put on the potential issue to transferring the costs to the tenants, trust towards the ESCO and perceived legal and accounting difficulties.

Finally, in order to study preference heterogeneity and attribute non-attendance patterns, the respondents have to state up to 4 of the most important attributes they were considering when making their choices.

### 3.3 Data collection

The survey creation software Sawtooth is used to prepare and host the survey online. A hundred respondents, corresponding to various building types, were selected for a first pretest in September 2015. A second pretest was targeted at the non-respondents of the first pretest and 25 additional respondents in order to obtain further feedback on the survey's structure and content.<sup>76</sup> After incorporating feedback from the pre-test, the main survey is sent to a further 2,090 participants in June 2016, using both post and e-mailing. Reminder e-mails and phone calls were undertaken in August 2016 and data collection ended in mid-October 2016.

### 3.4 Econometric framework

The decision to opt for energy efficiency measures, with or without contract, as opposed to adopt a simple overhaul is derived from the random utility framework (McFadden, 1974). Since the respondents in this study are public institutions and private firms, the framework is considered as a random profit maximization framework.<sup>77</sup>  $\pi_{it,j}$  represents the profit of respondent's institution  $i$  choosing alternative  $j$  which can be *epc* (for EPC), *ee* (for investment in energy efficiency measures without EPC) or *ovh* (for simple overhaul) in choice task  $t$ . Typically, the profit  $\pi_{it,j} = V_{it,j} + \varepsilon_{it,j}$  is constituted of an observed component  $V_{it,j}$  and a residual term  $\varepsilon_{it,j}$  capturing the unobserved heterogeneity across choice tasks, alternatives and institutions. The respondent selects the alternative in order to maximize her institution's profit. The observed component of the profit is described for each alternative as follows:

$$\begin{aligned} V_{it,ee} &= \beta_{0,ee} + \beta_1 cost_{it,ee} + \beta_2 savings_{it,ee} + \beta_3 risk_{it,ee} + \beta_4' measures_{it,ee} \\ V_{it,epc} &= \beta_{0,epc} + \beta_1 cost_{it,epc} + \beta_2 savings_{it,epc} + \beta_3 risk_{it,epc} + \beta_4' measures_{it,epc} \\ &\quad + \beta_5 financing_{it,epc} + \beta_6 guarantee_{it,epc} + \beta_7 payment_{it,epc} + \beta_8 duration_{it,epc} \\ V_{it,ovh} &= \beta_1 cost_{it,ovh} \end{aligned} \tag{2}$$

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<sup>76</sup> These pretests were initially also aimed at collecting initial preferences regarding the choice experiment attributes in order to estimate more precise priors to construct a D-efficient Bayesian design for the main survey's choice experiment. However, the number of respondents in the pretest is not sufficient to estimate these priors. Therefore, as for the pretest, I constructed a Bayesian D-efficient design using economic intuition for the sign of the coefficients of each attributes.

<sup>77</sup> This follows the strategy used by the empirical research on the firm's location decision problem which typically uses discrete choice experiments and the random profit maximization framework (e.g. Carlton, 1983).

where  $\beta_{0,j}$  denotes the alternative-specific constants with overhaul treated as baseline,  $cost_{it,j}$  is the upfront cost in CHF/heated m<sup>2</sup>,  $savings_{it,j}$  are the savings in % kWh saved,  $risk_{it,j}$  represents the energy savings variation determined in terms of the difference in percentage points from the expected savings, and  $measures_{it,j}$  is a vector of four types of energy efficiency measures (envelope, technique<sup>78</sup>, electricity or biogas mix, new heating system).<sup>79</sup> Energy performance contracting adds several attributes describing contractual terms which include  $financing_{it,j}$  (the amount of upfront cost financed by the ESCO in CHF/heated m<sup>2</sup>),  $guarantee_{it,j}$  (a dummy for guaranteed savings),  $payment_{it,j}$  (the annual payment to ESCO in CHF/m<sup>2</sup>) and  $duration_{it,j}$  (the contract duration in years). The overhaul alternative includes only the attributes' cost, with all other attributes set equal to zero.<sup>80</sup> In the baseline analyses, the parameters are assumed to be equal across alternatives (i.e. the cost has the same impact in the overhaul as in the energy efficiency or the EPC alternative), except from constants which are alternative-specific.

a) *Conditional logit model*

In the conditional logit framework (McFadden, 1974, also referred to as the multinomial logit by Hensher et al., 2015), the probability that individual  $i$  chooses alternative  $j$  in choice task  $t$  is expressed by:

$$Prob_{it}(choice = j) = \frac{\exp(V_{it,j})}{\sum_{j=1}^J \exp(V_{it,j})}, \quad j = 1, \dots, J \quad (3)$$

where  $V_{it,j}$  represents the observed part of the profit as described in equation (2). This expression follows from the assumption that the error terms  $\varepsilon_{it,j}$  are independently and identically distributed and drawn from a generalized extreme value distribution. This in turn implies that an individual's unobserved preference for a certain alternative is independent of her unobserved tastes for other alternatives, a restrictive hypothesis

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<sup>78</sup> Building automation (BA), installation of ventilation or durable energy operation optimization of ventilation and air conditioning (NEBO+)

<sup>79</sup> Taking groups for the type of energy efficiency measures reduces the number of parameters to estimate, which is particularly useful in the attribute non-attendance exploration with latent class models. The models were also improved when taking groups as opposed to individual dummies. This strategy is also supported by the fact that the purpose of the research is to study contractual mechanisms inducing investment in energy efficiency and not to estimate the willingness to pay for specific energy efficiency measures. The overhaul measures are not controlled for in the analyses since the emphasis is put on energy efficiency investments and EPC alternatives, while overhaul is taken as a baseline.

<sup>80</sup> In the design type 5, the overhaul alternative is replaced by the status quo in which all attributes -including cost- are set to zero.

known as the *independence of irrelevant alternatives* (IIA). The parameters  $\beta_i$  in equation (2) are the arguments maximizing the following log-likelihood function:

$$\ln \mathcal{L} = \sum_{i=1}^N \ln \prod_{t=1}^T Prob_{it} \quad (4)$$

where  $Prob_{it}$  is defined in equation (3).

### 3.4.2 *Relaxing the assumption of attribute full attendance*

Due to the complexity of the choice experiment, some respondents may have ignored some of the attributes when making their decision. Adopting an attribute processing rule under which, one or several attributes are ignored may come from a voluntary basis to focus only on the more salient and important attributes, or may be somehow unconscious and stem from a simplification of the decision process. The reason that leads respondents to ignore some attributes is difficult to establish empirically.<sup>81</sup> Regardless of its cause, numerous studies show that accounting for a so-called attribute non-attendance (thereafter referred to as ANA) has an important impact on the parameters estimates (e.g. Campbell et al., 2011; Rose et al., 2012; Hensher et al., 2012; Lagarde, 2013; Caputo et al., 2014; Hole et al., 2016).

Two methods may be used to analyze ANA in the decision process, based either on respondent's stated heuristics or on inferred attribute processing strategies.

#### a) *Conditional logit model with stated weights on attributes*

The first method consists in directly asking the respondents which attributes were taken into consideration or ignored during the decision process (Hensher et al., 2005; Hensher and Rose, 2009). In our survey, the respondents were asked to state one to four of the most important attributes in their decision. These answers may then be used to account for heterogeneity in the decision process and assess its impact on the parameters estimated. In practice, the parameters are interacted with dummies equating one if the attribute has been considered important in the respondent's decision. It is to be noted that this method crucially relies on the reliability of the

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<sup>81</sup> Weller et al. (2014) have studied the impact of choice experiment dimensions on attribute non-attendance and showed that it does not depend on the design dimension, but that it may be influenced by the number of alternatives and sets.

responses related to the importance of the attributes (see for instance Hess and Hensher, 2010).<sup>82</sup>

*b) Latent class model*

The second approach consists in exploring attribute processing strategies using inference. Typically, this is done using a latent class framework in which restrictions are imposed on the parameters to account for attribute ignorance (Campbell et al., 2011; Hensher et al., 2012; Lagarde, 2013). Hess and Hensher (2010) show that the ANA inferred at the individual-level is not consistent with the stated decision process answered directly by respondents. This supports the strategy to use both methods to compare the estimation results. The second advantage of latent class model is that it allows to account for both heterogeneity in attribute attendance and heterogeneity in attribute preferences. In the specific context of energy efficiency investments and EPC, accounting for this heterogeneity is important as it is expected to have a significant impact on the client's decision (Jaffe and Stavins, 1994, Allcott and Greenstone, 2012). Finally, the latent class model does not rely on the restrictive assumption of the independence of irrelevant alternatives (IIA).

In the latent class model, individuals are assigned into  $q$  classes of ANA patterns in a probabilistic fashion, which in the same framework as equation (3) results in the following probability of choosing alternative  $j$  in choice task  $t$ :

$$Prob_{it|q}(choice = j|class = q) = \frac{\exp(\beta_q' x_{it,j})}{\sum_{j=1}^J \exp(\beta_q' x_{it,j})} \quad (5)$$

where  $x_{it,j}$  are the attributes described in equation (2) and  $\beta_q$  is one possible vector of attribute non-attendance pattern in which the ignored attribute coefficients are set to zero. This approach can be seen as a random parameter model with a discrete distribution<sup>83</sup> allocating individuals into classes with different combinations of attributes ignored. The probability for each individual  $i$  to belong to class  $q$  is given by:

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<sup>82</sup> Because of the characteristics of the question asked, i.e. respondents could not tick more than four important attributes, we were forced to make some assumptions regarding heuristics for those who ticked four attributes. Specifically, we assumed that if the respondent chose four attributes or ticked the answer "no attribute is more important than another", then she was assumed to have fully attended to all attributes.

<sup>83</sup> The latent class method, as opposed to the mixed logit model, presents the advantage of having no specific assumption about the distribution of the parameters across respondents but only estimate the underlying distribution in a discrete manner. This allows me to detect some groups of respondents. The latent class model is also suitable to account for attribute non-attendance.

$$H_{iq} = \frac{\exp(\theta_q)}{\sum_{q=1}^Q \exp(\theta_q)} \quad (6)$$

And the log likelihood function to be maximized to estimate the parameters is transformed as follows:

$$\ln \mathcal{L} = \sum_{i=1}^N \ln \sum_{q=1}^Q H_{iq} \prod_{t=1}^T Prob_{it|q} \quad (7)$$

The allocation of individuals within classes is a priori unobserved by the researcher. The Bayes' formula can be applied to retrieve the posterior individual-specific class probabilities.

The difficulty in this method relates to the many combinations of ANA patterns. With eight attributes considered in this study, there are  $2^8=256$  possible combinations and therefore 256 potential classes. While some studies test all combinations (Lagarde, 2013) using an iterative algorithm eliminating the irrelevant classes in the process, other studies focus on a subset of attributes (Hensher et al., 2012; Weller et al., 2014). Accounting for all combinations requires the use of equality-constrained latent class models<sup>84</sup> (Lagarde, 2013; Hensher et al., 2012). This reduces the number of parameters to be estimated in the iteration and allows the analyst to detect irrelevant classes, which are determined by null average posterior class probabilities. This method however comes at the cost of restraining the heterogeneity to be only in attribute non-attendance patterns and not in preferences. While the method with equality-constrained latent class models has been tested and is provided in the appendix, the main results focus on a strategy using an unconstrained latent class model in order to account for heterogeneity in both attendance and preferences. In order to assess the most relevant ANA patterns, I use information provided by the respondents' stated importance of attributes:

1. Using respondents stated attribute importance, I analyze all combinations of important attributes concerning at least 4 persons in the sample. Each combination of important attributes represents a potential class.

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<sup>84</sup> In which parameters are constrained to be the same across classes.

2. Using an iterative process, the best combination of classes is determined by comparing unconstrained<sup>85</sup> latent class models' Akaike and Bayesian information criteria.
3. After selecting the best combination of ANA classes, I study how individual or building characteristics can affect the class allocation. In order to do the latter, equation (6) is transformed by replacing the vector of parameters  $\theta_q$  with a dot product of it with a vector of individual-specific variables  $z_i$ .

### 3.4.3 Interpretation of the coefficients

One should note that when interpreting the results, this study focuses on the sign and significance of the coefficients rather than on magnitudes or willingness to pay estimates. This is justified by the purpose of this study, which is to assess whether the determinants affect the customer's choice and if so, in which direction. While some estimates of willingness to pay are provided for some attributes, these must be viewed cautiously because of the specificities of this study's choice experiment. Indeed, the choice experiment involves two attributes for the cost, i.e. upfront cost and annual payment to the ESCO. For simplicity, the willingness to pay estimates provided in the results section account only for the coefficient on the upfront cost attribute. Other strategies to estimate willingness to pay in further research are presented in section 5.3.

## 4 Data

### 4.1 Response rate

In total, 2,215 survey invitations were sent, out of which 2,203 were successfully delivered (cf. Table 2.2). 533 (26%) of the respondents logged in the online survey, and 297 respondents fully completed the survey (13% of invitations delivered). The low completion rate is likely to be due to the complexity of the choice experiment and the required information about the building (e.g. retrofits done and planned, year of construction, year and type of heating system, yearly energy consumption). The response rate varies greatly between the categories of respondents. The highest rate

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<sup>85</sup> "Unconstrained" means that coefficients are not constrained to be equal across classes as opposed to the equality-constrained latent class model.

of response is obtained with schools (56 %), whereas hotels are associated with the lowest rate (4 %).

**Table 2.2: Response rate by participant group, including pretest.**

	Invitations sent	Non-delivered	Delivered	Survey started		Survey completed	
				Freq.	% of delivered	Freq.	% of delivered
Schools	247	3	244	201	82%	136	56%
Hospitals	92	1	91	26	29%	14	15%
Public entities	1010	2	1008	74	7%	48	5%
Sport facilities	33	1	32	0	0%	0	0%
Hotels	504	8	496	41	8%	20	4%
Shopping centers	91	4	87	9	10%	7	8%
Banks/insurance	233	0	233	31	13%	18	8%
Unspecific	5	0	12	-	-	-	-
Other				151	-	54	-
Total	2215	19	2203	533	26%	297	13%

## 4.2 Descriptive statistics of the participants

### 4.2.1 Building characteristics

Education facilities represent the largest share in the sample (Table 2.3), followed by public administration and offices. A majority of buildings in the sample are publicly-owned and not rented. A large number of buildings in the sample correspond to the typical EPC target: sizeable old buildings, medium to large energy consumption<sup>86</sup> and retrofit opportunities. Indeed, almost a third of the buildings are constructed between 1966 and 1979 and 85% of the sample are built before 1990. A majority of buildings (57%) has a surface larger than 2,000m<sup>2</sup>. In terms of retrofits opportunities, 60% of the heating systems were installed before 2005 and only 3% of the buildings had an envelope insulation enhancement since the construction.

<sup>86</sup> Median electricity costs are ca 50,000CHF/year and median energy costs (excluding electricity) are ca 25,000CHF/year.

**Table 2.3: Building types**

	Freq.	Percentage in sample (N=297) (%)	percentage of publicly- owned buildings (%)	Percentage of (partly) rented buildings (%)
Education facility	145	48.82	97.18	22.07
Offices	22	7.41	63.64	68.18
Hotel	20	6.73	0.00	15.00
Hospital	14	4.71	71.43	35.71
Public administration	50	16.84	100.00	48.00
Shopping center	7	2.36	0.00	100.00
Sport facility	10	3.37	100.00	30.00
Residential	14	4.71	71.43	100.00
Mixed	5	1.68	40.00	100.00
Other	10	3.37	80.00	40.00
Total	297	100	82.25	37.71

#### 4.2.2 Characteristics of respondents

195 respondents (66%) are located in the German speaking area of Switzerland. Respondents occupy different responsibilities within the institutions. Managers in charge of cantonal or municipal buildings represent the largest share of respondents (32%), followed by facility managers (25%), energy managers (16%), owners (12%), municipal councilors (10%) and financial managers (3%). All respondents are involved in the decision process regarding the building retrofits. 129 respondents (43%) take directly part in the decision. The remaining share plays a role in the pre-selection of the options, advising or making propositions to the decision-makers.

157 (53%) out of the 297 respondents who complete the survey state to be already familiar with the concept of energy performance contracting.<sup>87</sup>

<sup>87</sup> 93% of the respondents claim that they understand clearly the concept, after being exposed to the explanation on energy performance contracting in the survey.

### 4.3 Summary statistics of the attributes

The summary statistics of the attributes of interest are provided in Table 2.4. The upfront cost is zero for status quo alternatives. Expected savings and savings variation are set to zero in overhaul/status quo alternatives, involving no energy efficiency measures. Similarly, all the contractual elements concerning only the EPC alternative are set to zero in the other options. Some energy performance contracts do not provide any guarantee or do not involve financing of the ESCO. However, all contracts involve a yearly payment to the ESCO and a positive contract duration. The allocation of respondents across the 5 design types shapes the distributions of the attributes' levels (cf. end of appendix 7.3).

Before entering the choice experiments, 49% of the respondents are randomly provided with additional information on energy efficiency non-monetary benefits and 47% on the advantage of EPC of having a guarantee on the costs.<sup>88</sup>

**Table 2.4: Summary statistics of attributes**

Variable	Mean	Std. dev.	Min	Max	N
<i>Attribute of overhaul, energy efficiency, EPC alternatives</i>					
upfront cost (CHF/m <sup>2</sup> heated surface)	119.3	77.8	0	300	5,940
<i>Attributes of energy efficiency and EPC alternatives</i>					
expected savings (% kWh saved)	18.7	21.8	0	70	5,940
savings variation ( $\pm$ % from expected savings)	7.0	8.2	0	30	5,940
<i>Attributes of EPC alternatives</i>					
upfront cost by ESCO (CHF/m <sup>2</sup> heated surface)	16.8	46.8	0	300	5,940
savings guarantee (dummy)	0.1				5,940
payment to ESCO (CHF/m <sup>2</sup> year heated surface)	2.7	7.9	0	82.1	5,940
contract duration (years)	2.5	5.6	0	20	5,940

<sup>88</sup> Out of these, 54 participants (18%) receive both information.

The frequency at which each energy efficiency or overhaul measure was proposed to the respondents in the survey's choice experiment is presented in the appendix 7.4. In the empirical analysis, the technologies are grouped in four dummies, i.e. *technique* (building automation, exploitation optimization, controlled ventilation), *biogas/electricity mix* (biogas mix if already has a gas heating system, green electricity mix), *heating* (new heat pump, new wood heating, solar panels) and *envelope* (wall and windows insulation). Because building automation is proposed both alone and in combination with other measures, it is the most often proposed (46% of the alternatives). 28% of the options include envelope enhancement, 17% new heating systems and 14% propose a mix of biogas or green electricity.

#### **4.4 Stated attribute importance**

Cost, savings and energy efficiency measures are the attributes that are the most often stated as important (resp. by 78%, 74% and 73% of the respondents).<sup>89</sup> Savings variation and EPC contractual attributes are considered important for a smaller share of respondents (53% for guarantee and 60% for upfront financing from ESCO). Table 2.5 provides additional details on the patterns of attributed non-attendance stated by at least 6 persons. These are the patterns that are considered in the latent class models exploration. 23 individuals state that no attributes are more important than another in their decision making.<sup>90</sup> Although respondents could provide four attributes considered as important, a majority of them (52%) lists one to three attributes. This supports the hypothesis of attribute non-attendance in the sample.

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<sup>89</sup> A simple logit regression of stating the cost as an important attribute on a set of regressors does not allow to identify determinants of attribute importance, as these appear to be non-significant. The following regressors are tested: private buildings, rented buildings, the yearly energy and electricity costs of the building, the language, age, gender, education and experience of the respondent. Surprisingly, stated barriers to energy efficiency investments (e.g. non economic viability of these investments, destruction planned for the building, protected buildings) do not have an impact on considering the cost as an important attribute either.

<sup>90</sup> This can either be interpreted as full-attendance or none-attendance. In the empirical results, I assumed these respondents to have fully attended all attributes.

**Table 2.5: Combination of important attributes (>6 persons)**

<b>Combination of important attributes</b>	<b>Nb resp.</b>	<b>Share</b>
No attribute is more important than another	23	0.08
Cost-savings-measure	19	0.06
Cost- savings-measure-risk	16	0.05
Cost-savings	13	0.04
Cost- savings-measure-financing by ESCO	12	0.04
Cost	9	0.03
Cost- savings-measure-guarantee / savings-measure <sup>a</sup>	7 (2x)	0.02 (0.05)

<sup>a</sup> In the last line of the table, two groups of 7 individuals can be observed. 7 individuals considered costs, savings, measure and guarantee from the ESCO and 7 other stated that savings and measures were important attributes in their choices.

## 5 Results

### 5.1 Investment choices

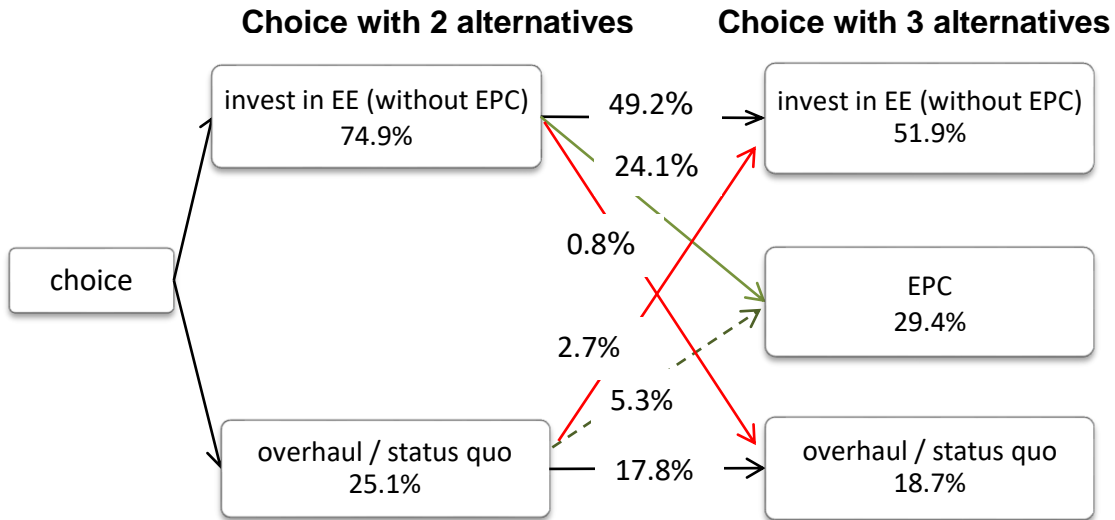


Figure 2.3 Experiment choices

Notes: percentage of respondents (out of N=297) choosing each option and switching from one option to another, once EPC is additionally proposed (percentage based on average number of persons across the four choice tasks). The dashed green arrow represents respondents who I call “EPC responsive”. The red arrows represent choices that do not satisfy the independence of irrelevant alternative (IIA) assumption.

The distribution of respondents by option choice is provided in Figure 2.3, averaged across the 4 choice tasks. The decisions when two alternatives are proposed (overhaul or energy efficiency without contract), are compared to the situation in which options of energy performance contracts are also included. On average 5.3% respondents choose the simple overhaul in the initial two alternatives case and switch for EPC when it becomes available. These represent more than 21% of the 75 respondents who choose overhaul in the first place. From another point of view, 34 out of the 297 respondents switch at least once from overhaul to EPC when it becomes available. This gives a rough idea on the number of persons for whom EPC might mitigate some barriers to investments in energy efficiency. I analyze in section 5.2.1 which mechanisms of EPC are valued by these respondents that I call “EPC responsive”.

An average of 2.7% persons chooses overhaul initially and changes to investment in energy efficiency without contract once the choice becomes available. Conversely, an average of 0.8% respondents change their mind from investment to overhaul once EPC alternative is added. These incoherent decisions, taken at least once by 29 out of 297 respondents, represent situations in which the independence of irrelevant alternative (IIA) assumption is not satisfied. This may result in biases in the estimations of conditional logit models. In the robustness checks section, the models are estimated after excluding these respondents.

Despite the variations in the attributes levels, the decision patterns are very similar across choice tasks, i.e. 46% of respondents choose the same alternatives (energy efficiency, EPC or overhaul) in all choice tasks.<sup>91</sup> This observation supports the assumption of heterogeneous preferences across respondents.

While 26 respondents never choose energy efficiency without contract, more than 50% (149) of the sample of 297 completes never opt for EPC. The main reason mentioned is the unwillingness to outsource the operation and maintenance. This may result from a reticence to lose control over the operation or a fear to forgive existing facility managers or employees. The latter case would however be a misperception since the ESCO typically supervises the operation by providing the facility managers with training courses to manage the new equipment (Swissesco, 2016). The second most frequently invoked argument is that EPC is not economically viable.<sup>92</sup> Other motives put forward by the respondents are legal issues resulting from such contracts, complex tendering process and contracts.<sup>93</sup> 14 respondents do not provide any reasons explaining why they never opt for EPC. All but one of these respondents were unfamiliar with EPC before completing the survey. A biased perception of EPC is visible in the other motivations provided by respondents for not choosing the contracts. For instance, some respondents stated that EPC was not

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<sup>91</sup> The respondents with persistent choices are not necessarily those who spent the least time on the choice tasks. This can be seen in a pairwise correlation of -0.14 between median time spent on choice tasks and a dummy equating one when the respondent chose always the same alternative. This correlation does not change when omitting the respondents stating that their building is already efficient, protected or planned to be destroyed to compute the median time spent on choice tasks.

