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# What encourages local authorities to engage with energy performance contracting for retrofitting? Evidence from German municipalities



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## HIGHLIGHTS

- Barriers to retrofitting can be addressed through energy performance contracts (EPC).
- Outsourcing has the potential to alleviate personnel and financial constraints.
- Standardised contracts and previous experience with outsourcing facilitate use of EPC.
- Engaging energy consultants has a negative influence on the willingness to adopt EPC.
- Policy makers could support facilitators and standard contracts to boost EPC market.

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## ABSTRACT

Municipalities aiming at mitigating climate change by implementing new energy efficiency technologies face budgetary and capacity constraints. Outsourcing through energy service contracting could provide a solution. This paper reports results from a survey of 1298 municipalities concerning barriers to retrofitting public street lighting and the possible role of energy service contracting to overcome these barriers. Using a logistic regression analysis, the authors investigate determinants of opting for energy service contracts in the specific context of LED retrofits. Results point to an advantage of outsourcing in a financially and capacity-constrained environment, which corresponds with the main reasons for engaging in contracting: minimising investments and financial risks. However, municipalities often do not fully grasp the risks associated with retrofitting especially using a novel technology such as LED. In relation to that they underestimate the risk reduction potential of energy performance contracts (EPC). Previous experience with outsourcing increases the probability to engage in servitization although certain existing partnerships, particularly with utilities, prevent municipalities from considering energy performance contracts. Interestingly, engaging an energy consultant has a negative propensity to use energy service contracts, while pre-negotiated standardised contracts for energy performance contracts have a positive influence.

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## 1. Introduction

Municipalities are required to modernise their aging infrastructure, increase energy and cost effectiveness to tackle climate change and provide public services while facing limited investment budgets (Sorrell, 2015; Sorrell

et al., 2004). Outsourcing services has been highlighted as a possible solution to this dilemma (Roehrich et al., 2014; Bennett, 2006; Sorrell, 2005). Energy service contracting is a means of outsourcing the procurement and delivery of energy services but it may only be appropriate for a subset of energy services in the public sector (Sorrell, 2005; Polzin et al., 2015).

The literature has engaged with the questions of outsourcing energy related public services on two levels: First, the energy service company (ESCo) business model has

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been analysed on a country level (Vine, 2005; Bertoldi et al., 2006, 2014; Marino et al., 2011). Second, there is micro-level conceptual and qualitative evidence of ESCo business models suitability for public service application (Hannon and Bolton, 2015; Hannon et al., 2013; Pätäri and Sinkkonen, 2014; Aasen et al., 2016; Polzin et al., 2015). Energy service contracts, specifically energy performance contracts (EPCs), have received specific attention in this context. EPCs (hitherto also referred to as ESCo solutions) are understood as contracts that deliver 'final energy services' where the capital investment is recovered from energy cost savings (see Sorrell (2005) for a more detailed account).

Quantitative analysis of drivers and barriers for energy service contracting and specifically EPCs in the public sphere have been lacking (Pätäri and Sinkkonen, 2014; Hannon and Bolton, 2015; Hartmann et al., 2014; Aasen et al., 2016). The purpose of this paper is to provide quantitative evidence of drivers and barriers for energy related public infrastructure modernisation (retrofitting) through energy service contracting, specifically EPCs. Our research question reads as follows: Which factors determine municipal engagement in an energy performance contract (EPC) for energy infrastructure modernisation?

We analyse the case of public sector application of LED (light-emitting diodes) street lighting in Germany as an example of a market where some of the barriers to retrofitting existing infrastructure are being addressed through energy service contracting alongside other forms of municipal energy infrastructure governance (in-house, energy utility (EUCo)<sup>1</sup>, multi-utility (MUCo)<sup>2</sup> solutions or concessions). Street lighting in Germany represents a major cost factor, accounting for almost one third of municipal electricity budgets (DStGB, 2010). This provides a strong incentive for municipalities to engage in modernisation activities to reduce costs as well as end-use energy demand and to alleviate budget constraints (Difu, 2014).

The remainder of this paper is structured as follows: Section 2 describes the theoretical background and develops the hypotheses which are operationalised through our research design (Section 3). Section 4 describes the main results of the survey analysis and discusses our findings in light of previous research. Overarching conclusions and policy implications are drawn in Section 5.

## 2. Literature review and hypotheses development

Governments around the world are facing challenges to finance, operate and maintain, let alone improve the energy performance of their properties (Zhang et al., 2015; Radulovic et al., 2011; dena 2015; Hannon and Bolton, 2015). Energy performance may be improved by procuring innovative green technologies and services

(Testa et al., 2016; Hannon et al., 2015; Sorrell, 2007). However, public sector engagement in modernisation activities using innovative end-use energy demand technologies ('retrofitting') requires significant upfront investments and enhanced capacities to handle the associated risks. These risks arise out of uncertain returns on investment as trusted information on quality, energy savings and durability of new products (such as LED) are missing. The payback period