<sup>92</sup> A t-test shows that there is no significant difference in the mean size among respondents who see EPC as not economically viable and the others. The size is described here in terms of the building's heated surface.

<sup>93</sup> See Klinke et al. (2017) for a qualitative analysis for other reasons why respondents never choose energy efficiency measures or EPC.

possible since the building is public or because they were financially constrained. In fact, EPC are typically targeted at institutions with these characteristics.

While EPC has been deemed a valuable instrument to facilitate investments in energy efficiency in foreign markets (e.g. Capelo, 2011; IEA-RETD, 2013), in an emerging market such as Switzerland it appears *a priori* that the willingness to adopt EPC is lower than the willingness to adopt energy efficiency investments without contracts.

## 5.2 Estimation results

The estimation results are provided in Table 2.6 for the basic conditional logit (column 1). The results based on a conditional logit and attributes interacted with dummies for attribute's importance is provided in column 2. These dummies equate one when the individual states to consider the attribute as important and zero otherwise.<sup>94</sup> The latent class model for inferred attribute non-attendance (ANA) is provided in Table 2.7 and the iterative process leading to this model's specification is presented in appendix 7.5. Comparing Tables 2.6 and 2.7, one concludes that accounting for ANA increases the performance of the models according to the log likelihood, the Bayesian information criterion (BIC) and the Akaike-Schwartz Information Criterion (AIC).

From a policy design perspective, relying on a latent class model is the appropriate estimation strategy. Indeed, this model distinguishes specific groups of respondents. This permits to avoid biases in the estimates due to respondents who did not attend to the attributes, while accounting for heterogeneity in both preferences and attribute non-attendance.

As compared to the other models, the conditional logit with full attendance (table 2.6, column 1) does not capture any effect for the contractual attributes of the yearly payment to the ESCO and the contract's duration. Except from the financing of the ESCO, all the contractual attributes become statistically significant once stated weights, i.e. attribute stated importance, are controlled for in column 2. The annual payment to the ESCO has the expected negative significant impact on the decision to opt for EPC. Contract duration has a statistically significant and negative impact for the respondents who considered this attribute, suggesting that the disadvantages of a

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<sup>94</sup> Full attendance (i.e. all dummies equate one) is assumed when the individual ticked the maximum number of attributes possible (i.e. 4 attributes) and when the respondent chose the option: "no attribute is more important than another".

long-term contract may, for these individuals, offset the advantages. The latent class model then permits to refine the analysis and shows that EPC contractual attributes are valued differently between classes.

**Table 2.6: Estimation conditional logit**

dependent variable: choice (=1 if choose alternative <i>j</i> )	Conditional logit full attendance (1)	Conditional logit stated weights (2)
upfront cost	-0.004*** (0.001)	-0.003** (0.001)
expected savings	0.011*** (0.003)	0.023*** (0.004)
savings variation	0.007 (0.008)	-0.001 (0.012)
upfront cost financed by ESCO	-0.001 (0.002)	0.002 (0.002)
savings guarantee	0.401** (0.160)	0.918*** (0.214)
payment to ESCO	-0.001 (0.011)	-0.018* (0.011)
contract duration	-0.017 (0.015)	-0.038** (0.015)
measure envelope	0.860* (0.441)	0.680*** (0.274)
measures group technique	0.409** (0.186)	0.087 (0.199)
measures group biogas/green electricity mix	0.025 (0.394)	0.167 (0.311)
measures group heating	-0.071 (0.392)	-0.073 (0.310)
alternative specific constant energy efficiency alternat.	0.409 (0.415)	0.638*** (0.221)
alternative specific constant EPC alternative	-0.243 (0.520)	-0.045 (0.251)
observations	5,940	5,580
individuals	297	279
Log-likelihood	-1,839	-1,641
AIC	3,709	3,307
BIC	3,792	3,393

Notes: Conditional logits are estimated using stata. Conditional logit stated weights uses an interaction of attributes with dummies of individual-stated attributes importance. These dummies equate one when the individual states that she considers this specific attribute as important and zero otherwise. Individual-clustered robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1.

**Table 2.7: Latent class model with inferred attribute non-attendance**

Dependent variable: choice (=1 if choose alternative <i>j</i> )	Latent class model Inferred attribute non-attendance (6classes)				
	(1)	(2)	(3)	(4)	(5)
Upfront cost	-0.016*** (0.005)	-0.006* (0.003)	-0.006 (0.006)	0	-0.111*** (0.025)
Expected savings	0.018* (0.011)	0.034*** (0.006)	0.031** (0.012)	0.017** (0.007)	0
Savings variation	-0.030 (0.032)	0	0	0	0
Upfront cost financed by ESCO	0.019 (0.012)	0	0	0	0
Savings guarantee	-0.167 (0.634)	0.660** (0.319)	0	0	0
Payment to ESCO	-0.147** (0.057)	0	0	0	0
Contract duration	-0.345*** (0.105)	0	0	0	0
Measures envelope	7.135*** (1.127)	0.280 (1.067)	-2.474*** (0.902)	-0.688 (0.796)	0
Measures technique	2.175*** (0.635)	0.282 (0.391)	1.874** (0.834)	-0.566 (0.356)	0
Measures biogas/electricity mix	2.800*** (0.654)	-0.819 (0.944)	-1.303* (0.757)	-1.291* (0.715)	0
Measures heating	1.095** (0.950)	-0.312 (0.975)	0.104 (0.851)	-2.098** (0.822)	0
ASC energy efficiency alternative	0	3.753*** (1.093)	0	0.691 (0.772)	0
ASC EPC alternative	0	3.978*** (1.138)	0	0.896 (0.823)	0
<b>Class probability as a function of stated weights group</b>					
Constant	1.046*** (0.297)	0.777** (0.313)	-0.716 (0.521)	0.652** (0.326)	0
Familiar with EPC (dummy)	0.625 (0.450)	0.808* (0.463)	0.938 (0.671)	-0.359 (0.589)	0
Average posterior class probabilities	0.363	0.309	0.075	0.159	0.094
observations	5,940				
Individuals	297				
Log-likelihood	-1214				
AIC	2,513				
BIC	2,755				

Notes: Estimated using Nlogit. Standard errors are in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Attribute non-attendance is expressed as coefficients being constrained to equal zero. Familiar with EPC means the concept was known to the respondent before the survey. ASC stands for alternative-specific constant.

Five classes are retained in the best latent class model specification.<sup>95</sup> Respondents considering EPC contractual clauses are split into two classes (classes 1 and 2). Both classes are characterized by an average posterior class probability around one third. In the first group, respondents value negatively the payment to the ESCO and the contract duration. The respondents are also more sensitive to the upfront cost. In the second class, respondents are relatively more sensitive to the savings and the guarantee offered by EPC. The individuals previously familiar with the EPC concept are more likely to belong to the second class, i.e. valuing positively the guarantee.<sup>96</sup> In the second class, respondents are also more likely to choose energy efficiency investments, with or without contracts, as expressed by the alternative-specific constants.

In the third and fourth classes, respondents consider savings and measures.<sup>97</sup> The sensitivity to energy savings and measures is different in these two classes. With a class probability slightly larger than 9%, the last class covers individuals considering only cost.

Some classes showed a very large p-value for alternative specific constants (ASC). This suggests another type of non-attendance, i.e. label non attendance. Indeed, for the respondents in these classes, the label of the alternative has no impact and the attributes entirely capture the differences of preferences among the alternatives. This type of non-attendance has to be accounted for. Thus for these classes, the alternative specific constants are also set to equal zero.<sup>98</sup>

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<sup>95</sup> See appendix 7.5 for an explanation on how this model's specification was selected.

<sup>96</sup> See appendix 7.5, other characteristics had no influence on the class probabilities. These include private vs. public buildings, tenants, yearly energy/electricity costs, heated surface, retrofits done and planned, random information on non-economic benefits of energy efficiency investments, random information on cost guarantee from EPC, EPC not economically viable as stated by the respondent, function, experience, age, gender, education of the respondent. I also tested whether dummies for belonging to specific groups of stated attribute importance matters in the class probability.

<sup>97</sup> Even if the cost is not significant in the third class, merging these two classes does not improve the model. The signs and significance, cost and savings attributes are the same when omitting class 4. The model performance is lower and the only difference lies in the signs and significance of the measures in class 3. This suggests that classes 3 and 4 have different preferences regarding measures and separating them permits to capture those differences.

<sup>98</sup> This phenomenon is however not observed in all classes (e.g. classes 2 and 4). The model of Table 10 was also tested by completely omitting ASC in all classes. The model showed a milder performance in terms of information criteria, but the results in terms of sign and significance are similar. Appendix 7.6 shows the results when the ASC are not constrained. The main difference lies in the fact that the payment to the ESCO is not significant in the first group. The most important results, i.e. financing from the ESCO being insignificant and the guarantee being positively values in the second class, remain. The willingness to pay for a guarantee is the same up to the thousandth. Moreover, merging classes 3 and 4 also result in poorer performance when ASC are not constrained.

The most important result relies in the fact that, in all the models, having part of the upfront cost financed by the ESCO is not significantly valued by the respondents which *a priori* contradicts hypothesis H1. This is also true in the latent class model, which did not show a specific class of respondents for whom financing of the ESCO would matter. This result, which may be specific to the current Swiss conjuncture, contrasts with the general observation by Panev et al. (2014) that financing EPC projects is one of the most important issues.

Conversely, the performance guarantee is positive and statistically significant in all the models. This coincides with hypothesis H2, as a guarantee from the ESCO is consistently increasing the probability of adopting EPC. The latent class model shows however that it concerns less than a third of the respondents. Using the coefficients of the second class of the latent class model, the willingness to pay for a guarantee in energy savings is estimated at 104.5 CHF/m<sup>2</sup>.<sup>99</sup> This positive impact of a guarantee contrasts with the evidence presented in Polzin et al. (2016b), who find that municipalities do not value positively the risk-sharing advantage of EPC in LED retrofits projects.

### 5.2.1 Differences in preferences of respondents who are EPC responsive

In order to test further the financing of the ESCO attribute (Hypothesis H1), I focus on the respondents whose decisions suggest that they may face barriers to energy efficiency investments potentially solved by EPC. These are typically the individuals who choose overhaul when EPC is not available and change for EPC when it is proposed. A dummy *EPC responsive* is created which equates one for all the respondents behaving in this way in at least one choice task. It concerns 34 participants (11% of the sample) and a majority of them (27) are representing public buildings, especially education facilities (17 buildings). The dummy *EPC responsive* is

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<sup>99</sup> This estimates is however not significant, and the 95% confidence interval is (-39;248). For the median respondent (with 2,500 m<sup>2</sup>), the willingness to pay for a guarantee equals 261,250CHF. The median building in the sample incurs yearly energy costs of around 19 CHF/m<sup>2</sup>.<sup>99</sup> Considering a median contractual duration of 10 years in the choice experiment, the energy costs over the lifetime of the contract can be approximated to 190 CHF/m<sup>2</sup>. The willingness to pay for a guarantee amounts to 55% of these energy costs.

interacted with all attributes and Table 2.8 shows the results when keeping only the interactions that are statistically significant.<sup>100</sup>

First of all, the coefficient for upfront cost presents a greater negative magnitude for these respondents, which may suggest that they are limited in terms of credit possibilities. The difference between the cost estimates is confirmed by a Wald test rejecting equality at more than 90% confidence level. These respondents are more likely to value significantly and positively financing by the ESCO, with a difference significant at more than 99% confidence level. These respondents also value to a greater extent the fact of having a guarantee, as displayed by the statistically significant coefficient on *Savings guarantee x EPC responsive* (>99% confidence level). Their estimated willingness to pay for a guarantee<sup>101</sup> amounts to 174 CHF/m<sup>2</sup> as compared to 70 CHF/m<sup>2</sup> for respondents who are not responsive to EPC.<sup>102</sup> For respondents being EPC responsive, the estimated willingness to pay for 1% of upfront cost financed by the ESCO is estimated at 1.09 CHF/m<sup>2</sup> (95% confidence interval [0.41; 1.78]). The median upfront cost being 100 CHF/m<sup>2</sup> in the choice experiment, the estimated willingness to pay is 1.09 CHF/m<sup>2</sup> for each additional 1 CHF/m<sup>2</sup> paid by the ESCO.

These results suggest that while a majority does not value the financing of the ESCO, a relatively small number of exceptions may be credit constrained. Since these are mostly public entities, this may suggest legal constraints on credit limits, such as debt ceilings. These respondents may also have limited budget for non-core activities. For these respondents, hypothesis H1 is favored and is in line with the findings of Polzin et al. (2016b) who find higher willingness to consider EPC when financially-constrained.

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<sup>100</sup> This dummy has also been tested as an individual characteristic influencing the classes' probabilities in the unconstrained latent class model. The model however could not converge when accounting for this variable.

<sup>101</sup> 95% confidence interval is [90; 259]. This equals to 435,000CHF for the median size respondent (2,500 m<sup>2</sup>) and 175,000CHF for respondents who are non-responsive to EPC.

<sup>102</sup> 95% confidence interval [-39; 178]

**Table 2.8: Impact of contractual clauses for individuals responsive to EPC**

Dependent variable: choice (=1 if choose alternative <i>j</i> )	Conditional logit
Upfront cost	-0.003** (0.002)
<b>Upfront cost x EPC responsive</b>	<b>-0.008*** (0.002)</b>
Expected savings	0.009*** (0.003)
Savings variation	0.011 (0.008)
Upfront cost financed by ESCO	-0.001 (0.002)
<b>Upfront cost financed by ESCO x EPC responsive</b>	<b>0.009*** (0.003)</b>
Savings guarantee	0.235 (0.175)
<b>Savings guarantee x EPC responsive</b>	<b>1.390*** (0.286)</b>
Payment to ESCO	0.001 (0.013)
Contract duration	-0.022 (0.016)
Measures envelope	0.965** (0.444)
Measures group technique	0.405** (0.187)
Measures group biogas/green electricity mix	0.142 (0.396)
Measures group heating	0.027 (0.398)
Alternative specific constant energy efficiency alt.	0.337 (0.415)
Alternative specific constant EPC alternative	-0.283 (0.525)
Observations	5,940
Individuals	297
Log-likelihood	-1,787
AIC	3,606
BIC	3,714

Notes: Individual-clustered robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. *EPC responsive indiv.* is a dummy which equates 1 for respondents who, at least in one choice task, chose overhaul when EPC was not available and then switched to EPC once proposed. 34 respondents (11% of the sample) belong to the group of EPC responsive individuals.

### 5.2.2 *Impact of individual or building characteristics*

As in the latent class model, being familiar with EPC is proven to be positively related to the willingness to adopt energy efficiency measures, with and without EPC in the basic conditional logit model (cf. Appendix 7.8, column (1)). This is shown by interacting a dummy for EPC familiarity with alternative-specific constants of energy efficiency and EPC options.

Other individual and building characteristics are tested and do not have a significant impact, neither in the latent class model (with class probabilities) nor when interacted with attributes in the conditional logit model. For instance, private vs. public buildings do not result in significantly different estimates (cf. Appendix 7.8, column (2)), even when interacted with the contract duration attribute in the conditional logit model (cf. Appendix 7.8, column (4)). This result contrasts with the presumption of a divergence in contract duration valuation. Moreover, private firms do not value significantly differently a guarantee or the financing of the ESCO, as compared to public entities (cf. Appendix 7.8, column (4)).

The fact of having tenants does not show a significant impact on the likelihood to invest in energy efficiency, with or without contract (cf. Appendix 7.8, column (2)). The determinant is not significant either when interacted with the payment to the ESCO. This results contrasts with the observation of split incentives in rented buildings resulting in lower energy efficiency investments.<sup>103</sup> This study's result may be explained by the fact that buildings with tenants are a minority in the sample (38%) and, more importantly, private rented buildings represent a small share of the buildings (8%). Split incentives issues may indeed be less representative in public rented buildings, for which the motivation to retrofit is not only economically-driven. Therefore, this sample may not be representative to analyze split incentives in energy efficiency investments.

There is no evidence of scale effects in the decision patterns, as captured by controls for energy and/or electricity yearly costs (cf. Appendix 7.8, column (2)), or heated surface. The reason not to adopt EPC as stated by the respondents, such as EPC

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<sup>103</sup> See Murtishaw and Sathaye (2006) and Davis (2010) for empirical evidence and the appendix of Gillingham et al. (2012) for a formal explanation.

being seen as not economically viable, are also tested and do not have a significant impact on the willingness to invest with or without EPC either (cf. Appendix 7.8, column (6)). Finally, the random information provided on the non-monetary benefits of energy efficiency investments, as well as the guarantee on costs provided by EPC, does not have a statistically significant impact on the decision to invest (cf. Appendix 7.8, column (5)).

I test whether the function of the respondent in the firm/institution has an impact on the investment decisions (cf. Appendix 7.8, column (3)). If the respondent is the energy manager of the building, the likelihood to invest in energy efficiency with and without EPC increases. This could be explained by the fact that energy managers are likely to be better informed about the options to invest in energy efficiency and their positive benefits, including EPC, which may induce adoption. This also means that energy managers do not perceive performance contracts as a threat to their job. When the respondent is a person in charge of municipal or cantonal buildings, there is a significant reticence to opt for energy efficiency, with and without EPC. Moreover, the participant's tenure within the firm/institution also affects negatively the propensity to opt for EPC. Age, gender and the role in the decision process of the respondent does not have any significant impact. Finally, the building types do not have statistically significant impact on the willingness to invest in energy efficiency, with or without contract.

### *5.2.3 Relaxing assumption of equality of parameters across alternatives*

149 respondents (50% of the sample) never opt for EPC. Moreover, the previous results show that a large share of individuals does not attend to attributes specific to the EPC alternative. This suggests a reticence to invest in energy efficiency through EPC, which is not entirely captured by the observed contractual attributes (e.g. payment to the ESCO, duration). In order to study this conjecture further, a conditional logit with alternative specific estimates for all attributes is estimated. The results are provided in Table 2.9.

**Table 2.9: Alternative-specific estimates of attributes**

Dependent variable: choice (=1 if choose alternative <i>j</i> )	clogit
Upfront cost x alt= <i>ee</i>	-0.004*** (0.002)
Upfront cost x alt= <i>epc</i>	-0.006*** (0.002)
Upfront cost x alt= <i>overhaul</i>	-0.003 (0.003)
Expected savings x alt= <i>ee</i>	0.014*** (0.005)
Expected savings x alt= <i>epc</i>	0.009 (0.006)
Risk: savings variation x alt= <i>ee</i>	0.002 (0.011)
Risk: savings variation x alt= <i>epc</i>	0.014 (0.014)
Upfront cost financed by ESCO	0.000 (0.002)
Savings guarantee	0.284** (0.144)
Payment to ESCO	-0.007 (0.011)
Contract duration	-0.026** (0.012)
Measure envelope	0.923** (0.436)
Measures group technic	0.474** (0.185)
Measures group biogas/green elec mix	0.007 (0.384)
Measures group heating	-0.081 (0.383)
Alternative specific constant <i>overhaul</i> alt.	-0.328 (0.425)
Observations	5,940
Individuals	297
Log-likelihood	-1,838
AIC	3,708
BIC	3,815

Notes: Individual-clustered robust standard errors in parentheses. \*\*\* $P < 0.01$ , \*\* $P > 0.05$ , \* $P < 0.1$ . Interactions of attributes with alternative specific constants, except from the measures which are used as controls and not interacted.

While the cost of the overhaul alternative does not have a significant impact on adoption, this attribute is perceived as worse in the EPC alternative than in the alternative of energy efficiency without contract (Wald test with a 95% confidence level). These significant differences in the cost attribute suggest a smaller willingness to invest in energy efficiency through EPC than without contract, even when controlling for all other observed differences between the two options. This means that other perceived obstacles, not presented in the choice experiment, explain a reticence to opt for EPC. An overview of the stated reasons was presented in section 5.1. Considering alternative-specific estimates results in a significant negative impact of contract duration as opposed to the basic conditional logit model in Table 2.6 column (1). This also points towards the perceived disadvantage of long run commitment with an external firm.

### **5.3 Robustness checks and further research**

I previously used an unconstrained latent class model, i.e. with varying coefficients across classes, to account for heterogeneity in both attributes attendance and preferences. As opposed to an equality-constrained latent class model<sup>104</sup> however, this increases the model's parameters to estimate and irrelevant classes are also more difficult to detect.<sup>105</sup> As a result, it is impossible to analyze all ANA combinations using unconstrained latent class model. In order to check the robustness of the latent class model of Table 2.7, I use a method with equality-constrained latent class models to assess the relevant ANA combinations. The method follows the iterative algorithm proposed by Lagarde (2013) to analyze ANA of single, pair and triple ignored attributes.<sup>106</sup> The irrelevant classes, i.e. with zero average posterior class probability, are dropped. The classes surviving to this process are then compared to patterns with four to seven attributes not attended to. In order to limit the number of

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<sup>104</sup> In which parameters are constrained to be the same across classes.

<sup>105</sup> Indeed, equality-constrained latent class models by forcing non-zero parameters to be equal across classes allows to detect irrelevant classes since these show an average posterior class probability equating zero. In unconstrained latent class model, it is really rare to obtain an estimated class probability of zero.

<sup>106</sup> This process, beginning with single attributes ignored and following with a higher number of attributes ignored makes the assumption that a single-attribute ignored pattern is considered irrelevant at an early stage has no chance to become relevant once more attributes are ignored. In this process, the dummies for technologies groups representing the attribute for the energy efficiency measures are considered as a block and therefore assumed to be either all ignored or fully considered. This is justified by the fact that in this study, the focus is not on the willingness to adopt specific technologies but rather to assess the willingness to opt for energy efficiency measures as a whole, i.e. taking the measures as controls and focusing on contractual clauses, cost and savings, driving the decision.

possible combinations to consider, I use the stated (one to four) important attributes. All combinations concerning at least 4 persons in the sample are tested. This process is implemented in the software Nlogit. The final model is presented in appendix 7.7 and includes 7 classes. As in the unconstrained model, two classes (classes 1 and 6) include attendance to EPC attributes. These however represent a smaller share (around one third) of the individuals than in the unconstrained model. Cost, savings and measures are still the attributes being the most often considered. While larger in magnitude, the coefficients obtained are similar in sign and significance to the results found in the conditional logit with stated weights (Table 2.6 column 2).<sup>107</sup> In order to test whether equality constraint across classes is a restrictive assumption, one can compare the information criteria of constrained and unconstrained models. Constraining the model of Table 2.7 leads to a poorer performance in terms of information criteria. This suggests that accounting for preference heterogeneity represents an advantage.

The design of the choice experiment, by asking the respondents to first choose between energy efficiency and simple overhaul and then propose the same two alternatives with an additional EPC option, provides information on potential incoherent choices. For instance, a respondent stating to prefer simple overhaul in the choice task with two alternatives should have no reason to switch for energy efficiency once an additional option, i.e. EPC, is proposed. This kind of decision patterns does not satisfy the assumption of independence of irrelevant alternatives (IIA), necessary to estimate conditional logit models without bias. One should however note that the latent class model does not suffer from the IIA restriction. I still check the robustness of the conditional logit models results when ignoring these incoherent choices that occur at least once for 29 respondents in this sample. Robustness is also tested by omitting the choice tasks in which the respondent take less than 5 seconds to answer<sup>108</sup>, and by eliminating the choice tasks in which the

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<sup>107</sup> Only risk has an unexpected significant positive sign, which may be explained in heterogeneity in the way risk is perceived. We can indeed show that some respondents considered the upper bound, the lower bound or both. This translates in a misleading positive coefficient in the equality constrained latent class model.

<sup>108</sup> This relates to 25 observations out of the 5,940.

participant states to be uncertain<sup>109</sup> on her choice. I also estimate all conditional logit models while omitting respondents who state that their building is already energy efficient (8 respondents), planned to be destroyed (3 respondents) or protected (6 respondents). Eliminating these choice tasks and individuals (cf. appendix 7.9), together or individually, does not affect the signs of the estimates shown for conditional logit models in Tables 2.6, 2.8 and 2.9. The differences in magnitudes are relatively small. This also has no impact on the sign and significance of coefficients related to individual and building characteristics described in section 5.2.2.

The models are also estimated when accounting for differences across choice tasks, by interacting choice tasks dummies with the alternative-specific constants, in order to control for the possibility of decreased attention throughout the choice experiment. Accounting for it also does not affect the variables of interest in all conditional logit models, with a maximal difference in the estimates of two-tenths (cf. appendix 7.10).

The present study is subject to limitations due to the limited sample size and the low response rate. This has to be put in the perspective of a complex survey with difficult decision processes for respondents.

Another limitation comes from the fact that the choice experiment involves hypothetical situations presented to respondents within public administration, firms or other institutions. Adapting the random utility model while accounting for profit maximization may be too simplistic in this case. The final decisions regarding energy efficiency investments are likely to involve a complex decision process with several decision-makers. This is not accounted for in this study. I tried to minimize this issue by selecting in the survey only the participants who have a role to play in the decisions regarding the building in the real life. Nevertheless, further research in this domain should consider organizational behavior of the institutions observed in order to analyze in further detail the relevance of the choices made by the respondents in the experiment.

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<sup>109</sup> Respondents stating that they consider their choice as being a clear decision are 62% in task 1, 68% in task 2 and 72% in tasks 3 and 4.

The estimates for willingness to pay presented in the analysis are also subject to limitations since they are computed using the upfront cost coefficient only. The choice experiment nevertheless involves two attributes for the cost, i.e. upfront cost and annual payment to ESCO. Another possibility to compute willingness to pay would include the coefficients on both these attributes. This would first require making an assumption on the interest rates considered by respondents, in order to translate it into actualized value of all the annuities paid to the ESCO during the contract duration. Moreover, the attribute non-attendance patterns found in the previous section suggest that there is heterogeneity in the way that respondents considered the two cost attributes. Some of the participants may have considered cost alone, payment to the ESCO alone or a combination of them. In the same way, some respondents may have translated payment into an actualized value and added it to the upfront cost. This heterogeneity in the decision process heuristics could be examined in further research relying, for instance, on more elaborated versions of latent class models. The attribute non-attendance latent class models I used in this chapter could be further developed using the so-called *common-metric attribute aggregation*. In the same way that Nlogit permits to constrain parameters to be equal to zero in certain classes to account for ANA, it can allow two parameters to be estimated as being aggregated in other classes.<sup>110</sup> Both ANA and aggregation can be part of the same class. This could be an interesting strategy to be applied in further research exploring the willingness to pay for energy savings, ESCO's guarantee, financing of the ESCO or willingness to accept contract duration.

Other research would also be needed in order to determine whether the lack of necessity of financing of the ESCO from a large share of the respondents is specific to the Swiss context, and if it is due to the current conjuncture or if it reflects a structural phenomenon.

The present study also focuses typically on potential clients of EPC, i.e. large energy consumers with consequent energy savings potential. It would however be interesting to enlarge the focus to assess how smaller energy consumers would value EPC

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<sup>110</sup> See Hensher et al. (2015) for more details.

contractual terms. Pätäri et al. (2016) show for instance that Finnish SMEs are financially constrained because of other investment needs. A survey targeted at SMEs could be useful to assess whether external financing becomes more interesting relative to a guarantee. This could bring other policy implications for small energy consumers.

Landlord-tenant split incentives and legal issues linked to the transfer of retrofit costs to the tenant did not show any significant impact on the willingness to adopt energy efficiency measures, contrasting with the results from the first chapter of this thesis in the context of energy supply contracting. This subject should be further tested using a sample with a higher share of privately-owned rented buildings, such as residential buildings, office buildings and shopping centers.

Finally, the exploration of attribute non-attendance provides insights into the behaviors influencing the decisions to invest in energy efficiency. Further research is needed to examine how non-standard behavior (according to the neoclassical economic theory) or strategy considerations could be exploited to foster investment in energy efficiency. More specifically, non-standard beliefs resulting from a systematic underestimation of discounted future energy costs as compared to the present purchase price may be examined using the aforementioned common-metric attribute aggregation to estimate willingness to pay for energy savings.

## **6 Conclusion**

This chapter analyzes the determinants underlying EPC adoption and how potential clients value the contractual attributes. The analysis is based on a survey of 297 managers and owners of large private and public energy-consuming buildings in Switzerland.

The econometric analysis shows that financing from the ESCO positively affects EPC adoption only for a minority of respondents. These are mostly public entities, presumably constrained by debt ceilings. They could also represent institutions with limited budget for non-core activities. This result implies that for a majority of respondents in our sample, the financing of ESCOs is not a driver of EPC adoption. A possible explanation is that one can always find the necessary financing for an

economically sound project (Cooremans, 2012). Moreover, this result has to be interpreted in the current Swiss economic context characterized by low interest rates.

A first implication of this result lies in the fact that, in order to attract new EPC clients, energy performance contract may be adapted to contribute to each clients' core business, for instance via non-energy benefits. This evolution in the EPC value proposition has already occurred in the mature US EPC market, where ESCOs have diversified and now propose new benefits within EPC, such as water conservation, tradable emission credits or avoided operation and maintenance. These benefits are transformed in dollar value and incorporated into the guaranteed or the shared savings schemes (Stuart et al., 2016).

A second implication is the need to clarify the extent to which public entities are legally entitled to use the financing from the ESCO to circumvent credit constraints such as debt ceilings. For budget constrained public entities with debt ceilings, this would be possible if they are allowed to consider the EPC project as an off-balance sheet operational expenditure. The rationale for legally allowing off-balance sheet financing in that case is supported by the fact that the risk is shared with the ESCO.

While the financing from the ESCO is positively valued only by a small minority of the respondents, the performance guarantee provided by the ESCO has a persistent and significantly positive impact on the willingness to adopt EPC. This result is important to develop the Swiss EPC market. While, in other countries, financing from the ESCO has triggered the EPC market in its early stage (Hansen, 2006; Marino et al., 2011), the Swiss context may be different. An implication for Swiss ESCOs relies in the fact that presenting EPC as a risk-sharing mechanism is likely to attract more customers than presenting it as a financing tool. This Swiss specificity may be an explanation of the relatively late development of the domestic EPC market, as compared to neighboring countries, such as Germany.

The positive effect of the risk sharing mechanism suggests that EPC could help mitigate barriers to energy efficient investment. This conjecture nevertheless needs further research of the impact of EPC guarantee on the probability to invest in energy efficiency. If risk sharing is proven to induce energy efficiency investment, this would

provide important policy guidance. While EPC may not be suitable for small energy consumers due to the entailed transaction costs, alternative instruments could provide other forms of performance guarantee to induce energy efficiency investments in all market segments.

This study fails to capture any impact of landlord-tenant split incentives on energy efficiency investments or EPC adoption. The conjecture should however be tested further by using a sample with a larger share of private rented buildings. I find no divergence in the decision-making or in the valuation of contractual attributes between private and public entities. The energy costs and the size of the building do not have a significant impact either. However, I show that if the respondent is an energy manager, the willingness to adopt EPC and energy efficiency increases. Directors of cantonal or municipal buildings show less interest in energy efficiency and EPC. This lack of interest towards EPC is stronger the longer the tenure of the respondent.

The results show important heterogeneity in the decision-making processes when it comes to energy efficiency and energy performance contracting. Some respondents simplified their decision process by using attribute non-attendance. This study provides insights into the complexity underlying the decision to invest in energy efficiency investment and to adopt EPC. Further research in that domain could provide crucial answers to foster energy efficiency investments.

Finally, while EPC risk sharing mechanism is valued positively, it also faces a reluctance from potential clients which is likely to be caused by a lack of understanding. I argue that informing clients about EPC is primordial to reduce this reticence. The recent efforts provided by the Swiss federal government to foster awareness of EPC solutions should therefore be upheld. More specifically, I pointed towards specific misunderstandings of EPC which could be easily overcome with information dissemination.

## 7 Appendix

### 7.1 Letter of invitation to participate to the survey



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Zürich, le XXX 2016

Institut  
Name Vorname  
Strasse Nr.  
PLZ Stadt/Dorf

#### Enquête 2016 sur l'efficacité énergétique: Votre participation compte

Chère Madame, cher Monsieur,

Pour améliorer l'efficacité énergétique des bâtiments existants, des outils tels que les contrats de performance énergétique (CPE) existent et ont déjà été mis en place avec succès dans d'autres pays.

Afin de connaître sous quelles conditions le potentiel des CPE peut également être exploité en Suisse, l'Office fédéral de l'énergie (OFEN) a chargé l'Université de Neuchâtel et TEP Energy de réaliser une enquête. En tant que responsable d'un bâtiment avec une grande consommation énergétique, nous vous invitons à participer à un sondage sur Internet, qui peut nous fournir des informations importantes du point de vue des utilisateurs possibles des CPE.

Pour accéder au questionnaire, veuillez saisir l'adresse suivante :

<https://escosurvey-unine.com/fr/login.html>

Et y indiquer le mot de passe: XXX

Remplir le questionnaire devrait vous prendre 20-25 minutes.

Nous vous serions reconnaissants de participer à l'enquête même si vous ne connaissez pas encore le concept des CPE. Des informations complémentaires sont fournies directement dans le questionnaire.

Les questions concernent le bâtiment indiqué dans l'adresse. Si vous hésitez entre plusieurs bâtiments, veuillez considérer celui qui sera le prochain à nécessiter une révision.

Les informations que vous nous communiquerez seront traitées de manière confidentielle et aucune donnée personnelle ne sera publiée. Si vous le souhaitez, nous serons ravis de vous communiquer les résultats une fois l'étude terminée.

En vous remerciant d'avance de votre précieuse collaboration, nous vous adressons, chère Madame, cher Monsieur, nos salutations distinguées.

FACULTÉ DES SCIENCES  
ÉCONOMIQUES

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## **7.2 Survey content**

### *Part 1: Introductory questions on the building and the respondent*

This section gathers general information on the building such as its type and location. The responsibility of the respondent and its decision role regarding the building is also assessed. If the respondent declares having no role in the decision process regarding investments, operation or revisions on energetic or technical aspects of the building, she is asked to give the contact of another person in charge and exits the survey. This implies that only respondents with a role to play in the decision process complete the survey. Therefore, part 1 is also intended to capture the potential heterogeneity in the respondents' roles.

### *Part 2: Current situation of the building*

The second part aims at capturing in detail the building characteristics, such as the construction year, the presence of tenants and the size in terms of heated floor area (square meters). Special emphasis is put on the type of heating system and its age. Information on energy and electricity yearly costs is also collected as well as the presence of ventilation or cold in the building. The respondents are then asked to state if the building is managed by an employee in charge of the energetic and technical aspects, if it is certified with the 'Minergie' label (Beyeler et al., 2009) and if an audit has been made since 1990. Finally, grid questions as in the following figure gather information on planned and realized retrofits on the walls, roof, windows, lighting, heating, ventilation and building automation.

**Veillez indiquer les types de rénovation réalisés ou prévus.**

(une ou plusieurs réponses possibles)

Eclairage	réalisé entre 2006-2010	réalisé entre 2011-2015	prévu pour 2016-2020	ni réalisé depuis 2006 ni prévu jusqu'en 2020	je ne sais pas
Remplacement des luminaires	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Installation de détecteurs de présence et/ou de lumière du jour, et/ou réglage automatique	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Chauffage</b>					
Nouveau système de chauffage (même agent énergétique)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nouveau système de chauffage (nouvel agent énergétique)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Automation du bâtiment</b>					
Mise en place/réparation de systèmes de contrôle et/ou automation du bâtiment (p.ex. contrôle et régulation, détecteurs de présence, système de gestion technique du bâtiment, smartmeter, etc.)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Figure 2.4 Example of question on realized and planned retrofits

### *Part 3: Information on Energy Performance Contracting*

Because the energy performance contracting market is only emerging in Switzerland, I expect to have a relatively high share of respondents unfamiliar with this notion. A complete section is therefore allocated to explain the concept in detail. This includes the following figure, describing the EPC concept; an EPC example illustrated and a simplified definition of these contracts:

“Some companies provide their client with adapted energy efficiency improvement measures. Through a contract of mid- to long-run, these providers insure the operation and maintenance of the installations. Sometimes they finance, completely or in part, the upfront investment and/or they guarantee the client that the energy savings will achieve a minimal amount, otherwise they pay the difference. In return, the client pays a fee during the contract duration.”

For simplicity, the definition of EPC does not distinguish the “shared-savings” from the “guaranteed-savings” scheme. In the choice experiment, some of the contracts proposed include both a guarantee and a part of the investment financed by the ESCO. It is therefore important in the definition not to exclude one from the other. Also, because of the necessity to simplify the choice tasks in the experiment, only fixed payments are presented in the contract. I therefore exclude from the definition

the case in which the client can pay according to a share of the energy savings achieved as in the “shared-savings EPC” scheme.

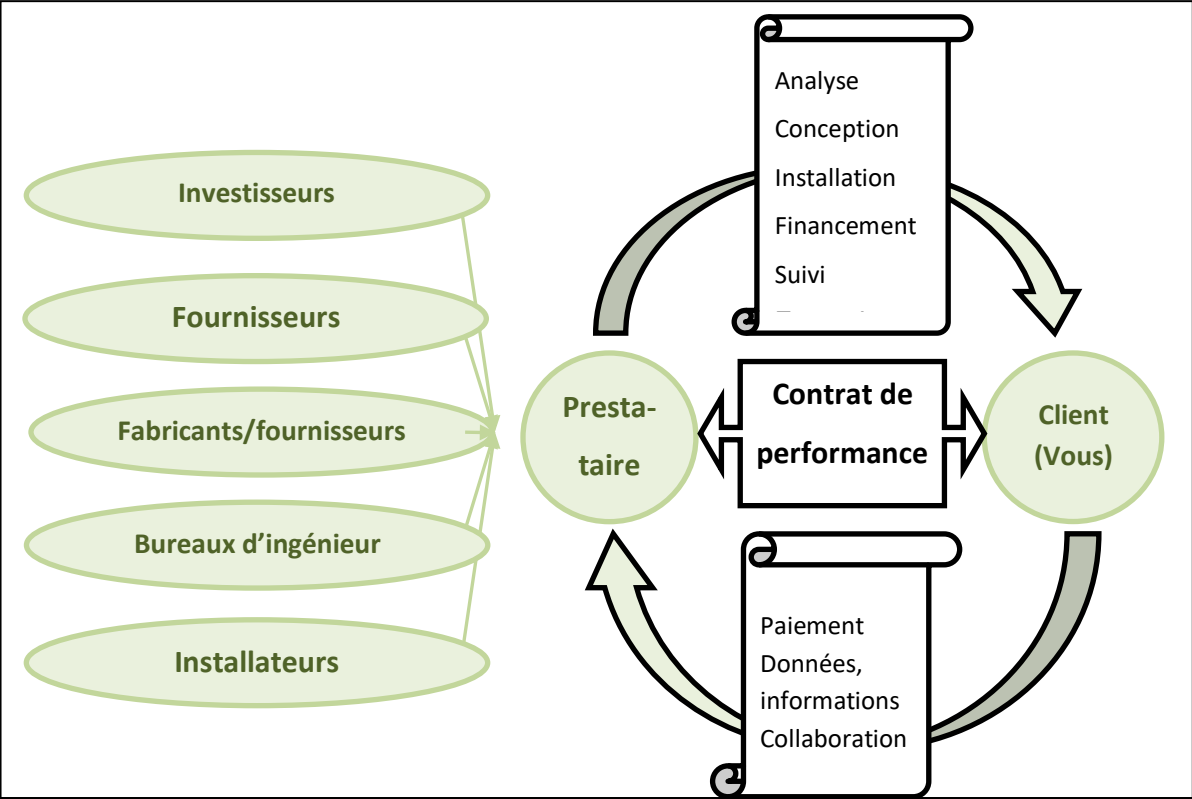


Figure 2.5 EPC concept diagram

The definition, diagram and example are selected in order to explain the EPC concept as precisely and briefly as possible. The selection is made on a pretest targeted at non-energy professionals in the circle of acquaintances of the authors. In these test survey, the respondents are asked between several combinations of explanations, examples and diagrams which one was the clearest. The combination used in the survey is the one which makes the majority of respondents satisfied in this pretest.

After the explanations of the EPC concept, the respondent is asked about her level of understanding of these contracts. This is used further to test the potential impact of misunderstanding on the choices made in the experiment.

**Un exemple pour illustrer:**

Le propriétaire d'un bâtiment, avec une facture énergétique de 50'000CHF/an, hésite à investir 150'000CHF dans un nouveau chauffage à pellets et un système d'automation du bâtiment, avec détecteurs de présence et de lumière du jour, éclairage et chauffage contrôlés automatiquement. Ce genre d'investissement peut amener des économies d'énergie de 10 à 30%.

Il a deux possibilités:

1) **Approche classique (sans contrat):** le propriétaire investit lui-même 150'000CHF. Les économies d'énergie ne sont pas garanties et varient de 10 à 30%.

2) **Contrat de performance énergétique:** Le prestataire finance 50'000CHF et le propriétaire 100'000CHF. Il lui garantit également que les économies atteindront un minimum de 20%. En échange, le client paye au prestataire 7500 CHF par an pendant 10 ans.

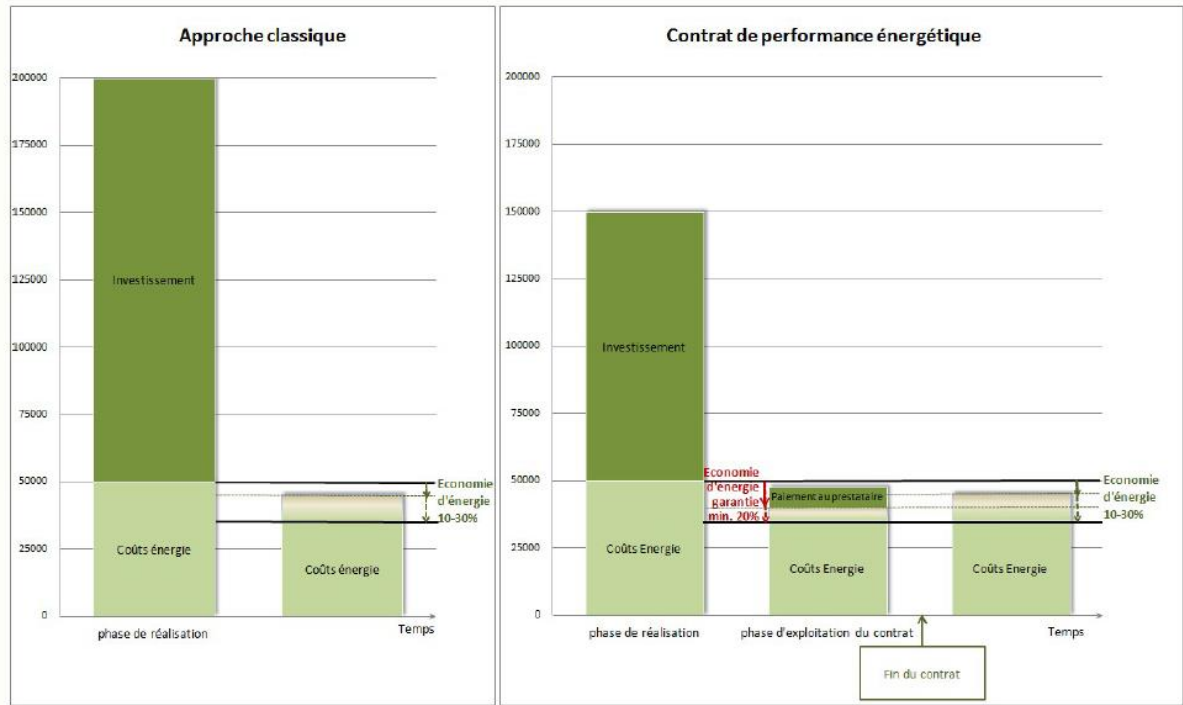


Figure 2.6 Example and illustration for EPC concept

*Part 4: Choice experiment*

See section 3.2.2.

*Part 5: Decision process*

Because of the potentially important heterogeneity in the decision process and the roles the respondent plays in it, this part aims at assessing some factors that can have an impact on the decisions made in reality. For instance, I ask whether in practice the respondent can take alone certain or all the decisions she makes in the choice experiment. It is also assessed whether a certain contract duration or a budget limit forces the respondent to consult other sections in the firm/entity to make the decision. This ensures that I account for the fact that there may be threshold effects in the levels of costs and duration for some respondents.

*Part 6: Socio-economic statistics of the respondent*

Since the emphasis of the survey is rather on the building characteristics, questions on the respondent himself are reduced to a minimum. These include only the age, the gender, the level of education and the number of years of experience in the current function in the entity/firm.

*Part 7: Contact and end*

Finally, the respondents are asked to give their e-mail address if they are interested in receiving the results of the study. An open question dedicated to remarks concludes the survey.

### 7.3 Allocation of energy efficiency measures according to upfront costs

The percentage represents the share of alternatives with the corresponding cost which is allocated with that type of energy efficiency measure.

**Table 2.10: Allocation measures type 1**

		COST (CHF/heated m <sup>2</sup> )							
		80	100	120	150	180	200	250	300
EE measure type	BA only	25% BA only	20%BA only	25% Envelope only	25% Envelope only	50%Envelope only	Env+BA	Env+BA	
		50% Heat pump +BA	20% Envelope only	50% Heat pump+BA	50% Heat pump+BA	50% Env+BA			
		25% Wood+BA	40% Heat pump+BA	25% Wood+BA	25% Wood+BA				
			20% Wood + BA						

Notes: BA: building automation and control system (BACS class B): This includes automatic detection for lighting and daylight control, combined light and heating automatically controlled, control and optimization of operations, alarming and monitoring functions. HP: heat-pump. Wood: woodchips or pellets. Nebo+: durable energy operation optimization ("Betrieboptimierung") of ventilation and air conditioning, adaptation of operation durations, reduction of air volumes, optimization of air humidity, reduction of electric needs for air transportation, control of air purification.

**Table 2.11: Allocation measures type 2**

		COST (CHF/heated m <sup>2</sup> )			
		80	100	120	150
EE measure type	BA only	25% BA only	25%BA only	50% Heat pump+BA	
		50% Heat pump +BA	50% Heat pump+BA	50% Wood+BA	
		25% Wood+BA	25% Wood + BA		

**Table 2.12: Allocation measures type 3**

		COST (CHF/heated m <sup>2</sup> )							
		80	100	120	150	180	200	250	300
EE measure type	BA only	BA only	50%BA only	Envelope only	Envelope only	50%Envelope only	Env+BA	Env+BA	
			50% Envelope only			50% Env+BA			

**Table 2.13: Allocation measures type 4**

COST (CHF/heated m <sup>2</sup> )				
	80	100	120	150
EE measure type	25% BA only	25% BA only	33% Nebo+ only	33% Nebo+ only
	25% Nebo+ only	25% Nebo+ only	33% solar panels	33% solar panels
	25% solar panels	25% solar panels	hotwater	hotwater
	hotwater	hotwater	33% biogas/green	33% biogas/green
	25% biogas/green	25% biogas/green	elec+BACS	elec+BACS
	elec+BACS	elec+BACS		

**Table 2.14: Allocation measures type 5**

COST (CHF/heated m <sup>2</sup> )				
	80	100	120	150
EE measure type	25% BA only	25% BA only	33% ventilation	33% ventilation
	25% ventilation	25% ventilation	33% solar panels	33% solar panels
	25% solar panels	25% solar panels	hotwater	hotwater
	hotwater	hotwater	33% biogas/green	33% biogas/green
	25% biogas/green	25% biogas/green	elec+BACS	elec+BACS
	elec+BACS	elec+BACS		

The allocation of respondents across the different types of choice experiment, depending on the revisions they already implemented since 2005, results in a large majority (68%) facing type 1, i.e. the design proposing both envelope enhancement and new heating systems (with or without building automation). Type 3, including only envelope enhancement, is faced by 68 respondents (23%). 12 respondents have already implemented envelope enhancement and are thus proposed measures including new heating systems and automation (type 2). A minority of respondents (4%) already revised both the envelope and the heating systems since 2005. Hence, they see type 4 (9 respondents) and type 5 (4 respondents).

## 7.4 Summary statistics of technology attributes

**Table 2.15: Summary statistics of measures**

N=5,940	Mean
Variables (dummies)	(% of N)
Group dummy <i>technique</i>	46.35
building automation	46.01
exploitation optimization	0.69
controlled ventilation	0.25
Group dummy <i>biogas/electricity mix</i>	13.64
biogas mix (if already gas)	13.43
green electricity mix	0.20
Group dummy <i>cheating</i>	16.90
new heat pump	11.03
new wood heating	5.13
solar panels	0.74
Dummy <i>envelope</i>	27.95
Overhaul façade, windows (painting)	23.54
Overhaul boiler revision	14.58
Overhaul technical revision	1.21

Note: In the choice experiment, one alternative can include several measures (e.g. heat pump + building automation).

N represents the total number of observations in the choice experiment analysis, i.e. the number of alternatives (3+2) multiplied by the number of choice tasks (4) and the total number of respondents (297).

## 7.5 Iterative process leading to the unconstrained latent class model of Table 2.7

This appendix described how the unconstrained latent class model specification has been chosen. The relevant ANA patterns are based on the respondents' stated weights. All combinations displayed in Table 2.5, which concern more than 6 persons, are considered. By an iterative process and starting with the groups representing the largest number of respondents, I test how including each group affects the efficiency of the model in terms of information criteria (Akaike and Bayesian information criteria). I start with a latent class model with two classes:

1. Full attendance, representing the group of respondents stating that no attribute was more important than another in their decision (23 persons)
2. Only upfront costs, savings and the energy efficiency measures are attended to (as these attributes are stated as important by 19 persons in the sample). All other attributes are constrained to zero.

I subsequently add the other classes, in the same order as in Table 2.5. When the class lead to smaller information criteria, it is kept, otherwise it is removed. In this manner, seven latent class models with two to six classes are tested.<sup>111</sup> The final combination of selected ANA patterns is presented in Table 2.7.

Once I determine the classes, I test whether individual or building characteristics have any impact on the class probabilities. Being familiar with EPC is the only characteristic showing a significant impact.<sup>112</sup>

Five classes are retained in the best model.

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<sup>111</sup> From the model which minimizes information criteria, I check whether a more efficient model can be found by omitting one of the classes, or by adding a class previously eliminated. A second full attendance class or a complete none attendance class (with and without ASC) are also added to check whether the model would be improved. This is not the case.

<sup>112</sup> I tested other characteristics such as private vs. public buildings, tenants, yearly energy/electricity costs, heated surface, retrofits done and planned, random information on non-economic benefits of energy efficiency investments, random information on cost guarantee from EPC, EPC not economically viable as stated by the respondent, function, experience, age, gender, education of the respondent. These individual and building characteristics were also tested by using interaction in conditional logit models. The results are provided in section 5.2.2 and appendix 7.8. I also tested whether dummies for belonging to specific groups of stated attribute importance matters in the class probability. These dummies happen to be non-significant. This might suggest that the inferred attribute non-attendance not exactly corresponds to the weights stated by the respondents.

## 7.6 Unconstrained latent class model without label non-attendance

**Table 2.16: Latent class model without ASC set to zero**

Dependent variable: choice (=1 if choose alternative <i>j</i> )	Latent class model Inferred attribute non-attendance (6classes)				
	(1)	(2)	(3)	(4)	(5)
Upfront cost	-0.017*** (0.005)	-0.007** (0.004)	-0.010*** (0.003)	0	-0.051 (0.056)
Expected savings	0.022** (0.011)	0.037*** (0.007)	0.017*** (0.006)	0.002 (0.019)	0
Savings variation	-0.048 (0.029)	0	0	0	0
Upfront cost financed by ESCO	0.019 (0.025)	0	0	0	0
Savings guarantee	-0.628 (0.780)	0.749** (0.331)	0	0	0
Payment to ESCO	-0.147 (0.148)	0	0	0	0
Contract duration	-0.304** (0.128)	0	0	0	0
Measures envelope	5.316*** (0.915)	0.496 (2.097)	-34.162 (0.22e07)	2.106 (4.823)	0
Measures technique	1.237* (0.691)	0.300 (0.384)	0.552 (0.356)	0.916 (0.568)	0
Measures biogas/electricity mix	2.094*** (0.592)	-0.667 (2.052)	-34.291 (0.22e07)	-0.978 (4.794)	0
Measures heating	0.501 (0.569)	0.178 (1.980)	-34.340 (0.22e07)	-33.068 (0.27e14)	0
ASC energy efficiency alternative	1.768 (0.78e07)	3.113 (1.951)	33.909 (0.22e07)	-1.039 (4.79e14)	-1.416 (1.77e27)
ASC EPC alternative	2.188 (1.53e07)	3.254* (1.969)	34.667 (0.22e07)	-3.330 (4.90e14)	-62.245 (0.77e27)
<b>Class probability as a function of stated weights group</b>					
Constant	1.098*** (0.364)	0.816** (0.374)	0.353 (0.419)	-0.025 (0.572)	0
Familiar with EPC (dummy)	0.612 (0.476)	0.809* (0.483)	0.318 (0.572)	-0.803 (0.919)	0
Average posterior class probabilities	0.372	0.315	0.151	0.070	0.092
observations	5,940				
Individuals	297				
Log-likelihood	-1,201				
AIC	2,500				
BIC	2,777				

Notes: Estimated using Nlogit. Standard errors are in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Attribute non-attendance is expressed as coefficients being constrained to equal zero. Familiar with EPC means the concept was known to the respondent before the survey. ASC stands for alternative-specific constant.

## 7.7 Equality-constrained latent class model with inferred attribute non-attendance

**Table 2.17: Equality-constrained latent class model**

Dependent variable: choice (=1 if choose alternative <i>j</i> )	Equality-constrained latent class model Inferred attribute non-attendance (7classes)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Upfront Cost	-0.019*** (0.003)	-0.019*** (0.003)	0	-0.019*** (0.003)	-0.019*** (0.003)	-0.019*** (0.003)	0
Expected savings	0.039*** (0.007)	0	0.039*** (0.007)	0	0.039*** (0.007)	0.039*** (0.007)	0
Risk: sav. variation	2.387*** (0.845)	0	0	0	0	0	0
Upfront ESCO	0.100 (0.131)	0	0	0	0	0	0
Savings guarantee	3.280*** (0.578)	0	0	0	3.280*** (0.578)	0	0
Payment to ESCO	-1.278** (0.588)	0	0	0	0	-1.278** (0.588)	0
Contract duration	-4.158*** (1.138)	0	0	0	0	0	0
Meas. Envelope	5.922*** (0.493)	5.922*** (0.493)	5.922*** (0.493)	0	5.922*** (0.493)	5.922*** (0.493)	0
Meas technic	1.501*** (0.277)	1.501*** (0.277)	1.501*** (0.277)	0	1.501*** (0.277)	1.501*** (0.277)	0
Meas. Mix	2.422*** (0.350)	2.422*** (0.350)	2.422*** (0.350)	0	2.422*** (0.350)	2.422*** (0.350)	0
Meas. Heating	1.562*** (0.299)	1.562*** (0.299)	1.562*** (0.299)	0	1.562*** (0.299)	1.562*** (0.299)	0
ASC ee alt.	-1.025*** (0.231)	-1.025*** (0.231)	-1.025*** (0.231)	-1.025*** (0.231)	-1.025*** (0.231)	-1.025*** (0.231)	0
ASC epc alt.	-1.523*** (0.261)	-1.523*** (0.261)	-1.523*** (0.261)	-1.523*** (0.261)	-1.523*** (0.261)	-1.523*** (0.261)	0
Average posterior class probabilities	0.206	0.082	0.179	0.130	0.129	0.104	0.170
Observations				5,940			
Individuals				297			
Log-likelihood				-1,279			
AIC				2,595			
BIC				2,705			

Notes: estimated using Nlogit. Standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1.

## 7.8 Conditional logit with individual and building characteristics

**Table 2.18: Conditional logit with individual and building characteristics**

dependent variable: choice (=1 if choose alternative <i>j</i> )	(1)	(2)	(3)	(4)	(5)	(6)
<b>ASC ee alt.</b>	0.102 (0.428)	1.046* (0.535)	0.793 (0.528)	0.344 (0.439)	0.486 (0.438)	-0.541 (0.622)
ASC ee x familiar with EPC	0.589** (0.233)					
ASC ee x rented building		-0.453 (0.324)				
ASC ee x privately owned building		-0.206 (0.398)				
ASC ee x energy consumption (CHF/year)		-0.000 (0.000)				
ASC ee x respondent=owner			-0.440 (0.339)			
ASC ee x respondent=financial Manager			-0.741 (0.488)			
ASC ee x respondent=facility manager			-0.509* (0.277)			
ASC ee x respondent=energy manager			0.827** (0.358)			
ASC ee x respondent=director of municipal/cantonal buildings			-0.440* (0.266)			
ASC ee x respondent=municipal counsellor			-0.191 (0.376)			
ASC ee x respondent=other type			-0.105 (0.811)			
ASC ee x experience of respondent in that function			-0.005 (0.015)			
ASC ee x random information on non-energy benefits of ee inv.					-0.083 (0.723)	
ASC ee x random information on cost guar. of epc					-0.181 (0.234)	
ASC ee x EPC seen as not economically viable						0.407 (0.344)
<b>ASC epc alt.</b>	-0.543 (0.545)	0.277 (0.710)	0.584 (0.639)	-0.242 (0.536)	-0.014 (0.550)	-19.554*** (0.709)
ASC epc x familiar with EPC	0.580** (0.284)					
ASC epc x rented building		-0.448 (0.405)				
ASC epc x privately owned building		-0.648 (0.482)				
ASC epc x energy consumption (CHF/year)		-0.000 (0.000)				
ASC epc x respondent=owner			-0.411 (0.402)			
ASC epc x respondent=financial Manager			-0.508 (0.569)			
ASC epc x respondent=facility manager			-0.559 (0.341)			
ASC epc x respondent=energy manager			0.969** (0.412)			
ASC epc x respondent=director of municipal/cantonal buildings			-0.666** (0.322)			
ASC epc x respondent=municipal counsellor			-0.079 (0.417)			
ASC epc x respondent=other type			-1.055 (1.154)			
ASC epc x experience of respondent in that function			-0.056*** (0.021)			
ASC epc x random information on non-energy benefits of ee inv.					-0.187 (0.288)	
ASC epc x random information on cost guar. of epc					-0.461 (0.288)	
ASC epc x EPC seen as not economically viable						0.239 (0.309)
upfront cost	-0.004*** (0.001)	-0.005*** (0.002)	-0.004*** (0.001)	-0.004*** (0.001)	-0.004*** (0.001)	-0.004 (0.003)
expected savings	0.011*** (0.003)	0.007 (0.004)	0.010*** (0.004)	0.011*** (0.003)	0.011*** (0.003)	0.009 (0.007)
savings variation	0.007 (0.008)	0.018* (0.010)	0.013 (0.009)	0.008 (0.009)	0.007 (0.008)	-0.006 (0.015)
upfront cost financed by ESCO	-0.001 (0.002)	-0.000 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.000 (0.002)
upfront cost financed by ESCO x privately owned building				0.001 (0.002)		
savings guarantee	0.403** (0.162)	0.473** (0.197)	0.390** (0.163)	0.365 (0.002)	0.403** (0.161)	0.038 (0.104)
savings guarantee x privately owned building				0.122 (0.308)		
payment to ESCO	-0.001 (0.011)	-0.009 (0.016)	0.003 (0.011)	-0.004 (0.011)	0.000 (0.011)	-0.005 (0.008)
contract duration	-0.017 (0.015)	-0.013 (0.019)	-0.012 (0.016)	-0.022 (0.016)	-0.016** (0.015)	-0.001 (0.011)
contract duration x privately owned building				0.000 (0.021)		
measure envelope	0.861* (0.442)	0.634 (0.545)	0.823* (0.454)	0.918** (0.464)	0.922 (0.437)	1.510** (0.720)
measures group technic	0.417** (0.186)	0.371 (0.251)	0.385** (0.190)	0.404** (0.189)	0.407** (0.186)	0.685* (0.400)
measures group biogas/green elec mix	0.013 (0.393)	-0.398 (0.480)	0.035 (0.418)	0.089 (0.417)	0.086 (0.388)	0.493 (0.570)
measures group heating	-0.069 (0.393)	-0.273 (0.466)	-0.059 (0.412)	-0.006 (0.414)	-0.007 (0.387)	0.403 (0.561)
observations	5,940	3,500	5,780	5,860	5,940	2,960
individuals	297	175	289	293	297	148
Log-likelihood	-1,822	-1,078	-1,744	-1,816	-1,835	-718
AIC	3,675	2,194	3,545	3,664	3,703	1,467
BIC	3,775	2,311	3,739	3,771	3,817	1,557

Notes: conditional logits (clogit) are estimated with Stata. ASC=alternative specific constants with alt. overhaul as baseline. Individual-cluster robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. In column (2), individual and building characteristics interacted with ASC taken individually in separate regressions are not significant either. In column (3), the status of respondent is given in non-mutually exclusive groups.

## 7.9 Robustness checks: dropping incoherent observations

**Table 2.19: Estimation conditional logit**

dependent variable: choice (=1 if choose alternative <i>j</i> )	Basis (1)		Without incoherent choices (IIA incompatible)		Without choices made in less than 5 seconds		Without uncertain choices		Without building energy efficient, planned to be destroyed or protected	
	clogit full attend.	clogit stated weights	clogit full attend.	clogit stated weights	clogit full attend.	clogit stated weights	clogit full attend.	clogit stated weights	clogit full attend.	clogit stated weights
upfront cost	-0.004*** (0.001)	-0.003** (0.001)	-0.004*** (0.002)	-0.003** (0.001)	-0.004*** (0.001)	-0.003** (0.001)	-0.003 (0.001)	-0.000 (0.002)	-0.004*** (0.002)	-0.003** (0.001)
expected savings	0.011*** (0.003)	0.023*** (0.004)	0.011*** (0.003)	0.023*** (0.004)	0.011*** (0.003)	0.023*** (0.004)	0.012*** (0.004)	0.021*** (0.005)	0.011*** (0.004)	0.021*** (0.004)
savings variation	0.007 (0.008)	-0.001 (0.012)	0.009 (0.009)	0.000 (0.012)	0.008 (0.008)	-0.001 (0.012)	0.006 (0.010)	0.000 (0.014)	0.010 (0.009)	0.007 (0.012)
upfront cost financed by ESCO	-0.001 (0.002)	0.002 (0.002)	-0.001 (0.002)	0.002 (0.002)	-0.001 (0.002)	0.002 (0.002)	0.000 (0.002)	0.001 (0.002)	-0.002 (0.002)	0.002 (0.002)
savings guarantee	0.401** (0.160)	0.918*** (0.214)	0.413** (0.161)	0.950*** (0.216)	0.437** (0.159)	0.951*** (0.213)	0.626*** (0.204)	1.241*** (0.260)	0.416** (0.161)	0.900*** (0.215)
payment to ESCO	-0.001 (0.011)	-0.018* (0.011)	-0.002 (0.012)	-0.018 (0.011)	-0.002 (0.011)	-0.019* (0.011)	-0.006 (0.014)	-0.013 (0.012)	0.002 (0.011)	-0.019* (0.011)
contract duration	-0.017 (0.015)	-0.038** (0.015)	-0.018 (0.015)	-0.039** (0.015)	-0.019 (0.015)	-0.038** (0.015)	-0.026 (0.020)	-0.038** (0.018)	-0.014 (0.015)	-0.035** (0.015)
measure envelope	0.860* (0.441)	0.680*** (0.274)	0.828 (0.518)	0.689*** (0.294)	0.852* (0.441)	0.680*** (0.275)	0.563 (0.492)	0.633** (0.274)	0.960** (0.457)	0.759*** (0.283)
measures technique	0.409** (0.186)	0.087 (0.199)	0.427** (0.192)	0.119 (0.210)	0.397** (0.189)	0.074 (0.200)	0.330 (0.244)	0.000 (0.248)	0.375** (0.191)	0.067 (0.200)
measures biogas/green electric. mix	0.025 (0.394)	0.167 (0.311)	-0.040 (0.468)	0.130 (0.340)	0.019 (0.394)	0.166 (0.311)	-0.177 (0.415)	0.268 (0.376)	0.060 (0.413)	0.246 (0.310)
measures heating	-0.071 (0.392)	-0.073 (0.310)	-0.146 (0.467)	-0.157 (0.333)	-0.070 (0.392)	-0.062 (0.310)	-0.135 (0.418)	0.063 (0.370)	-0.104 (0.410)	-0.005 (0.317)
ASC ee	0.409 (0.415)	0.638*** (0.221)	0.490 (0.493)	0.705*** (0.243)	0.422 (0.416)	0.640*** (0.221)	0.508 (0.443)	0.480 (0.258)	0.698 (0.435)	0.929*** (0.231)
ASC epc	-0.243 (0.520)	-0.045 (0.251)	-0.103 (0.584)	-0.067 (0.268)	-0.243 (0.521)	-0.055 (0.252)	-0.357 (0.611)	-0.488 (0.298)	0.021 (0.542)	0.274 (0.257)
observations	5,940	5,580	5,730	5,380	5,915	5,565	4,065	3,890	5,600	5,260
individuals	297	279	297	279	297	279	250	238	280	263
Log-likelihood	-1,839	-1,641	-1,753	-1,555	-1,830	-1,636	-1,240	-1,123	-1,614	1,434
AIC	3,709	3,307	3,532	3,137	3,687	3,298	2,505	2,273	3,255	2,893
BIC	3,792	3,393	3,619	3,223	3,774	3,384	2,587	2,354	3,342	2,979

**Notes:** Conditional logit (clogit) are estimated using stata. Conditional logit stated weights uses an interaction of attributes with dummies of individual-stated attributes importance. These dummies equate one when the individual states that she considers this specific attribute as important and zero otherwise. ASC=alternative specific constants with alt. overhaul as baseline. Ee=energy efficiency alternative, epc=EPC alternative. Individual-clustered robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1.

## 7.10 Robustness checks: controlling for the choice task

**Table 2.20: Estimation conditional logit**

dependent variable: choice (=1 if choose alternative <i>j</i> )	Basis		Controlling for choice tasks <sup>a</sup>	
	Conditional logit full attendance	Conditional logit stated weights	Conditional logit full attendance	Conditional logit stated weights
upfront cost	-0.004*** (0.001)	-0.003** (0.001)	-0.004*** (0.002)	-0.003** (0.001)
expected savings	0.011*** (0.003)	0.023*** (0.004)	0.011*** (0.004)	0.023*** (0.004)
savings variation	0.007 (0.008)	-0.001 (0.012)	0.007 (0.009)	-0.002 (0.012)
upfront cost financed by ESCO	-0.001 (0.002)	0.002 (0.002)	-0.001 (0.002)	0.002 (0.002)
savings guarantee	0.401** (0.160)	0.918*** (0.214)	0.403** (0.159)	0.917*** (0.214)
payment to ESCO	-0.001 (0.011)	-0.018* (0.011)	0.003 (0.012)	-0.017* (0.011)
contract duration	-0.017 (0.015)	-0.038** (0.015)	-0.012 (0.015)	-0.037** (0.015)
measure envelope	0.860* (0.441)	0.680*** (0.274)	0.904* (0.449)	0.692*** (0.276)
measures group technique	0.409** (0.186)	0.087 (0.199)	0.423** (0.194)	0.074 (0.202)
measures group biogas/green electricity mix	0.025 (0.394)	0.167 (0.311)	0.028 (0.399)	0.182 (0.314)
measures group heating	-0.071 (0.392)	-0.073 (0.310)	-0.059 (0.395)	-0.062 (0.310)
ASC ee	0.409 (0.415)	0.638*** (0.221)	0.490 (0.430)	0.631** (0.276)
ASC epc	-0.243 (0.520)	-0.045 (0.251)	-0.438 (0.552)	-0.209 (0.286)
observations	5,940	5,580	5,940	5,580
individuals	297	279	297	279
Log-likelihood	-1,839	-1,641	-1,838	-1,640
AIC	3,709	3,307	3,813	3,317
BIC	3,792	3,393	3,840	3,443

**Notes:** <sup>a</sup>Controlling for choice tasks: all choice tasks dummies are added to the models and interacted with the alternative specific constants. Choice task dummies and interactions coefficients are not displayed here but available upon request to the author. Conditional logits are estimated using stata. Conditional logit stated weights uses an interaction of attributes with dummies of individual-stated attributes importance. These dummies equate one when the individual states that she considers this specific attribute as important and zero otherwise. Individual-clustered robust standard errors in parentheses. ASC=alternative specific constants with alt. overhaul as baseline. Ee=energy efficiency alternative, epc=EPC alternative \*\*\*P<0.01, \*\*P>0.05, \*P<0.1.



### 3 The provision of energy service contracting<sup>113</sup>

#### **Abstract**

The market of energy service contracting is growing slowly in Switzerland and some types of contracts are only emerging. This study focuses on the supply of energy service contracting. It aims to assess the extent to which changes in the energy market and energy policies can affect the firms' willingness to provide energy service contracting. Based on a choice experiment among 208 actual and potential suppliers in Switzerland, the willingness to supply certain types of energy service contracts is empirically investigated in different hypothetical market and regulatory contexts. The results show that an obligation for utilities to increase their clients' energy efficiency, as in a White Certificates scheme, has a positive impact on the provision of energy service contracts from competitors and non-utilities. An exogenous and positive demand shock positively impacts the willingness to supply only if the shock affects both public and private clients. Hypothetical changes in the regulatory context, such as a total liberalization of the electricity market or new taxes on fuels and electricity, do not show significant impacts on the willingness to enter the market. This chapter finally shows that focusing on the supply side brings new insights in the possibility to develop the market of energy service contracting. Yet, further research is needed in order to fully understand the decision to enter the market of energy service contracting.

**Keywords:** Energy Service Company, supply, market entry

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# 1 Introduction

As we have seen in the introduction, energy service contracting consists in outsourcing the design, the structure and sometimes the financing of energy services or energy-conservation projects to a contractor called Energy Service Company (ESCO). Two main types of energy contracting exist: Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC) (Sorrell, 2005). ESC usually covers the financing, operation and maintenance of the energy equipment, but the contractor exert no or little control over the demand for energy services. EPC differs from ESC in that, in the former, the contractor has a financial incentive to reduce energy costs. In both type of contracts, the client shares the technological risks with the contractor and benefits from economies of scale and incentive from the ESCO to maintain performance over contractual time (Sorrell, 2007). In addition to possible social benefits resulting from the energy savings and renewable energy systems implemented through these contracts (Soroye and Nilsson, 2010; Goldman et al., 2012; Bleyl, 2011), energy service contracting represents business opportunities (Gilligan, 2011; Eikmeier et al., 2009).

The ESC market is growing slowly in Switzerland and the EPC market is only emerging and lagging behind in comparison to the situation in neighboring countries, such as Germany, France and Italy (Bertoldi and Boza-Kiss, 2017). In order to explain this lag, existing market studies are mostly based on interviews of experts and focus on obstacles concerning the demand-side, such as a lack of awareness and trust (Marino et al., 2010; Bertoldi et al., 2014). In the existing literature, little emphasis has been put on the supply-side. Nevertheless, the number of competitors and their experience are also likely to play a major role in the development of the market. Indeed, competition between ESCOs has been shown to reduce not only EPC prices, but also the payment periods and enhanced the guaranteed energy savings (Iimi, 2016).

This study aims to analyze how the supply of energy service contracting can be developed in Switzerland by using an analysis among active and potential suppliers. I study how hypothetical regulatory contexts affecting the energy market can motivate

energy market players to offer certain types of energy service contracts. This chapter attempts to provide empirical evidence on the extent to which policy instruments affecting the energy market interact with market-based instruments such as EPC and ESC. The analysis is based on a survey of 208 energy utilities, gas providers, engineering firms, appliances and heating systems suppliers. The willingness to provide energy service contracts is estimated based on a choice experiment. In the latter, certain types of energy performance contracts (EPC) as well as energy supply contracts (ESC) are proposed in different hypothetical regulatory contexts. The choice experiment makes it possible to analyze how energy policies interact and may expand the supply of energy service contracting. I also examine how the firm's characteristics can affect the decision to enter the market.

The contribution of this paper lies in the fact that it brings a new perspective on the potential of energy service contracting by focusing on the mechanisms that can foster the supply-side. An extensive survey on the supply side of the ESCO market, covering also the potential entrants, is rare in the literature.<sup>114</sup> The analysis of the interaction of energy policies with the willingness to provide energy service contracts is also a contribution of this study. The discrete choice experiment allows me to analyze the impact of hypothetical regulatory changes that may affect the Swiss energy market in the coming years. While such experiments have been used in other contexts (e.g. Banfi et al., 2008; Rose et al., 2012; Blasch and Farsi, 2014; Caputo et al., 2014; Hole et al., 2016) they have, to my knowledge, never been employed in the field of energy service contracting.

A brief literature review focusing on the supply side of the energy service contracting market is provided in the next section together with the research question. The methodology is presented in section 3, which covers the survey design and the econometric method. The data are presented in section 4. Section 5 includes the econometric results, together with a series of robustness checks. Finally, section 6 discusses the results and concludes.

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<sup>114</sup> One exception is Kindström et al. (2017)

## **2 Background**

### **2.1 The supply of energy service contracting**

An extensive survey on the supply side of energy service contracting, covering also the potential entrants, is absent from the literature. The closest attempt to fill this gap is made by Kindström et al. (2017), who analyze the driving forces and barriers related to the provision of energy service contracting among 78 local energy companies in Sweden. While they find evidence of an interest by potential suppliers, they also observe several obstacles on the supply side such as the lack of a clearly defined strategy for the firm, a lack of interest and trust on the demand side and insufficient resource commitment to energy services. The perceived drivers are the desire to strengthen the company's position in the market and a clear strategy from the top management, as well as a sound customer demand. More generally, they argue that local and regional energy providers can be key actors in the development of the market of energy service contracting. While these results provide insights into the point of view of potential entrants, the authors do not study how the regulatory context and energy policies can affect the decision to enter the market.

The motivations for Swiss ESCOs to provide energy service contracting may depend on their core business. Energy service contracting allows the facility management companies to increase their market volume for equipment and maintenance portfolio. Energy equipment providers may also sell their products via energy service contracting. Other elements may be important for all types of firms. For instance, energy service contracting can be a mean to gain captive clients over long term contracts. It also permits the firms to stabilize and plan their cash flows on an annual basis. Finally it has also been mentioned that offering these services allow the firms to keep a competitive advantage. While this may appear contradictory, the previous arguments explain why energy providers, such as electricity or gas utilities, may be interested in providing EPC, even if it means reducing the energy consumption of their clients. Additional explanations may stem from the ownership composition of the firm. If a public entity is the major stakeholder, the firms may also be constrained by energy efficiency, renewable energy and energy independence objectives. Energy

service contracting is also an opportunity for utilities to increase their supervision over the energy demand and reduce peak loads. Finally, the willingness to enter the market of energy service contracting may also be driven by an increased competition resulting from changes in the regulatory context of the energy market.

## **2.2 Research questions**

The present chapter assesses whether the regulatory context and energy policies affect the willingness of firms to provide energy service contracting. Several policy-driven exogenous shocks on the energy market can enhance competition and therefore are expected to have an impact on the supply of energy service contracting.

First, the liberalization of the electricity market is expected to increase competition as electric suppliers try to maintain their market share. Energy market liberalization has been cited as an important driver of growth in the market of energy service contracting (Marino et al., 2011, Vine, 2005, Adnot et al., 2002). Second, electricity or gas suppliers may also choose to diversify with energy services when reacting to the implementation of taxes on fuels and electricity. Then, legal energy savings targets for energy suppliers, that arise with a White Certificates scheme for instance (Langniss and Praetorius, 2006), are also expected to induce competition from utilities and may thus increase the supply of energy service contracting (Oikonomou et al., 2008). New entrants may also be attracted by a positive shift in the demand for energy efficiency, energy conservation or renewable energy. These demand shocks can typically arise after the implementation of energy policies, such as new legal requirements of energy efficiency (Popp et al., 2010; Nesta et al., 2014), which stimulate the market of EPC and ESC services (Capelo, 2011; Marino et al., 2011). Taxes on fuel and electricity may also affect the demand for energy services, if the tax burden is supported by the demand side.

To summarize, this study examines the responses of firms as a reaction to the following exogenous policy-driven shocks:

1. Complete liberalization of the electricity market
2. Introduction of new taxes on fuels and electricity

3. White Certificates: energy utilities have the obligation to increase the energy efficiency of their clients
4. Introduction of a new law allowing energy service contracting to satisfy the legal requirement for large private energy consumers
5. Introduction of a new law requiring energy service contracting to be considered when retrofitting public buildings

All these policy-driven shocks may affect the supply side through competition (liberalization and White Certificates), an increase in the demand side (large private consumers, and public buildings) or both (taxes on fuels and electricity).

The fact that these policies are hypothetical constitutes the main shortcoming of the methodology in this study. However, these are public policies that have all been discussed by the Swiss parliament. Some of them, such as the White Certificates, have already been implemented in neighboring countries, such as France, Italy and the UK. The electricity market is already partially liberalized for large<sup>115</sup> electricity consumers since 2009. Thus, the suppliers' perception of the impact of a second planned liberalization phase, targeted at smaller consumers, will likely be grounded upon their experience after the first phase. As a result, one can plausibly expect the firms which are already active in the energy market to have devoted an in-depth pondering on the way they could adapt their business model to these new policies. Moreover in the survey, all policy shocks are framed in a way that can be perceived as plausible with future Swiss energy policies (cf. 3.1.2.c). Still, in order to account for this potential shortcoming, the respondents' perceived plausibility of the hypothetical policies has been assessed and is used as a robustness check in the empirical analysis.

## **3 Methodology**

### **3.1 Survey design**

#### *3.1.1 Target group*

The survey is targeted at active and potential suppliers of energy service contracting in Switzerland. These include electricity and gas providers at municipal and cantonal

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<sup>115</sup> With a yearly electricity consumption superior to 100,000 kWh.

levels, engineering and consulting firms, contractors, facility managers, heating systems and energy appliances providers. In total 835 addresses were collected through associations (e.g. electricity industry and gas industry) and web-sites. Some of the contacts were provided by the swissesco association, of which most active Swiss EPC providers are members. The addresses collected include participants from three main linguistic regions and the survey has been prepared in both German and French.<sup>116</sup>

Within each firm, the person contacted depended on the size of the company and available public information.<sup>117</sup> For public utilities of gas and/or electricity, the person of contact was the head of energy services, the department head, the CEO or the president of municipalities or energy commissions. The CEO or the department heads were primarily targeted for all the other companies.

### 3.1.2 *Survey structure*

The survey is composed of five main parts, which are described in the appendix. The choice experiment is described in the next subsection.

#### a) *Choice experiment*

All respondents are directed to a choice experiment, in which they have to state whether their firm would consider offering a certain type of contract, provided that the market situation were to hypothetically change in several possible ways.

All respondents face four choice tasks with one of the following contracts proposed:

1. Shared-savings EPC: In this type of contract, the ESCO provides its client with a reduction in energy consumption. The ESCO finances the equipment and installation. The ESCO is remunerated through an agreed percentage of the energy savings achieved during the contractual period.
2. Guaranteed-savings EPC: In this type of contract, the ESCO provides its client with a reduction in energy consumption. The client finances the equipment and installation. During the contractual period, the ESCO guarantees that the energy

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<sup>116</sup> Italian speakers are invited to complete the survey in the language of their choice.

<sup>117</sup> For each utility, the web-page was consulted in order to find an organization chart.

savings will reach a certain amount, otherwise it reimburses the client. The ESCO is remunerated through a fixed fee.

3. Energy Supply Contracting (ESC): In this type of contracts, the ESCO provides its client with energy service supply (heating, cooling, hot water, etc.). The ESCO finances the equipment and the installation. The ESCO is remunerated through an agreed fixed fee and a variable fee for energy consumption.

For respondents from firms already offering these contracts, they are asked whether their firm would consider offering the contract “more often than currently”. A typical choice task is presented in Figure 3.1.

The two EPC contract’s types are randomly assigned to the first three choice tasks while the ESC contract is assigned to the fourth choice task. A constraint on the randomness insures to have each EPC type proposed at least once. The five policy shocks described above are presented to the respondents in the box of figure 3.1 and correspond to the levels in Table 3.1. One can note that the choice experiment presented to the respondents (figure 3.1) combines several attributes per row (cf. Table 3.1), in order to simplify the visualization for respondents. For instance, the row corresponding to the “demand” combines the attributes private market demand and public market demand. It could show an increase in private demand, an increase in public demand, both or none of them. A similar framing has been applied to the “political context”, including liberalization and/or taxes or no changes. Nevertheless, all attributes are considered independently as in Table 3.1 for the choice experiment design. The latter has been defined using the Ngene software and determined by a full factorial design of 32 rows, and by using an orthogonal design to combine the rows in 8 blocks of 4 choice tasks.<sup>118</sup> Full factorial is preferred in this context to a D-efficient design, because the number of attributes and levels is limited and no priors exist on the impact of these on the willingness to offer energy service contracting.

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<sup>118</sup> The design was modified to avoid the case with no changes, i.e. all attributes are associated with the first level.

**Energy performance contract (EPC) with guaranteed savings:**

In the EPC with guaranteed savings, you provide the client with a reduction in her energy consumption. The client finances the equipment. During the contractual period, the client pays a fixed fee. You guarantee to the client that the energy savings will reach a certain amount, otherwise you will pay the difference.

**In the following hypothetical context, will you firm consider supplying this type of contract [script]?**

*You can place your mouse on the elements with a dashed underline to get additional information.*

<u>The demand</u>	<u>from large private energy consumers increases: EPC now satisfies to the universal convention of objectives (AeNec/ACT)</u>			
<u>The Supply</u>	<u>Increases after the legal obligation for energy utilities to increase the energy efficiency of their clients</u>			
<u>Political context</u>	<u>The liberalization of the electricity market for small customers will be implemented in the next months</u>			
	<input type="checkbox"/> yes	<input type="checkbox"/> rather yes	<input type="checkbox"/> rather no	<input type="checkbox"/> no

Choice task 1/4

**Notes:** additional information is provided with pop-up for elements with a dashed-underline. "script" is replaced by a blank for respondents who state not to offering this contract, and by "more often than currently" for the one already offering it. The market demand can include changes on private or public demands, on both or stay as current. The supply can increase after a legal obligation as presented in the figure or stay as current. The regulatory context can include a complete liberalization or energy tax levies, both of them or a status quo with respect to the current situation.

Figure 3.1 Example of choice task

**Table 3.1: Attributes and levels in the choice experiment design**

<u>Attributes</u>	<u>Levels</u>
Market demand (private)	<ol style="list-style-type: none"> <li>1. same as current</li> <li>2. demand from large energy consumers of the private sector increases: EPC (or ESC)<sup>a</sup> is now sufficient to meet the universal convention of objectives</li> </ol>
Market demand (public)	<ol style="list-style-type: none"> <li>1. same as current</li> <li>2. demand from all public building increases: public entities are obliged to systematically consider EPC (or ESC) as a possible solution to energy efficiency projects</li> </ol>
Market supply from utilities (White Certificates)	<ol style="list-style-type: none"> <li>1. same as current</li> <li>2. EPC (or ESC)<sup>a</sup> supply increases because the government obliges the utilities to implement energy efficiency measures in their clients' buildings</li> </ol>
Regulatory context (liberalization)	<ol style="list-style-type: none"> <li>1. same as current</li> <li>2. liberalization of electricity market for small energy consumers will be implemented</li> </ol>
Regulatory context (taxes on fuels and electricity)	<ol style="list-style-type: none"> <li>1. same as current</li> <li>2. new constitutional article (131.a) has been accepted and will be implemented in the next months: subsidy schemes will be stopped and replaced with electricity and fuel taxes.</li> </ol>

<sup>a</sup>The mention of EPC (or ESC) corresponds to the contract proposed.

All policy shocks are framed in a way that they can be perceived as plausible with future Swiss energy policies. For instance, the electricity market liberalization is presented as the second phase of a complete liberalization, which is expected to occur in the coming years. Taxes on fuels and electricity are presented as the project of a new constitutional article (131a, Swiss Federal Council, 2015; Arrêté federal, 2015). This article constitutes the second step of the 2050 energy strategy and aims at regulating the transformation of a subsidies scheme to a system of tax levies on fuels and electricity.<sup>119</sup> The consequent modification of incentives provided by such a tax levy scheme is likely to have an important impact on both the demand and the supply sides of the energy market. This will force the suppliers to find innovative products and services to respond to the clients' needs. Assessing the perceived impact from the suppliers' point of view is relevant for policy-makers, even though the implementation of this project of constitutional article is still uncertain.<sup>120</sup>

The White Certificates scheme is simplified and presented as an obligation for utilities to increase the energy efficiency of their clients. Private demand for EPC (resp. ESC) is presented as increasing because of EPC (resp. ESC) being sufficient to meet the universal convention of objectives, which is one of the possibilities for large energy consumers to meet legal requirements on energy efficiency.<sup>121</sup> Finally, the public demand for EPC (resp. ESC) is shifted because of an obligation of public entities to consider EPC (resp. ESC) as a solution to energy efficiency projects. The hypothetical changes on market demand and supply are presented in order to be perceived by the respondents as exogenous shocks on which their firm have no influence.

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<sup>119</sup> This constitutional article project also aims at incorporating the current CO<sub>2</sub> tax and the supplement to electricity network into these fuels and electricity tax levies.

<sup>120</sup> It is important to note that both the finance commission (CdF-N, 2017) and the environmental commission (CEATE-N, 2017) of the national council have recently decided not to proceed on this project. The arguments evoked were the insufficiency of the instruments proposed, their lack of diversity and little predicted impact, given the current energy market. The negative impact of such a taxation scheme on the competitiveness of the Swiss firms has also been invoked. The commission however did not deny the need of an incentive scheme and will work on another project. The parliament will also take a decision on the CO<sub>2</sub> taxation reform by the end of the year. The final constitutional article project will be submitted to the Swiss population and cantons. Most of the respondents answered the survey before the deliberations at the finance and environmental commissions.

<sup>121</sup> Yearly electricity consumption above 0.5 GWh and/or yearly heat demand above 5 GWh.

### *Follow-up questions*

Follow-up questions after the choice tasks were aimed at complementing the qualitative analysis on the EPC business model.<sup>122</sup> Depending on the answer to the choice task, firms affirmatively considering offering this type of contract are asked about the activities they would implement in order to do so. Respondents not considering offering this type of contract are asked to state whether they would change their mind if one or several of the market's components (demand, supply, regulatory context) would change.

The survey then assesses the perceived credibility of each hypothetical changes proposed in the choice experiment by using a 4 point Likert scale (very plausible to not plausible at all).

### **3.2 Econometric framework**

In the choice experiment tasks, the respondents are asked to state whether their firm would consider offering a certain type of contract. The answer is a 4 points Likert scale:

0. No
1. Rather no
2. Rather yes
3. Yes

In order to account for the ordinal characteristics of the outcome, as well as to capture all the information provided by the Likert scale, the appropriate model is the ordered logit or probit model, also known as the proportional odds model (Long and Freese, 2014). Because each respondent  $i$  faces 4 choice tasks  $j$ , I treat the data as a panel and estimate a random-effects ordered logit model. In this model, a latent continuous response  $y_{ij}^*$  is expected to have the following impact on the observed outcome  $y_{ij}$ :

$$y_{ij} = \begin{cases} 0 & \text{if } y_{ij}^* \leq \kappa_1 \\ 1 & \text{if } \kappa_1 < y_{ij}^* \leq \kappa_2 \\ 2 & \text{if } \kappa_2 < y_{ij}^* \leq \kappa_3 \\ 3 & \text{if } \kappa_3 < y_{ij}^* \end{cases} \quad (1)$$

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<sup>122</sup> See Klinke et al. (2017) for further details.

in which  $\kappa_i$  are the cut-off points and the latent variable is defined by:

$$y_{ij}^* = \text{context}_{ij}\lambda + \text{contract}_{ij}\delta + z_i\gamma + v_i + \epsilon_{ij} \quad (2)$$

$\text{context}_{ij}$  is a vector of dummies describing the hypothetical context in choice task  $j$ . The vector  $\text{contract}_{ij}$  includes two dummies for the following types of contracts: EPC shared-savings, EPC guaranteed-savings. The contract dummy ESC is omitted and therefore considered as the benchmark. The vector  $z_i$  includes the firm's characteristics, such as the type of services already offered by the firm and the familiarity with the EPC concept. The impact of other firm characteristics, detailed in the next section, on the willingness to consider offering EPC or ESC is also tested. The random effects  $v_i$  are assumed to be normally, independently and identically distributed with mean zero and variance  $\sigma_v^2$ , and the errors  $\epsilon_{ij}$  are assumed to follow a logistic distribution and are independent from  $v_i$ .

The probability of observing outcome  $k$  for response  $y_{ij}$  is given by:

$$P(y_{ij} = k | \kappa, x_{ij}, v_i) = \frac{1}{1 + \exp(-\kappa_k + x_{ij}\beta + v_i)} - \frac{1}{1 + \exp(-\kappa_{k-1} + x_{ij}\beta + v_i)} \quad (3)$$

in which  $x_{ij}\beta$  represents the product of the coefficients' vector to be estimated with the explanatory variables described in equation (2). This probability is used to compute the conditional distribution and the likelihood function, which relies on an integral that must be approximated. I opted for the mean-variance adaptive Gauss-Hermite quadrature to approximate the integrated function.

## 4 Data

### 4.1 Collection process and response rate

A total of 827 firms were contacted. 41 firms were randomly chosen to participate in a pilot survey, while the main survey was targeted at 786 respondents. The data collection lasted two months, from December 1<sup>st</sup>, 2016 to January 31<sup>st</sup>, 2017.

280 respondents, (34%) out of the 827 participants invited, accessed the online survey. The analysis is based on the 208 respondents who completed the choice experiment, representing 25% of the invited participants. The average response rate

is similar across the different types of firms surveyed, i.e. electric utilities (26%), gas providers (23%) and others (22%).

#### 4.2 Characteristics of the firms in the sample

Goods and services offered by the firms, as stated by the respondents, are described in table 3.2 and mainly include electricity and gas. Other services offered by the firms are street lighting, regional energy planning, consulting on energy services, water supply, digital network or telecommunication services. 45% of the firms in the sample also stated to provide services related to energy efficiency other than EPC, e.g. energy consulting, programs of incentives to increase energy efficiency of the clients, energy optimization and planning, consulting for large energy consumers, smart metering, building automation, audits or cantonal energy certificate for buildings (CECB+). The sample includes representatives of all significant sectors in the energy market.

**Table 3.2: Stated goods and services provided by the firm**

Goods and services provided	Not providing	Providing	Share providing	N
Electricity	46	162	0.78	208
Gas	168	40	0.19	208
Heating systems	188	20	0.10	208
Electric appliances	198	10	0.05	208
Energy control and optimization	184	24	0.12	208
Facility management	199	9	0.04	208
Technical maintenance	172	36	0.17	208
Energy supply contracting (ESC)	177	31	0.15	208
Energy performance contracting (EPC)	199	9	0.04	208
Engineering consulting	152	56	0.27	208
Other energy efficiency services	114	94	0.45	208
Other services	185	23	0.11	208
Other activities	167	41	0.20	208

While 31 firms are active on the ESC market, 9 (4%) out of the 208 firms in the sample are already active in the EPC market, confirming that the market is only at its infancy in Switzerland. EPC is never stated as the main activity within the active firms. These are instead primarily electricity providers (for 4 EPC providers), ESC providers (2 EPC providers), while some are gas provider, supplier of energy control and optimization and technical maintenance supplier. Out of the nine EPC providers, five firms are privately held with a major public shareholder, one is a public firm and three are private. Three ESCOs controlled by a public entity stated that the latter is exerting pressure to decrease their clients' energy consumption. These numbers can be compared with those for the non-EPC providers in Table 3.3. Note that only a minority of publicly controlled firms (28 %) are receiving pressure from the public owner to reduce energy consumption or increase energy efficiency of their clients.

**Table 3.3: Private vs. public firms**

EPC provider	public	Private with public major stakeholder	private	total
No	107 (54%)	36 (18%)	56 (28%)	199 (100%)
Yes	1 (11%)	5 (56%)	3 (33%)	9 (100%)
Total	108 (52%)	41 (20%)	59 (28%)	208 (100%)
	149 (72%)			
	<hr/> Pressure from the controlling public institution to increase energy efficiency of the clients (missing answers: 11)			
	No	Yes		
No	96 (73%)	36 (27%)	132 (100%)	
Yes	3 (50%)	3 (50%)	6 (100%)	
Total	99 (72%)	39 (28%)	138 (100%)	

A majority of firms (68 %) in the sample supply clients in only one canton. This probably stems from the companies not having yet taken advantage of the market liberalization which allows to target new clients beyond the cantonal border. 23 firms

(11 %) have clients in many cantons and 24 firms (12 %) cover the whole Swiss territory. A remaining 5 % are also active abroad.

Figure 3.2 compares the firms' size, in terms of employees, of EPC and ESC providers and in the whole sample. As compared to the whole sample, firms active in the EPC and ESC market are instead mostly medium to large size enterprises. This suggests that being present in these markets necessitates a sufficient size in terms of personnel capacity. The econometric analysis in the next section will test empirically whether larger firms are more likely to provide ESC and EPC.

While the sample appears to be representative in terms of sectors, there is currently no exhaustive statistics on the suppliers' composition of the energy market. Hence, it cannot be assessed whether the study sample is also representative in terms of size. The sample, with 92 % of small and medium enterprises (SMEs) with less than 250 employees, is however close to the population of firms in the Swiss market, where 99% of the firms are SMEs (OFS, 2017)

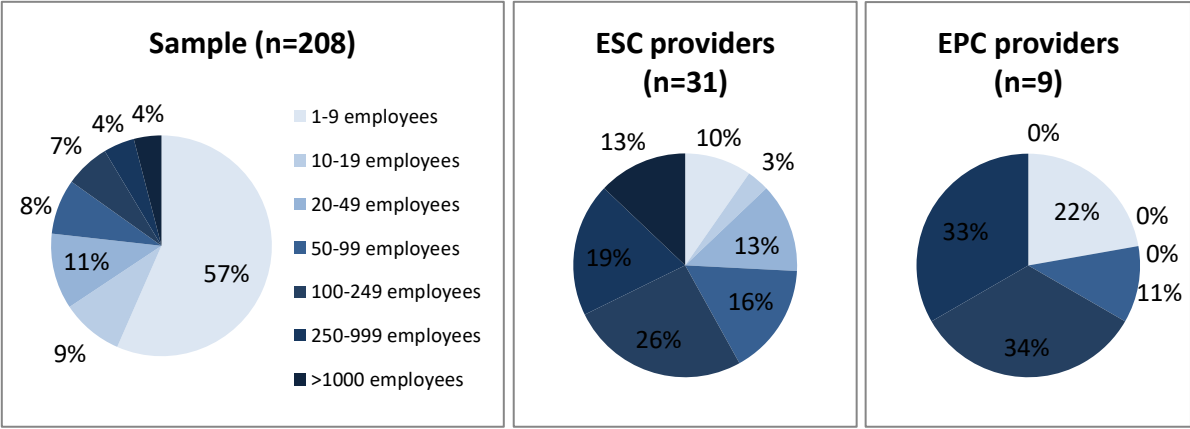


Figure 3.2 Number of employees

**4.3 Descriptive statistics of the choice experiment variables**

The choice experiment aims at analyzing how firms react to diverse shocks on the energy market. The willingness to consider offering EPC or ESC in each of the four choice tasks is presented in Table 3.4.

The share of respondents rejecting the contracts proposed (stating “no” or rather “no”) represent a large majority (varying from 68-75% across choice tasks). ESC is

however less often rejected than EPC. The results are consistent with the 140 (67 %) respondents stating to be (rather) not interested in providing EPC in the future as described in section 4.4. The choices do not vary much across choice tasks. Finally, the respondents do not consistently prefer EPC shared-savings over guaranteed-savings. This suggests that the choice between both schemes is more likely to be driven by the client's choice, or the context, than by the firm's preference.

**Table 3.4: Consideration to offer contracts**

	EPC shared-savings	EPC guaranteed-savings	ESC	All types of contracts
<b>Choice task 1</b>				
No	33 (29%)	45 (49%)	N/A	78 (38%)
Rather no	49 (44%)	27 (29%)	N/A	76 (37%)
Rather yes	24 (21%)	14 (15%)	N/A	38 (19%)
yes	6 (5%)	6 (7%)	N/A	12 (6%)
Total	112 (100%)	92 (100%)	N/A	204 (100%)
<b>Choice task 2</b>				
No	36 (35%)	40 (41%)	N/A	76 (38%)
Rather no	31 (30%)	36 (37%)	N/A	67 (34%)
Rather yes	29 (28%)	15 (15%)	N/A	44 (22%)
yes	6 (6%)	7 (7%)	N/A	13 (7%)
Total	102 (100%)	98 (100%)	N/A	200 (100%)
<b>Choice task 3</b>				
No	37 (38%)	32 (31%)	1 (50%)	70 (35%)
Rather no	34 (35%)	35 (34%)	0	69 (34%)
Rather yes	21 (22%)	27 (26%)	1 (50%)	49 (24%)
yes	5 (5%)	9 (9%)	0	14 (7%)
Total	97 (100%)	103 (100%)	2 (100%)	202 (100%)
<b>Choice task 4</b>				
No	0	N/A	82 (40%)	82 (40%)
Rather no	1 (50%)	N/A	57 (28%)	58 (28%)
Rather yes	1 (50%)	N/A	39 (19%)	40 (20%)
yes	0	N/A	25 (12%)	25 (12%)
Total	2 (100%)	N/A	203 (100%)	205 (100%)

Notes: In the main survey, the first 3 choice tasks are randomly assigned to EPC contracts (shared- or guaranteed savings) and the 4<sup>th</sup> choice task is assigned to ESC. The few ESC in choice task 3 (resp. EPC in choice task 4) are gathered in the pilot survey. The total number of respondents is smaller than 208 due to missing values in the contract variable. This is due to the fact that some respondents began to respond to the survey in the pilot and finished in the main survey. When this occurred, a technical problem resulted in missing values for the randomized contracts seen in the choice experiment, therefore excluding these choice tasks from the estimation. Also, in the pilot survey, some respondents are also proposed Integrated Energy Contracts (IEC), which is no longer the case in the main survey. These choice tasks were dropped from the main estimations.

The descriptive statistics of the hypothetical contexts and types of contracts proposed in the choice experiment data are presented in Table 3.5. The share represents the frequency at which each hypothetical context or contract's type was proposed to the respondents. In the regression, I include a two-way interaction term between private and public demand increase, so that the explanatory variables include three dummies:

1. Only public demand increases (private demand remains unchanged)
2. Only private demand increases (public demand remains unchanged)
3. Both public and private demand increase (public x private demand increase)

The empirical analysis based on the choice experiment will also control if the contract proposed in the choice experiment is already offered by the firm. This is the case in 7.2% of the choice tasks.

**Table 3.5: Descriptive statistics of attributes in the choice tasks**

Attributes (dummies)	share	N
<b>Hypothetical context</b>		
public demand increases	0.507	811
private demand increase	0.485	811
public increases (private unchanged)	0.238	811
private increases (public unchanged)	0.260	811
public x private demand increase	0.247	811
supply increase	0.502	811
liberalization	0.544	811
new taxation system (constitutional article)	0.520	811
<b>Contracts proposed</b>		
EPC shared-savings	0.386	811
EPC guaranteed-savings	0.361	811
ESC	0.253	811
<i>Contract already being offered</i>	0.072	811

#### 4.4 EPC supply in Switzerland

The market size of EPC is quite limited in Switzerland (see Klinke et al., 2017 for estimated number of actors and contracts signed). A majority of ESCOs have started providing EPC since 2012. This is in line with the recent emergence of the EPC market in Switzerland.

Out of the 199 firms which are inactive on the EPC market, 59 firms may be interested to provide EPC in the future. The main reason invoked by the 140 firms unwilling to enter the market is a lack of internal competencies and personnel capacity (58% of the firms). This result relates to the fact that many respondents represent small firms.<sup>123</sup> If these firms were convinced of the market potential for EPC, one solution for them to provide EPC would be to group their competencies or to opt for partial outsourcing.

Other respondents mention a lack of interest from clients (26%), a poor economic viability (25%) or a lack of energy savings (21%). This must however be contrasted by the fact that only five (4%) of the 140 firms not interested in EPC stated to have conducted a market analysis to confirm these conjectures. Lack of financing is also cited as a barrier for 23% of firms unwilling to enter the market, and risk is stated as too high for 9% of them. Finally, a minority of respondents cited inadequacy with the core business (10%), an objection from the company's management (6%) or no interest from the firm (2%). The latter barriers are structural and are therefore more difficult to overcome. The fact that they represent only a small minority of firms is however encouraging for the development of the EPC supply.

124 (62%) were not familiar with the EPC concept before answering the survey. This indicates that information campaigns on EPC could also be beneficial on the supply side. Table 3.6 shows a positive correlation between familiarity with the EPC concept and the stated consideration to provide such contracts in the future. While 44% of the firms familiar with EPC state to be potentially interested in providing EPC (Maybe and Yes), only 20.9% of the firms not familiar with the concept are interested in providing EPC. The relationship between the familiarity with the EPC concept and the

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<sup>123</sup> Indeed, 72 of the 81 respondents claiming a lack of internal competencies are part of firms with less than 50 employees.

willingness to offer EPC in the future will be further explored empirically in the next sections.<sup>124</sup> The stated consideration to provide EPC in the future is also used to check the robustness of the results based on the choice experiment, and especially to examine how the firms' characteristics affects the interest in providing EPC.<sup>125</sup>

**Table 3.6: Familiarity and consideration to provide EPC in the future**

Considering to provide EPC in the future	Familiar with the EPC concept		Total
	no	yes	
No	64 (51.6%)	17 (22.7%)	81 (40.7%)
Rather no	34 (27.4%)	25 (33.3%)	59 (29.6%)
Maybe	23 (18.5%)	24 (32.0%)	47 (23.6%)
Yes	3 (2.4%)	9 (12.0%)	12 (6.0%)
Total	124 (100%)	75 (100%)	199 (100%)

<sup>124</sup> In order to include both active ESCOs and potential entrants, the variable *familiar with EPC* will take the value 1 for active ESCOs.

<sup>125</sup> In order to include both active ESCOs and potential entrants, the variable *consideration to provide EPC* will take the value 3 (=yes) for active ESCOs.

#### 4.5 Plausibility of the hypothetical situations presented in the choice experiment

The respondents state their perceived credibility of the regulatory contexts presented in the choice experiment (Table 3.7).

**Table 3.7: Plausibility of the hypothetical situations**

	Not plausible	Hardly plausible	plausible	Very plausible	Don't know	Total
Increased public demand: publicly-owned buildings have to consider EPC/ESC						
	20 (10%)	49 (24%)	100 (49%)	16 (8%)	20 (10%)	205 (100%)
Increased private demand: EPC/ESC satisfies the universal convention of objectives						
	9 (4%)	48 (23%)	110 (54%)	18 (9%)	20 (10%)	205 (100%)
Increased supply: utilities forced to increase their clients' energy efficiency						
	33 (16%)	65 (32%)	68 (33%)	14 (7%)	25 (12%)	205 (100%)
Liberalization of the electricity market extended to small consumers						
	36 (18%)	70 (34%)	53 (26%)	16 (8%)	30 (15%)	205 (100%)
Subsidies will be replaced by fuel and electricity tax levies						
	28 (14%)	57 (28%)	75 (37%)	13 (6%)	32 (16%)	205 (100%)

The hypothetical situation perceived as the most plausible is an increase in the private demand for EPC and ESC due to a certification of EPC and ESC as satisfying the universal convention of objectives. The second most plausible situation is an increased of the public demand due to a federal obligation for collectivities to always consider EPC and ESC when retrofitting or investing in energy efficiency. The project of a constitutional article replacing subsidies with fuel and electricity tax levies is then considered plausible or very plausible by 43 % of the respondents. This legislation is

also the one implying the highest share of uncertainty (16 % of “don’t know”). The obligation for utilities to increase their clients’ energy efficiency, as in the White Certifications scheme, is considered plausible or very plausible by 40 % of the respondents. White Certificates scheme had already been rejected by the Swiss parliament at the time of the survey. The complete liberalization of the electricity market is considered as being the least plausible situation, with 52% of the respondents perceiving it as hardly plausible or not plausible. Regulatory contexts (liberalization and constitutional article) are the one associated with the least certainty according to the respondents (15 and 16% of “don’t know”). Using this information, I test whether these hypothetical situations have different impacts when considered as plausible by the respondents.

## 5 Estimation results

The results of the random effects ordered logit, based on the choice experiment data, are presented in Table 3.8.<sup>126</sup> Column (1) first shows the results when the dependent variable is the willingness to offer ESC or EPC. Column (2) focuses only on the choice to provide EPC, i.e. ignoring choice tasks with ESC. The last column adds another covariate, namely the fact that the public entity in charge of the firm exerts pressure for it to increase its clients' energy efficiency.<sup>127</sup>

A complete liberalization of the electricity market has no significant impact on the consideration to offer ESC or EPC. This may be explained by the fact that energy service contracting is targeted at larger consumers that are already part of the liberalized segment of the market. Therefore, energy service contracting may not be a response to the potentially increased competition for the market segment of small electricity consumers. Replacing subsidies by tax levies on fuels and electricity has no significant effect either. It may result from the difficulty for suppliers to foresee its concrete impacts on the market. Since this policy is only likely to be implemented in the second phase of the energy strategy 2050, if at all, respondents may not have evaluated its potential consequences when filling the survey.

An exogenous supply increase from utilities due to a White Certificates scheme affects positively the probability of offering EPC or ESC. Implementing such a policy on the supply side does not only affect utilities, but all the actors in the energy market. Indeed, an interaction term between a dummy variable equating one if the firm is a utility and the White Certificates dummy variable is not significant. *Ceteris paribus*, the odds of willing to offer energy service contracting<sup>128</sup> are around 1.5 greater if energy utilities increase their supply after an obligation to increase the energy efficiency of their clients.

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<sup>126</sup> Column (1) does not necessarily include 4 choice tasks by respondent and column (2) does not necessarily include 3 choice tasks per respondent. This is due to the fact that some respondents began to respond to the survey in the first pilot and finished in the main survey. When this occurred, a technical problem resulted in missing values for the randomized contracts seen in the choice experiment, therefore excluding these choice tasks from the estimation. Also, in the pilot survey, some respondents are proposed Integrated Energy Contracts (IEC), while this is no longer the case in the main survey. We therefore dropped these choice tasks from the main estimations.

<sup>127</sup> Controlling for public pressure also results in a decrease of the number of observations. This is why it is presented in a separated column

<sup>128</sup>Odds of answering yes vs. combined rather yes, rather no and no categories.

**Table 3.8: Determinants of ESC and EPC supply**

<b>Dependent variable: consider offering contract <i>j</i></b> <b>(4pts Likert scale)</b>						
Random effects ordered logit						
Attributes	ESC and EPC proposed		Only EPC proposed		Only EPC proposed	
	(1)	(2)	(1)	(2)	(3)	(3)
	coefficients	odds ratio	coefficients	odds ratio	coefficients	odds ratio
Public demand increases (private unchanged)	-0.000 (0.258)	1.000 (0.258)	0.039 (0.335)	1.04 (0.349)	0.177 (0.330)	1.193 (0.394)
Private demand increases (public unchanged)	-0.059 (0.268)	0.943 (0.252)	-0.132 (0.371)	0.877 (0.325)	-0.186 (0.384)	0.830 (0.319)
Public x private demands increase	0.391* (0.210)	1.479* (0.310)	0.453* (0.257)	1.573* (0.404)	0.491* (0.270)	1.634* (0.441)
Supply increase from utilities (White certificates)	0.394** (0.161)	1.482** (0.238)	0.530** (0.220)	1.699** (0.374)	0.462** (0.229)	1.587** (0.363)
Liberalization	-0.228 (0.200)	0.796 (0.159)	-0.258 (0.260)	0.773 (0.202)	-0.253 (0.278)	0.776 (0.216)
Taxation system	-0.077 (0.177)	0.926 (0.164)	-0.071 (0.217)	0.931 (0.202)	-0.076 (0.231)	0.927 (0.214)
Contract proposed =shared-savings	-0.110 (0.238)	0.895 (0.213)	0.056 (0.211)	1.057 (0.223)	0.087 (0.224)	1.091 (0.245)
Contract proposed =guaranteed-savings	-0.112 (0.280)	0.894 (0.250)	.	.	.	.
Contract proposed x contract already offered	2.189** (1.096)	8.928** (9.782)	.	.	.	.
<b>Firm's characteristics about current activities</b>						
Familiar with EPC	1.270** (0.639)	3.562** (2.276)	1.232* (0.678)	3.429* (2.326)	1.353** (0.684)	3.869** (2.647)
EPC provider	-1.663 (1.736)	0.190 (0.329)	2.296 (1.480)	0.662 (3.398)	1.939 (1.525)	0.939 (2.958)
ESC provider	0.741 (0.905)	2.098 (1.899)	0.640 (0.957)	1.897 (1.815)	0.561 (1.027)	1.753 (1.800)
Electricity provider	0.321 (0.690)	1.378 (0.952)	-0.130 (0.714)	0.878 (0.627)	-0.527 (0.748)	0.590 (0.442)
Gas provider	1.576** (0.781)	4.835** (3.774)	1.428* (0.797)	4.169* (3.323)	1.418* (0.770)	4.130* (3.181)
Heating systems provider	2.088** (1.033)	8.065** (8.330)	2.245** (1.104)	9.438** (10.421)	2.524** (1.110)	12.475** (13.847)
Appliances provider	-1.124 (1.192)	0.325 (0.387)	-0.844 (1.330)	0.430 (0.572)	-0.450 (1.323)	0.638 (0.844)
Energy control optimization provider	1.250 (0.873)	3.492 (3.048)	2.141** (0.886)	8.504** (7.534)	2.514*** (0.875)	12.349*** (10.809)
Facility management provider	1.070 (1.125)	2.916 (3.279)	0.795 (1.172)	2.215 (2.595)	0.894 (1.269)	2.445 (3.103)
Technical maintenance provider	-0.085 (0.892)	0.918 (0.818)	-0.112 (0.938)	0.894 (0.839)	-0.718 (0.922)	0.488 (0.450)
Engineering consulting	-0.368 (0.765)	0.692 (0.530)	-0.629 (0.816)	0.533 (0.435)	-0.988 (0.820)	0.372 (0.305)
Other energy efficiency services provider	1.142* (0.638)	3.131* (1.998)	1.268* (0.668)	3.554* (2.375)	0.660 (0.672)	1.935 (1.301)
Public direction pressure to improve clients' energy efficiency					1.753** (0.808)	5.773** (4.665)
<b>Cut-off point 1</b>	0.834 (0.865)		0.395 (0.944)		0.057 (0.986)	
<b>Cut-off point 2</b>	4.592 (0.939)		4.609 (1.054)		4.298 (1.077)	
<b>Cut-off point 3</b>	8.036 (1.047)		8.598 (1.232)		8.366 (1.234)	
<b>Observations</b>	811		591		769	
<b>Individuals</b>	208		200		197	
<b>Log pseudo likelihood</b>	-713.295		-541.534		-676.678	
<b>AIC</b>	1,476.591		1,129.067		1,405.356	
<b>BIC</b>	1,594.048		1,230.43		1,526.129	

Notes: 4-points Likert scale of the dependent variable are: 0 "no", 1 "rather no", 2 "rather yes", 3 "yes". Robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Baseline contract is ESC in column (1) and EPC guaranteed-savings in column (2). *contract x already offered* means the firm is already proposing this type of contract (equivalent to EPC provider for columns 2 and 3). The question was in this case: "Would you consider offering this contract more often than currently given this hypothetical situation?". All estimations are performed with 36 integration points: The quality of the quadrature approximation of the integrated likelihood function was examined by changing the number of integration points. Because the default of 12 integration points was not sufficiently accurate (the relative differences in the estimates with 8 or 16 integration points were larger than 1% for some estimates), I increased the number to 36 points, which resulted in more robust estimates.

A hypothetical exogenous increase in demand covering both the public and private sectors has a significant positive impact on the willingness of potential providers to consider ESC or EPC. The impact is slightly lower than that associated with White certificates, but the odds ratio is still around 1.5. However, an increase of only one of these sectors (private or public) is not sufficient to have an impact. This result may suggest that entering the energy service contracting market represents an important up-front investment.

Column (1) also shows that there is no preference for EPC schemes (guaranteed or shared-savings) over ESC. Similarly, shared-savings is not preferred to guaranteed-savings, as can be seen in column (2). This suggests that the potentially active ESCOs are quite flexible regarding financing and contracting schemes. In general, the hypothetical shocks have similar impacts on the supply of both ESC and EPC, which may suggest that these two markets are related.

A dummy variable *contract x already offered* captures the fact that some firms were already offering the type of contract proposed. In this case, the respondent is asked whether her firm would consider offering the contract more often than is currently the case, given the hypothetical situation. In column (1), where both ESC and EPC contracts are proposed, the coefficient on this variable is significant and positive, suggesting that active firms would be willing to offer the contracts more often than they currently do. However, when considering only EPC contracts, the active ESCOs (captured in the variable *EPC provider*) do not consider offering the contracts more often than the suppliers inactive in EPC. This suggests that regardless of the hypothetical situation, current ESCOs may not be able to offer EPC more often.

The results show a positive relationship between the respondent's familiarity with the EPC concept and the consideration to offer these contracts (as well as ESC). The odds are around 3.5 greater when the respondent is familiar. Although this variable may suffer from endogeneity due to reverse causality, it may suggest that information campaigns may be needed on the supply side of the EPC market.

A series of dummies for the activities already offered by the firm were used as control, resulting in the following findings: Gas suppliers, and to a larger extent heating

system providers, are more inclined to offer both ESC and EPC. Firms offering energy control and optimization appliances are also more likely to consider offering EPC (columns 2 and 3).

Several other firms' characteristics have been tested but did not show any significant impact. This is the case for the location of the firm's clients (one or several cantons, whole of Switzerland and/or abroad). The number of employees (as a proxy for the firm's size) has no significant influence either. This contrasts with the descriptive statistics showing that early active ESCOs are rather large firms, which thus confirms the necessity to have sufficient personnel capacities in order to be an early entrant in a market such as the EPC market. Being a private or a public firm does not impact the consideration of providing EPC or ESC either. However, if the respondent stated that the public entity in charge of the organization exerts pressure to increase the energy efficiency of its clients, then the firm is more likely to consider providing EPC or ESC, as shown in column (3). This result suggests that a solution to foster EPC supply would be to inform the public entities in charge of these companies.

## **5.1 Robustness checks**

One of the limitations of this study relies on the choices and regulatory contexts being hypothetical. I control for the plausibility of the hypothetical situations presented as perceived by the respondents (cf. appendix 7.3). The situations attributes are interacted with dummies equating 1 if the respondent perceived the situation as being plausible or rather plausible. While some coefficients gained in magnitudes and/or in significance, controlling for the perceived plausibility of the policy-driven shocks does not affect the overall results described above.

Another shortcoming of this study lies in the fact that the mix of incumbent and non-active suppliers results in a dependent variable which has a different meaning for these two groups. Indeed, for respondents who are already offering these types of contracts, they were asked whether they would be willing to offer these more frequently given the particular context proposed. On the other hand, inactive firms were asked whether they would consider offering these contracts in the stated situation. In order to account for the difference in the outcome variable, I run two

separated regressions depending on the outcome variable. The results are presented in appendix 7.5. For firms inactive in the energy service contracting market, the results are confirmed, i.e. only the White Certificates and a combined increase in the public and private demands have an impact on the supply. However for firms already on the ESCO market, the results change: no energy policy has an impact when both ESC and EPC are proposed. When focusing on EPC only, the actors seem more reactive to the changes in the regulatory contexts. Nevertheless, the results of the regressions including only active firms should be interpreted cautiously due to the small samples (58 observations with ESC and EPC proposed and 27 observations with EPC proposed).

The random effects ordered logit provides a likelihood-ratio test showing a sufficient variability between the respondents to favor a random-effects model<sup>129</sup>, as opposed to a standard ordered logit model, which would ignore that several choice tasks correspond to the same individual. The ordered logit is also preferred to a logit regression as it would mean losing some preferences information by transforming the 4-points Likert scale into a binary variable.

The random effects model however assumes uncorrelated effects. I thus relax this assumption by using a conditional logit model (cf. appendix 7.4). In order to do so, the 4 points Likert-scale was transformed in a binary variable (equal to 1 if yes or rather yes and 0 if no or rather no). This comes at the cost of losing the individuals for whom the only variations occurred between yes and rather yes (resp. no and rather no). Also, in such a conditional logit, all firm's specific characteristics are omitted. In this model, only the energy utilities' supply increase (White Certificates) keeps its significant positive impact. But this is likely to be due to the critical decrease in the number of observations (147 individuals corresponding to 567 observations dropped and 61 individuals, respectively 244 observations, remaining). Another alternative to relax the assumption of uncorrelated effects is the blow-up and cluster (BUC) method suggested by Baetschmann et al. (2015) (cf. appendix 7.4). It consists in using conditional logit model with 3 observations per individual, each time considering

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<sup>129</sup> The likelihood-ratio test of xtologit vs. ologit model shows a Chi-bar squared of 297.53 when considering only EPC (resp. 455.19 when considering both ESC and EPC) and a p-value of 0.000.

another cut-off<sup>130</sup> to determine the binary dependent variable. The sample is clustered by individuals. This avoids the important decrease in the number of observations. Using this method validates the results presented in the previous section.

I then checked the ordered logit parallel lines assumption at the 0.05 level of significance in the regression model with ESC and EPC. All the variables meet this assumption except for the variables *contract proposed is shared savings*, *EPC provider* and *heating systems provider*. The results of the generalized ordered logit model, in which the constraints for parallel lines are not imposed for these three variables, are presented in appendix 7.6. It is compared to the standard ordered logit model without random effects, in which the constraints for parallel lines are imposed for all parameters. The main empirical conclusions remain unaltered, i.e a positive impact associated with a White Certificates scheme and with an increase in both public and private demands. Relaxing the assumption of parallel lines for the three variables suggests a reticence to offer shared-savings EPC. Indeed, the coefficient is significantly positive at the cut-point no (vs. rather no, rather yes and yes) and significantly negative at the cut-point yes (vs. no, rather no, rather yes). The generalized ordered logit results also suggest that EPC providers are less likely to reject a contract with a “no” and appliances providers are less likely to accept a contract with a “yes” answer.

I also checked the robustness of the firms’ characteristics in affecting the choice to enter the EPC market. In order to do so, I used the firm’s stated intention to propose EPC in the future. This question is asked in part 2 of the survey and the answer is a 4 point Likert scale. The choices are analyzed using an ordered logit model. Already active ESCOs are considered as confirmed entrants. The results are provided in appendix 7.7 and are similar to those found with the choice experiment, except for the following elements. First, being familiar with the EPC concept becomes insignificant once I add the control for the public direction pressure to increase the energy efficiency of the clients.<sup>131</sup> Second, unlike the baseline results, providing ESC

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<sup>130</sup> 3 observations per individual with 3 different dependent variables per individual, one binary dependent variable with the cut-off between no and rather no, one between rather no and rather yes and one between rather yes and yes.

<sup>131</sup> This is likely to be due to the correlation between these two variables. When there is a public entity exerting pressure, the firm is not only more likely to be willing to provide EPC but also more likely to be aware of the existence of this instrument.

significantly and positively affects the decision to enter the EPC market, suggesting ESC to work as a complement to EPC. I again tested other firm's characteristics, such as the number of employees, the fact of being a private or a public firm and the location of the firm's clients. These factors had no significant impact on the decision.

While this research is focusing on how energy policies would affect the provision of energy service contracting, further research will be needed in order to understand how the contractual schemes, such as the degree of risk taken by the supplier, might affect the firms' decisions. Such an analysis could also consider how the project's duration, the costs and the number of actors involved affects the willingness to offer these contracts.

## **6 Discussion and conclusions**

This study aims at exploring how the supply-side of the ESCO market may evolve, and how the regulatory context affects the firm's business decisions regarding the supply of EPC and ESC. The analysis is based on a survey and a choice experiment addressed to 208 active and potential suppliers of energy service contracting, including energy utilities, gas providers, engineering offices as well as appliances and heating systems suppliers.

The empirical analyses show that a complete liberalization of the electricity market does not affect the willingness to provide energy service contracting. A first explanation could be a lack of attention from the respondents or heterogeneity across respondents. This may also be due to the fact that these contracting schemes are not targeted at small energy consumers, who are concerned by such a hypothetical liberalization. The replacement of subsidies with taxes on fuels and electricity does not affect the willingness to offer energy service contracting either. Again, this may come from inattention or heterogeneity. Another explanation could be that the respondents may fail to foresee the impact of such a policy. This may also reflect inertia from suppliers who fail to adapt their business model to the new regulatory context.

Increased competition on the ESCO market may still be induced by an exogenous increase in the supply originating from utilities. In the choice experiment, this

hypothetical context is presented as being the consequence of a new regulation forcing the energy utilities to increase the energy efficiency of their clients. Such a policy can be considered similar to a White Certificates scheme, as implemented in several European countries. This affects the willingness to enter the market from both utilities and non-utilities, suggesting that the resulting competition would concern the major part of the energy market players.

A demand shock can also affect the supply of energy services. It is nevertheless the case only if both private and public demands rise together. This result may suggest that an important upfront investment is necessary to enter the market. The latter conjecture is confirmed by firms answering in the survey that they are unwilling to enter the EPC market primarily because of a lack of both internal competencies and personnel capacity. Vocational training on the design, risk assessment, elaboration and operation of energy service contracts may be useful. Furthermore, in the current Swiss context in which EPC remains a market niche, strategic collaboration between the market stakeholders appears to be primordial.

Certain firms are more reactive to market developments, namely gas suppliers, heating systems or energy control and optimization systems providers. On the other hand, the project's size, its location or being a public firm does not significantly affect the willingness to provide energy service contracting. However, I show that firms controlled by a public entity exerting pressure to increase energy efficiency of the clients, increases the likelihood to offer energy service contracting. This provides another lead to foster the ESCO market, i.e. increasing awareness among public entities in charge of utilities. The motivations of firms are likely to differ substantially based on their core business. This point should be examined in further research.

While a large majority of the existing research focuses on the demand side, the supply side of the energy market is rarely considered. The exceptions are studies exploring how policies and competition affect prices or technical innovation. Further research is therefore needed in order to better understand the provision of energy services and business model innovation. The literature on energy service contracting could also gain further understanding by focusing on the supply side, and especially

on firms that are not yet active in the market. I show for instance that the concept of EPC was unknown to 62% of the respondents in this sample of firms. This share is higher than that on the demand side (cf. Chapter 2). Changing the focus may not only facilitate the implementation of projects involving energy efficiency or renewable energy projects. It may also unlock important business opportunities and market innovations that will support environmental policies in a new way.

## 7 Appendix

### 7.1 Letter of invitation to the survey



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Zürich, le 25.1.2016

Institut  
Name Vorname  
Strasse Nr.  
PLZ Stadt/Dorf

#### Enquête 2016 sur l'efficacité énergétique: Votre participation compte

Chère Madame, cher Monsieur,  
Pour améliorer l'efficacité énergétique des bâtiments existants, des outils tels que les contrats de performance énergétique (CPE) existent et ont déjà été mis en place avec succès dans plusieurs pays.

Afin de connaître sous quelles conditions le potentiel des CPE peut également être exploité en Suisse, l'Office fédéral de l'énergie (OFEN) a chargé l'Université de Neuchâtel et TEP Energy de réaliser une enquête. Nous menons, entre autres investigations, un sondage auprès des fournisseurs potentiels de CPE. Nous estimons que votre entreprise en fait partie et par conséquent, nous vous invitons à participer à notre sondage.

Remplir le questionnaire devrait vous prendre environ 20 minutes.

Nous vous serions reconnaissants de participer à l'enquête même si vous pensez que votre entreprise n'est pas concernée par ce genre de contrat ou même si vous ne connaissez pas encore le concept des CPE. Des informations complémentaires sont fournies directement dans le questionnaire.

Vous pouvez accéder au questionnaire en saisissant l'adresse suivante dans votre navigateur web:

<https://TO BE CHANGED>

Votre mot de passe est: W364VD

Les informations que vous nous communiquerez seront traitées de manière confidentielle et aucune donnée personnelle ne sera publiée. Vous pouvez adresser vos questions concernant le contenu et la réalisation de l'enquête à [sandra.klinke@unine.ch](mailto:sandra.klinke@unine.ch).

En vous remerciant d'avance de votre précieuse collaboration, nous vous adressons, chère Madame, cher Monsieur, nos salutations distinguées.

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## 7.2 Survey structure

The survey is composed of five main parts:

- Part 1: General questions on the firm
- Part 2: Questions regarding the current relation with EPC
- Part 3: Choice experiment
- Part 4: Credibility of hypothetical situations
- Part 5: Contact details and end of the survey

The survey creation software Sawtooth is used to prepare and host the survey online.

### a) *General questions on the firm*

The first part of the survey includes introductory questions aimed at gathering a general picture about the firm, its products and services provided. The first part also questions the presence of a public institution in the direction or in the stockholders, and if so its impact on strategies to improve energy efficiency of its clients. Information on the regions of activities as well as the number of employees is also collected in this first part.

### b) *Firms' experience of EPC*

In the second part of the survey, the respondents are directed towards different sets of questions depending on their background and experience with respect to EPC (see illustration in the next Figure). The respondents are split into two categories.

On the one hand, the respondents who state that their firm is already offering EPC in Switzerland are directed towards questions on their experience and activities related to EPC. On the other hand, respondents stating no current EPC activities are directed towards the definition of the concept and asked whether their firm could envisage offering those services in the future.

Both ESCOs active on the EPC market (i.e. already trying to offer EPC in Switzerland) and those who state a potential willingness to enter that market in the future are then directed to seven questions intended to capture the business model implemented or envisaged.

All the firms inactive on the EPC market are asked about services related to energy efficiency (other than EPC and ESC) they are already providing to their clients.

*c) Choice experiment*

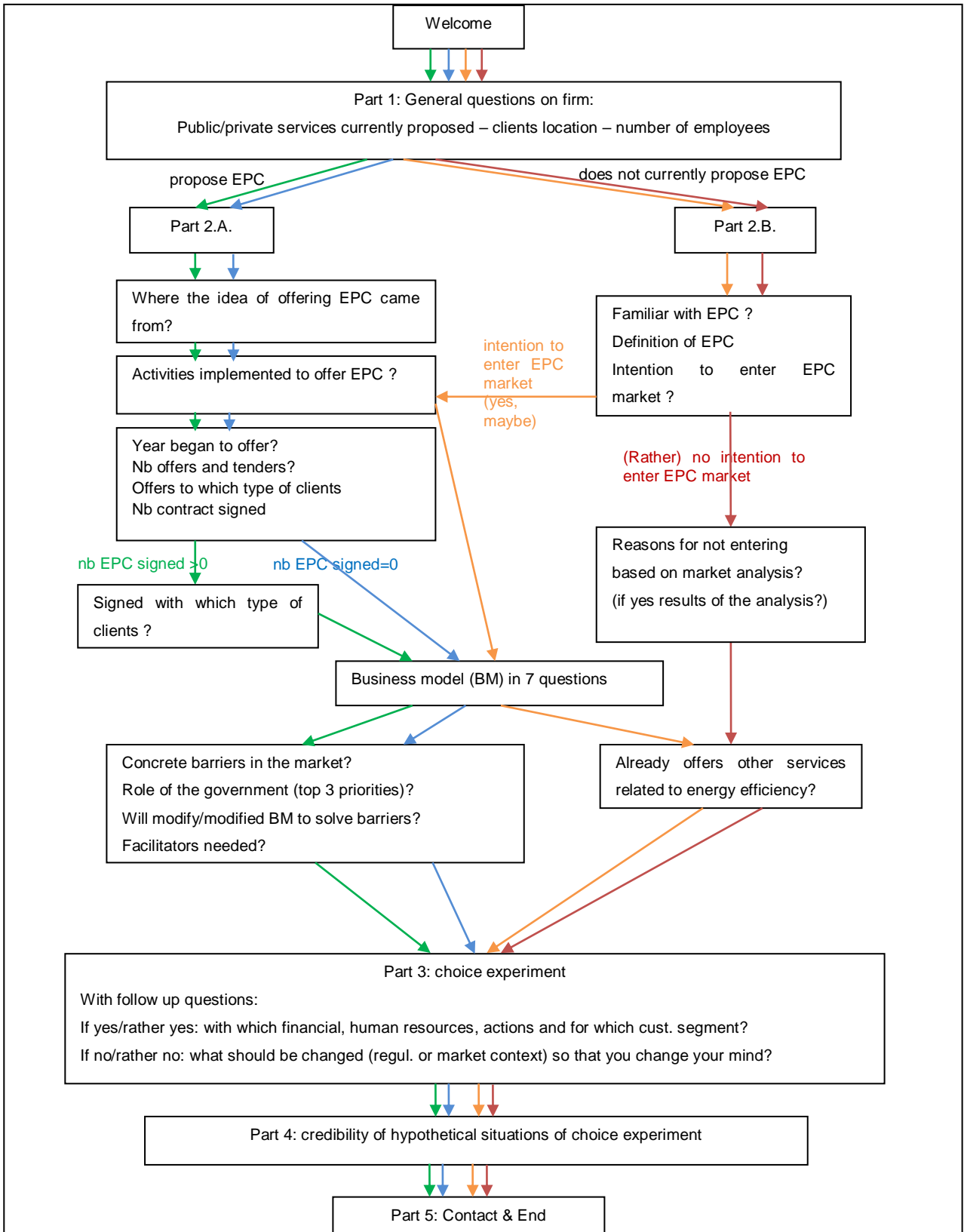
All respondents are then directed to a choice experiment, which is described in section 3.1.2.

*d) Credibility of hypothetical situations*

The survey then assesses the perceived credibility of each hypothetical changes proposed in the choice experiment by using a 4 point Likert scale (very plausible to not plausible at all).

*e) Contact and end*

Finally, the respondents are asked if they desire to obtain the results of the study, and if so are requested to provide contact information. They can provide remarks on the survey and are thanked for completed the survey.



Notes: green arrows describe active ESCOs with signed contracts, blue are active ESCOs without any contracts signed, red are firms unwilling to provide EPC and orange are potential future entrants.

### 7.3 Controlling for perceived plausibility

**Table 3.9: Controlling for perceived plausibility-potential suppliers choices**

Dependent variable: consider offering contract <i>j</i> (4pts Likert scale)		random effects ordered logit	
<b>Attributes</b>	both ESC and EPC proposed (1)	only EPC proposed (2)	
Public demand increases (private unchanged) x (rather) plausible	0.167 (0.297)	0.552 (0.403)	
Private demand increases (public unchanged) x (rather) plausible	0.006 (0.318)	0.101 (0.391)	
Public x private demands increase x (rather) plausible	0.527* (0.279)	0.649* (0.333)	
Supply increase x (rather) plausible	0.678*** (0.244)	1.050*** (0.306)	
Liberalization x (rather) plausible	-0.212 (0.293)	0.081 (0.292)	
Taxation system x (rather) plausible	0.075 (0.257)	0.042 (0.280)	
Contract=shared-savings	-0.087 (0.225)	0.057 (0.203)	
Contract=guaranteed-savings	-0.080 (0.252)	.	
Contract x already offered	2.071* (1.100)	.	
<b>Firm's characteristics</b>			
Familiar with EPC	1.236** (0.628)	1.136* (0.642)	
EPC provider	-1.793 (1.737)	0.541 (1.390)	
ESC provider	0.854 (0.897)	0.778 (0.935)	
Energy efficiency services provider (other than EPC)	1.086* (0.626)	1.140* (0.637)	
Electricity provider	0.395 (0.677)	-0.029 (0.674)	
Gas provider	1.539** (0.764)	1.453* (0.757)	
Heating systems provider	1.984* (1.016)	2.009* (1.048)	
Appliances provider	-1.020 (1.173)	-0.684 (1.276)	
Energy control optimization provider	1.256 (0.860)	2.184** (0.854)	
Facility management provider	1.096 (1.129)	0.911 (1.135)	
Technical maintenance provider	0.022 (0.878)	-0.040 (0.889)	
Engineering consulting	-0.362 (0.753)	-0.635 (0.782)	
Cut-off point 1	0.978	0.629	
Cut.off point 2	4.710	4.759	
Cut-off point 3	8.137	8.701	
Observations	811	606	
Individuals	208	205	
Log pseudolikelihood	-712.714	-539.290	
AIC	1,475.429	1,124.581	
BIC	1,592.886	1,225.939	

Notes: Robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Baseline contract is ESC in column (1) and EPC guaranteed-savings in column (2). Both estimations are performed with 36 integration points. All contextual attributes are interacted with a dummy equating one if the attribute is considered as plausible or rather plausible by the respondent.

## 7.4 Conditional logit (chap. IV)

**Table 3.10: Conditional logit-Blow-Up and Cluster estimator**

Dependent variable: consider offering contract <i>j</i> (binary variable)	Conditional logit		Conditional logit	
	(binary variable 0=no or rather no, 1=yes or rather yes)		Blow-Up and Cluster (BUC) estimator (binary variable with changing cut-off)	
	both ESC and EPC proposed	only EPC proposed	both ESC and EPC proposed	only EPC proposed
<b>Attributes</b>	(1)	(2)	(1)	(2)
Public demand increases (private unchanged)	-0.508 (0.464)	-0.616 (0.644)	-0.166 (0.363)	0.108 (0.519)
Private demand increases (public unchanged)	0.119 (0.499)	0.510 (0.584)	0.259 (0.388)	0.205 (0.482)
Public x private demands increase	0.292 (0.394)	0.392 (0.432)	0.634** (0.293)	0.722** (0.347)
Supply increase	0.658** (0.270)	0.785** (0.391)	0.583** (0.227)	0.690** (0.301)
Liberalization	-0.376 (0.352)	-0.316 (0.432)	-0.124 (0.287)	-0.300 (0.350)
Taxation system	0.100 (0.270)	0.022 (0.335)	-0.143 (0.229)	-0.139 (0.282)
Contract=shared-savings	-0.423 (0.419)	0.399 (0.397)	-0.336 (0.335)	0.008 (0.282)
Contract=guaranteed-savings	-0.713 (0.525)	.	-0.296 (0.391)	.
Contract x already offered	0.556 (0.767)	.	1.531** (0.730)	.
Observations	244	138	513	282
Individuals	61	46	89	73
log pseudo-likelihood	-90.240	-50.536	-174.629	-93.628
AIC	184.226	104.493	367.257	201.257
BIC	215.700	124.984	405.420	226.750

Notes: Robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Baseline contract is ESC in column (1) and EPC guar-savings in column (2). Blow-Up and Cluster estimator as suggested by Baetschmann et al. (2015).

## 7.5 Separated regressions for active and non-active

**Table 3.11: separated regressions for active and non-active suppliers**

Dependent variable (4pts Likert scale)	Random effects ordered logit			
	ESC and EPC proposed		Only EPC proposed	
	(1)		(2)	
Attributes				
Dependent variable: offer contract <i>j</i>	For the first time	more often than currently	For the first time	more often than currently
Public demand increases (private unchanged)	-0.134 (0.286)	0.431 (1.096)	-0.138 (0.360)	6.894*** (1.773)
Private demand increases (public unchanged)	-0.168 (0.280)	0.679 (1.076)	-0.175 (0.389)	-0.318 (3.088)
Public x private demands increase	0.407* (0.236)	-0.135 (1.052)	0.480* (0.265)	1.164 (1.788)
Supply increase from utilities (White certificates)	0.506*** (0.173)	0.340 (0.569)	0.601** (0.234)	-1.560** (0.662)
Liberalization	-0.244 (0.216)	-0.244 (0.747)	-0.101 (0.281)	-5.249*** (1.443)
Taxation system	-0.109 (0.197)	-0.266 (0.595)	-0.016 (0.230)	2.187* (1.117)
Contract proposed =shared-savings	-0.220 (0.267)	-0.439 (0.789)	0.128 (0.222)	-2.139 (1.751)
Contract proposed =guaranteed-savings	-0.262 (0.308)	0.287 (0.805)		
<b>Firm's characteristics about current activities</b>				
Familiar with EPC	1.212* (0.686)	1.660 (1.701)	1.254* (0.700)	
EPC provider	-35.925*** (2.625)	-1.280 (1.832)		
ESC provider	0.251 (1.072)	0.707 (3.012)	0.380 (1.100)	11.359*** (4.255)
Electricity provider	0.888 (0.801)	0.487 (1.326)	0.426 (0.797)	-7.749*** (2.948)
Gas provider	2.231** (0.890)	-2.081 (1.603)	1.897** (0.884)	
Heating systems provider	2.818** (1.280)	1.365 (1.702)	2.634** (1.321)	
Appliances provider	-0.441 (1.429)	-2.883** (1.159)	-0.184 (1.460)	-6.627** (3.061)
Energy control optimization provider	1.111 (0.941)	-0.497 (2.103)	1.813** (0.910)	4.626** (2.126)
Facility management provider	1.121 (1.360)	-1.110 (2.494)	1.054 (1.366)	-9.368** (3.788)
Technical maintenance provider	0.052 (0.985)	1.504 (1.393)	0.112 (1.000)	
Engineering consulting	-0.309 (0.890)	-0.952 (1.702)	-0.601 (0.921)	1.500 (2.862)
Other energy efficiency services provider	1.428* (0.738)	-0.082 (1.775)	1.488** (0.744)	7.196** (3.062)
<b>Cut-off point 1</b>	1.303	-2.994	1.148	4.494**
<b>Cut-off point 2</b>	5.430***	-1.249	5.601***	6.827**
<b>Cut-off point 3</b>	9.368***	1.215	9.868***	11.199***
<b>Observations</b>	753	58	579	27
<b>Individuals</b>	199	32	196	9
<b>Log pseudo likelihood</b>	-625.883	-63.743	-501.834	-18.245

Notes: 4-points Likert scale of the dependent variable are: 0 "no", 1 "rather no", 2 "rather yes", 3 "yes". Robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Baseline contract is ESC in column (1) and EPC guaranteed-savings in column (2). All estimations are performed with 36 integration points. Variables omitted because of colinearity in the last column.

## 7.6 Generalized ordered logit model

Table 3.12: Ordered logit vs. generalized ordered logit model

<b>Dependent variable: consider offering contract <i>j</i></b> <b>(4pts Likert scale)</b>					
<b>ESC and EPC proposed</b>	Standard ordered logit (parallel lines imposed)	Generalized ordered logit (parallel lines not imposed for the variables not satisfying the assumption)			
	(1)	(2)	No	Rather no	Rather yes
Public demand increases (private unchanged)	0.019 (0.158)	0.035 (0.157)	0.035 (0.157)	0.035 (0.157)	0.035 (0.157)
Private demand increases (public unchanged)	-0.010 (0.162)	0.006 (0.168)	0.006 (0.168)	0.006 (0.168)	0.006 (0.168)
Public x private demands increase	0.217** (0.104)	0.238** (0.107)	0.238** (0.107)	0.238** (0.107)	0.238** (0.107)
Supply increase from utilities (White certificates)	0.217*** (0.076)	0.227*** (0.078)	0.227*** (0.078)	0.227*** (0.078)	0.227*** (0.078)
Liberalization	-0.096 (0.135)	-0.076 (0.138)	-0.076 (0.138)	-0.076 (0.138)	-0.076 (0.138)
Taxation system	-0.045 (0.093)	-0.052 (0.094)	-0.052 (0.094)	-0.052 (0.094)	-0.052 (0.094)
<b>Contract proposed</b>	0.113 (0.123)	<b>0.310**</b> <b>(0.140)</b>	<b>-0.010</b> <b>(0.141)</b>	<b>-0.609**</b> <b>(0.269)</b>	<b>-0.609**</b> <b>(0.269)</b>
<b>=shared-savings</b>					
Contract proposed =guaranteed-savings	-0.082 (0.146)	-0.073 (0.143)	-0.073 (0.143)	-0.073 (0.143)	-0.073 (0.143)
Contract proposed x contract already offered	1.558*** (0.597)	1.343** (0.600)	1.343** (0.600)	1.343** (0.600)	1.343** (0.600)
<b>Firm's characteristics about current activities</b>					
Familiar with EPC	0.482* (0.252)	0.484* (0.254)	0.484* (0.254)	0.484* (0.254)	0.484* (0.254)
<b>EPC provider</b>	-1.103 (0.923)	<b>-1.774*</b> <b>(1.021)</b>	<b>-0.597</b> <b>(0.978)</b>	<b>-1.007</b> <b>(0.776)</b>	<b>-1.007</b> <b>(0.776)</b>
ESC provider	0.187 (0.414)	0.206 (0.432)	0.206 (0.432)	0.206 (0.432)	0.206 (0.432)
Electricity provider	0.123 (0.289)	0.131 (0.290)	0.131 (0.290)	0.131 (0.290)	0.131 (0.290)
Gas provider	0.675* (0.347)	0.670* (0.347)	0.670* (0.347)	0.670* (0.347)	0.670* (0.347)
Heating systems provider	0.957* (0.508)	0.972* (0.521)	0.972* (0.521)	0.972* (0.521)	0.972* (0.521)
<b>Appliances provider</b>	-0.535 (0.557)	<b>0.251</b> <b>(0.943)</b>	<b>-0.743</b> <b>(0.681)</b>	<b>-13.867***</b> <b>(0.524)</b>	<b>-13.867***</b> <b>(0.524)</b>
Energy control optimization provider	0.695 (0.425)	0.752* (0.447)	0.752* (0.447)	0.752* (0.447)	0.752* (0.447)
Facility management provider	0.551 (0.500)	0.538 (0.944)	0.538 (0.944)	0.538 (0.944)	0.538 (0.944)
Technical maintenance provider	-0.047 (0.423)	-0.113 (0.439)	-0.113 (0.439)	-0.113 (0.439)	-0.113 (0.439)
Engineering consulting	-0.128 (0.326)	-0.109 (0.322)	-0.109 (0.322)	-0.109 (0.322)	-0.109 (0.322)
Other energy efficiency services provider	0.454* (0.266)	0.473* (0.265)	0.473* (0.265)	0.473* (0.265)	0.473* (0.265)
<b>Observations</b>	811		811		
<b>Individuals</b>	208		208		
<b>Log pseudo likelihood</b>	-940.892		-927.723		

Notes: 4-points Likert scale of the dependent variable are: 0 "no", 1 "rather no", 2 "rather yes", 3 "yes". Individual clustered standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Parallel lines assumption using the 0.05 level of significance is satisfied for all variables except those in bold. Baseline contract is ESC. *contract x already offered* means the firm is already proposing this type of contract. The question was in this case: "Would you consider offering this contract more often than currently given this hypothetical situation?"

## 7.7 Ordered logit with willingness to enter the EPC market

**Table 3.13: Potential supplier's choice to enter the EPC market**

Dependent variable: entering the EPC market (4pts Likert scale)		ordered logit	
<b>Firm's characteristics</b>	(1)	(2)	
Familiar with EPC	0.506* (0.270)	0.468 (0.297)	
ESC provider	0.799 (0.500)	0.836 (0.538)	
Energy efficiency services provider (other than EPC)	0.409 (0.317)	0.283 (0.326)	
Electricity provider	-0.151 (0.369)	-0.200 (0.389)	
Gas provider	0.750** (0.366)	0.688* (0.363)	
Heating systems provider	1.386*** (0.590)	1.613*** (0.618)	
Appliances provider	-0.070 (0.483)	-0.080 (0.542)	
Energy control optimization provider	1.327*** (0.481)	1.378*** (0.502)	
Facility management provider	0.101 (0.804)	-0.030 (0.930)	
Technical maintenance provider	0.042 (0.391)	-0.040 (0.418)	
Engineering consulting	-0.079 (0.378)	-0.179 (0.402)	
Public direction pressure to increase clients' energy efficiency		0.892** (0.359)	
Cut-off point 1	0.148 (0.419)	0.185 (0.437)	
Cut-off point 2	1.600 (0.438)	1.635 (0.458)	
Cut-off point 3	3.604 (0.517)	3.666 (0.561)	
Observations (=individuals)	234	220	
Log pseudo-likelihood	-261.319	-242.140	
AIC	552.638	516.281	
BIC	604.468	570.579	

Notes: Robust standard errors in parentheses. \*\*\*P<0.01, \*\*P>0.05, \*P<0.1. Dependent variable: Does your firm intend, in the future, to propose energy performance contracting to its clients? 0 (no) 1 (rather no) 2 (maybe) 3 (yes). Replaced by 3 if already active in the EPC market.

# Conclusion and further research

The literature on energy contracting is wide and has benefitted from the contribution of experts coming from many fields. Existing research provides insights into the evolution of the ESCO markets around the world and the potential driving forces and barriers to the deployment of a sustainable contracting market.

By exploring the determinants of adoption of energy service contracting, the academic contribution of my PhD thesis consists in analyzing how the economics of outsourcing decision applies in the context of energy. The results show that the risk-sharing mechanism dominates, while the financing advantage of energy service contracting is positively valued only by a minority of potential clients. The results on the importance of the risk sharing mechanism not only show the potentials of energy service contracting, it also suggests that risk may be an important determinant in the customer's choice to invest in renewable energy or energy efficiency. This study also provides insights into the complexity and heterogeneity underlying the decision to invest in energy efficiency. Finally, by focusing on the supply side, it also contributes to the analyses of the market and business model innovation in the energy sector.

Yet, my research also shows that further research is needed in this domain. My thesis focuses on the economic perspective in a narrow sense by considering transaction costs economics, risk sharing and economies of scale. Further research in the domain should enlarge the scope to account for the organizational behavior involved in the decision to adopt energy service contracting, especially in the case of institutions or firms (see for instance Cooremans, 2012). This would also permit to explore the role of behaviors that differ from the neoclassical economic theory or from financial considerations and how they could be exploited. Future studies should better account for the investments categories, such as the level of risk, the number of actors involved, the incentives or the scope of the investment with respect to the core business. These should be analyzed by considering specific types of firms and institutions. The decision mechanisms should not only be explored from a profitability point of view but also in terms of the firm's strategy, i.e. related to the potential of increasing the competitiveness of the core business.

A second important area of research related to energy service contracting follows from the results of my study. If risk sharing is indeed an important determinant of adoption of energy service contracting, one should further study the implications in terms of moral hazard and adverse selection. The ESCO market may indeed be considered as an insurance market subject to similar problems of market inefficiency. If this problem is indeed prevalent, then policy intervention could be warranted in order to foster renewable and energy efficiency investments, for instance by increasing the standards or opting for stringent regulations.

The impact of the technologies may also be further explored since they are likely to involve different technological and financial risks, different levels of profitability and different kind of non-financial benefits.

Other questions are left unanswered and could be explored in further research. For instance, can energy service contracting induce investment in energy efficiency or renewable energy, and if so, through which mechanisms? Are there other business models that could reduce the risk of energy efficiency investments and reach other market segments, such as small energy customers or SMEs? How will these business models adapt to technology innovation in order to foster energy efficiency? What will be the impact of the energy market transition on energy service contracting and market innovation?

While these questions are left for further research, my PhD thesis will hopefully convince the reader of the great interest of new business models such as contracting in energy markets. These markets are impacted by an enormous transition, with drastic changes in the regulatory frameworks at the cantonal, federal and international levels (DETEC, 2017; OFEV, 2017). Boosted by relevant business innovations, new technologies could revolutionize the supply chain at every level. In such a context, it is of primary interest for researchers to study how the incumbents, the new market players and the customers will respond to these developments.

# References

Adnot, J., Guerre, F., Jamet, B., 2002. A short history of Energy Service in France. In: Proceedings of 2nd International Conference on Improving Electricity Efficiency in Commercial Buildings (IEECB). Nice, France, 261-270.

Allcott, H., Greenstone, M., 2012. Is there an energy efficiency gap? *The Journal of Economic Perspectives*, 3-28.

Allcott, H., Wozny, N., 2012. Gasoline prices, fuel economy, and the energy paradox. *Review of Economics and Statistics*, 96(5), 779-795.

Anderson, S. T., and Newell, R. G., 2004. Information programs for technology adoption: the case of energy-efficiency audits. *Resource and Energy Economics*, 26(1), 27-50.

Arrêté fédéral, 2015. Arrêté fédéral sur un article constitutionnel concernant la taxe climatique et la taxe sur l'électricité. FF 2015 72 15, Assemblée fédérale de la Confédération Suisse. October 28, 2015.

Backlund, S., Thollander, P., 2011. The energy-service gap: What does it mean? In: Proceedings of European Council for an Energy Efficient Economy (ECEEE). Linköping University, Sweden, pp. 649 - 656.

Baetschmann, G., Staub, K. E., and Winkelmann, R., 2015. Consistent estimation of the fixed effects ordered logit model. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 178(3), 685-703.

Banfi, S., Farsi, M., Filippini, M. and Jakob, M. 2008. Willingness to pay for energy-saving measures in residential buildings. *Energy Economics*, 30, 503-516.

Bertoldi, P., Berrutto, V., de Renzio, M., Adnot, J., Vine, E., 2003. How are EU ESCOs behaving and how to create a real ESCO market. In: Proceedings of the 2003 ECEEE Summer Study. European Council for an Energy-Efficient Economy, 909–916.

Bertoldi, P., Boza-Kiss, B., 2017. Analysis of barriers and drivers for the development of the ESCO markets in Europe. *Energy Policy*, 107, 345-355.

Bertoldi, P., Boza-Kiss, B., Panev, S., and Labanca, N., 2014. ESCO Market Report 2013. Technical report, JRC scientific technical reports, Joint Research Centre, Institute for Energy and Transport, Italy.

Bertoldi, P., Rezessy, S., Vine, E., 2006. Energy service companies in European countries: Current status and a strategy to foster their development. *Energy Policy*, 34 (14), 1818–1832.

Beyeler, F., Beglinger, N., and Roder, U., 2009. Minergie: The Swiss sustainable building standard. *Innovations*, 4(4), 241-244.

Blasch, J. and Farsi, M. 2014. Context effects and heterogeneity in voluntary carbon offsetting – a choice experiment in Switzerland. *Journal of Environmental Economic and Policy*, 3(1), 1-24.

Bleyl, J. W., 2011. Conservation first! The new integrated energy-contracting model to combine energy efficiency and renewable supply in large buildings and industry. In: Proceedings of European Council for an Energy Efficient Economy (ECEEE). ECEEE Summer Studies.

Bleyl, J. W., Adilipour, N., Bareit, M., Kempen, G., Cho, S.-H., Vanstraelen, L., 2012. ESCO market development: A role for facilitators to play. Technical report, International Agency's Demand Side Management Implementing Agreement (IEA DSM Task XVI).

Borchers, A. M., Duke, J. M., Parsons, G. R., 2007. Does willingness to pay for green energy differ by source? *Energy Policy*, 35 (6), 3327–3334.

Brunner, R., 2009. Das Ziel ist eine ganzheitliche Dienstleistung: Ronny Brunner interview (Geschäftsführer von Swiss Contracting) von Gentina Mirko. Intelligent Bauen.

Bundesamt für Energie, B., 1999. Energie-contracting in der Schweiz, Ausgestaltung, Wirkungen, Marktpotentiale. Technical report, BFE, Zürich.

Butler, J. S., Moffitt, R., 1982. A computationally efficient quadrature procedure for the one-factor multinomial probit model. *Econometrica*, 50 (3), 761-764.

Campbell, D., Hensher, D.A. and Scarpa, R., 2011. Non-attendance to attributes in environmental choice analysis: a latent class specification. *Journal of Environmental Planning and Management*, 54(8), 1061-1076.

Capelo, C., 2011. Modeling the Diffusion of Energy Performance Contracting. In: International System Dynamics Conference. Washington DC, 500-519.

Caputo, V., Van Loo, E., Scarpa, R., Nayga, R. M., and Verbeke, W., 2014. Using experiments to address attribute non-attendance in consumer food choices. In 2014 AAEA Annual meeting. Agricultural and Applied Economics Association (AAEA).

Carlton, D., 1983. The location and employment choices of new firms: An econometric model with discrete and continuous endogenous variables. *Review of Economics and Statistics*, 65(3), 440-449.

CdF-N, 2017. Programme de stabilisation : la commission propose à son conseil de maintenir toutes ses décisions. Communiqué de presse, Commission des finances du Conseil national, January 13, 2017.

CEATE-N, 2017. Un non clair et net au système incitatif en matière climatique et énergétique. Communiqué de presse, Commission de l'environnement, de l'aménagement du territoire et de l'énergie du Conseil national (CEATE-N), January 31, 2017.

Cooremans, C., 2011. Make it strategic! Financial investment is logic is not enough. *Energy Efficiency*, 4, 473-492.

Cooremans, C., 2012. Investment in energy efficiency: do the characteristics of investments matter? *Energy Efficiency*, 5(4), 497-518.

- Davis, L. W., 2010. Evaluating the slow adoption of energy efficient investments: are renters less likely to have energy efficient appliances? Technical report, NBER Working Paper 16114.
- DETEC, 2017. Stratégie énergétique 2050. Département fédéral de l'environnement, des transports, de l'énergie et de la communication (DETEC). URL : <https://www.uvek.admin.ch/uvek/fr/home/energie/strategie-energetique-2050.html>, last accessed Apr. 30, 2018
- Dixit, A. K., Pindyck, R. S., 1994. Investment under uncertainty. Princeton UP, Princeton.
- EICom, 2014. Données brutes des gestionnaires suisses de réseau de distribution (2009-2014). Commission fédérale de l'électricité. URL: <http://www.elcom.admin.ch/themen/00002/00097/index.html?lang=fr>, last accessed Jun. 24, 2014.
- Eikmeier, B., Neusser, W., Bleyl, J., Arzt, C., 2009. Contracting im Mietwohnungsbau. Technical report, BMVBS, Bonn.
- EPRI, 2009. Assessment of achievable potential from energy efficiency and demand response programs in the US 2010-2030. Technical report, Electric Power Research Institute.
- Fang, W. S., Miller, S. M., Yeh, C.-C., 2012. The effect of ESCOs on energy use. *Energy Policy*, 51, 558–568.
- Fell, M.J., 2017. Energy services: A conceptual review. *Energy Research & Social Science*, 27, 129-140.
- Gibbons, R., 2005. Four formal(izable) theories of the firm? *Journal of Economic Behavior and Organization*, 58 (2), 200 - 245.
- Gilligan, D., 2011. U.S. energy service company industry: History and Business Models. In: Presentation at the Second U.S.-China Energy Efficiency Forum.
- Gillingham, K., Harding, M., Rapson, D., 2012. Split incentives in residential energy consumption. *Energy Journal*, 33 (2), 37-62.
- Gillingham, K., Palmer, K., 2013. Bridging the energy efficiency gap: Insights for policy from economic theory and empirical analysis. Resources for the Future Discussion Paper (13-02).
- Goldman, C. A., Hopper, N. C., Osborn, J. G., 2005. Review of US ESCO industry market trends: An empirical analysis of project data. *Energy Policy*, 33 (3), 387 - 405.
- Goldman, C. A., Larsen, P., Sat, 2012. Evolution of the US energy service company industry: Market size and project performance from 1990-2008. Technical report, Ernest Orlando Lawrence Berkely National Laboratory.
- Greene, D. L., German, J., Delucchi, M. A., 2009. Fuel economy: the case for market failure. In: Reducing climate impacts in the transportation sector. Springer, pp. 181–205.

- Hansen, S. J., 2006. Performance contracting: Expanding horizons. The Fairmont Press, Inc.
- Helle, C., 1997. On energy efficiency-related product strategies - illustrated and analysed using contracting approaches in Germany as an example. *Utilities Policy*, 6 (1), 75-85.
- Hausman, J. A., 1979. Individual discount rates and the purchase and utilization of energy-using durables. *The Bell Journal of Economics*, 33-54.
- Helle, C., 1997. On energy efficiency-related product strategies illustrated and analysed using contracting approaches in Germany as an example. *Utilities Policy*, 6 (1), 75-85.
- Hensher, D.A., Rose, J.M. and Greene, W.H., 2005. The implications of willingness to pay of respondents ignoring specific attributes. Technical Report, Working Paper ITLS-WP-05-02, Institute of transport and logistic studies, University of Sydney.
- Hensher, D.A., Rose, J.M. and Greene, W.H., 2012. Inferring attribute non-attendance from stated choice data: implications for willingness to pay estimates and a warning for stated choice experiment design. *Transportation*, 39(2), 235-245.
- Hensher, D.A., Rose, J.M., 2009. Simplifying choice through attribute preservation or non-attendance: Implications for willingness to pay. *Transportation Research Part E*, 45, 583-590
- Hensher, D.A., Rose, J.M. and Greene, W.H., 2015. Applied Choice Analysis, second edition, Cambridge University Press.
- Hess, S. and Hensher, D.A., 2010. Using conditioning on observed choices to retrieve individual-specific attribute processing strategies, *Transportation Research Part B*, 44(6), 781-90.
- Hole, A.R., Norman, R. and Viney, R., 2016. Response patterns in health state valuation using endogenous attribute attendance and latent class analysis. *Health Economics*, 25, 212-224.
- Holmstrom, B., 1999. The firm as a subeconomy. *Journal of Law, Economics, and Organization*, 15 (1), 74-102.
- Holmstrom, B., Milgrom, P., 1991. Multitask principal-agent analyses: Incentive contracts, asset ownership, and job design. *Journal of Law, Economics, and Organization*, 7, 24-52.
- Hossain, T., Morgan, J., 2006. Plus Shipping and Handling: Revenue (Non) Equivalence in Field Experiments on eBay. *Advances in Economic Analysis and Policy*, 6 (2).
- ICF, 2007. Introduction to Energy Performance Contracting. Technical report, Prepared for U.S. Environmental Protection Agency ENERGY STAR, ICF International and Buildings National Association of Energy Services Companies.
- IEA, 2016. Energy Efficiency Market Report 2016. Technical report, International Energy Agency.

IEA-RETD, 2013. Business models for renewable energy in the built environment. International Energy Agency-Renewable Energy Technology Deployment (IEA-RETD), Book, Routledge.

limi, A., 2016. Multidimensional auctions for public energy efficiency projects: evidence from Japanese ESCO market. *Review of Industrial Organization*, 49(3), 491-514.

Irrek, W., Thomas, S., Attali, S., Benke, G., Borg, N., Figorski, A., Filipowicz, M., Laban-ca, N., Pindar, A., Ochoa, A., 2005. Public internal performance contracting-managing and financing energy-efficiency measures in public administrations. In: Energy Savings: What Works and Who Delivers? ECEEE Summer Study Proceedings. V. 1-3.

Jaffe, A. B., Stavins, R. N., 1994. The energy-efficiency gap: What does it mean? *Energy Policy*, 22 (10), 804 – 810.

Jensen, J., Oesten, P., Balslev Nielsen, S., 2010. ESCO as innovative facilities management in Danish municipalities. In: Sustainability or FM future and Innovation. EFMC2010, Madrid, Spain.

Kindström, D., Ottosson, M. and Thollander, P., 2017. Driving forces for and barriers to providing energy services – a study of local and regional energy companies in Sweden. *Energy Efficiency*, 10, 21-39.

Klinke, S., Reiter, U., Jakob, M., Farsi, M., 2017. Contracting the gap: Energy efficiency investments and transaction costs. Technical report, Swiss Federal Office of Energy.

Klinke, S., 2018. The determinants for adoption of energy supply contracting: Empirical evidence from the Swiss market. *Energy Policy*, 118, 221-231.

Khoury, J., Hollmuller, P., 2017. Deliverable Report D70 on (i) performance gap in building retrofits and benchmarking of best practice vs. current practice; (ii) cost assessment of diverse energy efficiency solutions in building retrofit. Technical report, Swiss Competence Center for Energy Research. January 2017, Geneva.

King, G. and Zeng, L., 2001. Logistic regression in rare events data. *Political analysis*, 9 (2), 137-163.

Lafontaine, F. and Slade, M., 2007. Vertical integration and firm boundaries: The evidence. *Journal of Economic Literature*, 45 (3), 629-685.

Lagarde, M., 2013. Investigating attribute non-attendance and its consequences in choice experiments with latent class models. *Health economics*, 22(5), 554-567.

Langlois, P., Hansen, S. J., 2012. World ESCO Outlook. Fairmont Press.

Langniss, O., and Praetorius, B., 2006. How much market do market-based instruments create? An analysis for the case of “white” certificates. *Energy Policy*, 34(2), 200-211.

- Larsen, P. H., Goldman, C. A., Satchwell, A., 2012. Evolution of the US energy service company industry: Market size and project performance from 1990-2008. *Energy Policy*, 50, 802-820.
- Lee, M.-K., Park, H., Noh, J., Painuly, J. P., 2003. Promoting energy efficiency financing and ESCOs in developing countries: experiences from Korean ESCO business. *Journal of Cleaner Production* 11, (6), 651–657.
- Lee, P., Lam, P., Lee, W., 2015. Risks in energy performance contracting (EPC) projects. *Energy and Buildings*, 92, 116-127.
- Levine, M., Urge Vorsatz, D., Blok, K., Geng, L., Harvey, D., Lang, S., Levermore, G., Mongameli Mehlwana, A., Mirasgedis, S., Novikova, A., Rilling, J., Yoshino, H., 2007. Residential and commercial buildings. In: *Climate Change 2007, Mitigation*. Cambridge University Press, Cambridge.
- Li, Y., Qiu, Y., Wang, Y. D., 2014. Explaining the contract terms of energy performance contracting in China: The importance of effective financing. *Energy Economics*, 45, 401-411.
- Long, J.S., and Freese, J. 2014. *Regression Models for Categorical Dependent Variables using Stata*. 3<sup>rd</sup> ed. College Station, TX: Stata Press.
- Lyons, B., 1996. Empirical relevance of efficient contract theory: inter-firm contracts. *Oxford Review of Economic Policy*, 12 (4), 27-52.
- Marino, A., Bertoldi, P., Rezessy, S., Boza-Kiss, B., 2010. Energy service companies market in Europe-Status report 2010. Technical report, European Commission Joint Research Centre.
- Marino, A., Bertoldi, P., Rezessy, S., Boza-Kiss, B., 2011. A snapshot of the European energy service market in 2010 and policy recommendations to foster a further market development. *Energy Policy*, 39 (10), 6190-6198.
- Masten, S. E., 1996. Empirical research in transaction cost economics: challenges, progress, directions. In: *Transaction cost economics and beyond*. Springer, 43-64.
- Mathew, P., Kromer, J. S., Sezgen, O., Meyers, S., 2005. Actuarial pricing of energy efficiency projects: Lessons foul and fair. *Energy Policy*, 33 (10), 1319-1328.
- McAfee, R. P., McMillan, J., 1986. Bidding for contracts: a principal-agent analysis. *The RAND Journal of Economics*, 17 (3), 326-338.
- McKinsey Company, 2009. Pathways to a low-carbon economy: Version 2 of the global greenhouse gas abatement curve. Technical report.
- McFadden, D., 1974. Conditional logit analysis of qualitative choice behavior, in Zarembka, P. (ed.), *Frontiers in Econometrics*, Academic Press: New York, 105-142.
- Mills, E., 2003. Risk transfer via energy-savings insurance. *Energy Policy*, 31 (3), 273 - 281.
- Murtishaw, S., Sathaye, J., 2006. Quantifying the effect of the principal-agent problem on us residential energy use. Technical report, Lawrence Berkeley National Laboratory.

- Nesta, L., Vona, F., and Nicolli, F., 2014. Environmental policies, competition and innovation in renewable energy. *Journal of Environmental Economics and Management*, 67(3), 396-411.
- Nguene, G., 2008. Strategic options of energy service companies in competitive energy markets. Ph.D. Thesis, Ecole Polytechnique Fédérale de Lausanne.
- Nolden, C., Sorrell, S., 2016. The UK market for energy service contracts in 2014-2015. *Energy Efficiency*, 9 (6), 1405-1420.
- Nolden, C., Sorrell, S., Polzin, F., 2016. Catalysing the energy service market: the role of intermediaries. *Energy Policy*, 98, 420-430.
- OCDE, 2017. Ination (IPC) indicator. OCDE doi: 10.1787/29ad7eaf-fr. URL: <https://data.oecd.org/fr/price/inflation-ipc.htm>, last accessed Jun. 11, 2017.
- OFEV, 2017. Révision totale de la loi sur le CO<sub>2</sub>. Office fédéral de l'environnement (OFEV). URL : <https://www.bafu.admin.ch/bafu/fr/home/themes/climat/droit/totalrevision-co2-gesetz.html>, last accessed Apr. 30, 2018.
- OFS, 2013. Communiqué de presse: 200'000 ménages de plus propriétaires de leur logement en dix ans. Relevé structurel du recensement de la population 2010, Construction et Logement, March, Neuchâtel.
- OFS, 2014. IPC (décembre 2010=100) résultats détaillés, niveau de l'indice et structure du panier-type 2010. Office fédéral de la statistique. URL: <http://www.bfs.admin.ch/bfs/portal/fr/index/themen/05/02/blank/data.html>, last accessed Sep. 9, 2014.
- OFS, 2015. Domaine de l'énergie: Bâtiments selon les cantons, la catégorie de bâtiment, le système de chauffage, la production d'eau chaude, les agents énergétiques et l'époque de construction. Années 1990, 2000 et 2009-2014. Office Fédéral de la Statistique, Statistique des bâtiments et des logements. URL: <https://www.pxweb.bfs.admin.ch/default.aspx?px language=fr.>, last accessed Jan.11, 2016.
- OFS, 2016. IPC, prix moyens de l'énergie et des carburants, valeurs mensuelles (depuis 2000) et annuelles (depuis 1966). Office fédéral de la statistique. URL: <http://www.bfs.admin.ch/bfs/portal/fr/index/themen/05/02/blank/data.html>, last accessed Jan. 8, 2016.
- OFS, 2017. Chiffres sur les PME : entreprises et emplois. Statistique structurelle des entreprises (STATENT) de l'office fédéral de la statistique (OFS). URL : <https://www.kmu.admin.ch/kmu/fr/home/politique-pme/politique-pme-faits-et-chiffres/chiffres-sur-les-pme/entreprises-et-emplois.html>, last accessed Feb. 23, 2018
- Oikonomou, V., Jepma, C., Becchis, F., and Russolillo, D., 2008. White Certificates for energy efficiency improvement with energy taxes: A theoretical economic model. *Energy Economics*, 30(6), 3044-3062.
- Okay, N., Akman, U., 2010. Analysis of ESCO activities using country indicators. *Renewable and Sustainable Energy Reviews*, 14 (9), 2760–2771.

- Osterwalder, A., Pigneur, Y., and Tucci, C. L., 2005. Clarifying business models: Origins, present, and future of the concept. *Communications of the association for Information Systems*, vol. 16, no 1, p. 1.
- Painuly, J. P., 2001. Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy*, 24 (1), 73–89.
- Painuly, J. P., Park, H., Lee, M.-K., Noh, J., 2003. Promoting energy efficiency financing and ESCOs in developing countries: mechanisms and barriers. *Journal of Cleaner Production*, 11 (6), 659–665.
- Palmer, K., Walls, M., and Gerarden, T., 2012. Borrowing to save energy: An assessment of energy-efficiency financing programs. Technical report, Resources for the Future.
- Panev, S., Labanca, N., Bertoldi, P., Serrenho, T., Cahill, C., Kiss, B. B., 2013. ESCO market report for non-European countries 2013. Technical report, European Commission, Joint Research Centre.
- Pätäri, S., Annala, S., Jantunen, A., Viljainen, S., Sinkkonen, A., 2016. Enabling and hindering factors of diffusion of energy service companies in Finland|results of a Delphi study. *Energy Efficiency*, 9 (6), 1447-1460.
- Phillips, R., 2010. Pompes à chaleur - questions et réponses. Technical report, Office fédéral de l'énergie (OFEN) et Groupement promotionnel suisse pour les pompes GSP.
- Pindyck, R. S., 1991. Irreversibility, uncertainty, and investment. Technical report, National Bureau of Economic Research.
- Polzin, F., von Flotow, P., Nolden, C., 2016a. Modes of governance for municipal energy efficiency services – The case of LED street lighting in Germany. *Journal of Cleaner Production*, 139, 133-145.
- Polzin, F., von Flotow, P., Nolden, C., 2016b. What encourages local authorities to engage with energy performance contracting for retrofitting? Evidence from German municipalities. *Energy Policy*, 94, 317-330.
- Popp, D., Newell, R. G., and Jaffe, A. B., 2010. Energy, the environment, and technological change. *Handbook of the Economics of Innovation*, 2, 873-937.
- Rose, J.M., Hensher, D.A., Greene, W.H. and Washington, S.P., 2012. Attribute exclusion strategies in airline choice: accounting for exogenous information on decision maker processing strategies in models of discrete choice. *Transportmetrica*, 8(5), 344-360.
- Saussier, S., 2000. Transaction costs and contractual incompleteness: The case of électricité de France. *Journal of Economic Behavior and Organization*, 42 (2), 189-206.
- Satchwell, A., Goldman, C., Larsen, P., Gilligan, D., Singer, T., 2010. A survey of the US ESCO industry: Market growth and development from 2008 to 2011. Technical report, Lawrence Berkeley National Laboratory BNL-3479E.

- Scarpa, R., Willis, K., 2010. Willingness-to-pay for renewable energy: Primary and discretionary choice of British households' for micro-generation technologies. *Energy Economics*, 32 (1), 129–136.
- Soroye, K. L., Nilsson, L. J., 2010. Building a business to close the efficiency gap: The Swedish ESCO Experience. *Energy Efficiency*, 3 (3), 237 - 256.
- Sorrell, S., 2005. The contribution of energy service contracting to a low carbon economy. Technical report, Tyndall Centre.
- Sorrell, S., 2007. The economics of energy service contracts. *Energy Policy*, 35 (1), 507 - 521.
- Sorrell, S., O'Malley, E., Schleich, J., Scott, S., 2004. The economics of energy efficiency: barriers to cost-effective investment. Book, Edward Elgar, Cheltenham.
- Spence, M., 1977. Nonprice competition. *The American Economic Review*, 67(1), 255-259.
- Stuart, E., Larsen, P. H., Carvallo, J. P., Goldman, C. A., Gilligan, D., 2016. US energy service company (ESCO) industry: Recent market trends. Technical report, Electricity Markets and Policy group, Energy Analysis and Environmental Impacts Division, Lawrence Berkeley National Laboratory.
- Suhonen, N., Okkonen, L., 2013. The energy services company (ESCO) as business model for heat entrepreneurship - A case study of North Karelia, Finland. *Energy policy*, 61, 783-787.
- Surveillant des prix, 2014. Données des prix de l'électricité par commune et classe de consommateur (2004-2008-2009). Confédération Suisse.
- Swissesco, 2016. Energiespar-Contracting – Leitfaden für die Vorbereitung und die Durchführung von Energiespar-Contracting. Technical report, Bern.
- Swiss Federal Council, 2015. Message relatif à l'article constitutionnel concernant un système incitatif en matière climatique et énergétique. Objet du Conseil Fédéral 15.072, October 28, 2015.
- Tadelis, S., Williamson, O. E., 2013. Transaction cost economics. In: Gibbons, R., Roberts, J. (Eds.), *The Handbook of Organizational Economics*. Book, Princeton University Press, Ch. 4, 159-190.
- Thollander, P., Backlund, S., Trianni, A., Cagno, E., 2013. Beyond barriers – a case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden. *Applied Energy*, 111, 636–643.
- Tietenberg, T., 2009. Reflections: Energy Efficiency Policy: Pipe Dream or Pipeline to the Future? *Review of Environmental Economics and Policy*, 3(2), 304–320.
- Vine, E., 2005. An international survey of the energy service company (ESCO) industry. *Energy Policy*, 33 (5), 691-704.

Weller, P., Oehlmann, M., Mariel, P. and Meyerhoff, J., 2014. Stated and inferred attribute non-attendance in a design of designs approach. *The Journal of Choice Modeling*, 11, 43-56.

Williamson, O. E., 1971. The vertical integration of production: Market failure considerations. *American Economic Review*, 61 (2), 112-23.

Wooldridge, J. M., 2009. Correlated random effects models with unbalanced panels. Manuscript (version July 2009). Michigan State University.

Xu, P., Chan, E. H.-W., Qian, Q. K., 2011. Success factors of energy performance contracting (EPC) for sustainable building energy efficiency retrofit (BEER) of hotel buildings in China. *Energy Policy*, 39 (11), 7389-7398.

Yik, F., Lee, W., 2004. Partnership in building energy performance contracting. *Building Research and Information*, 32(3), 235-243.

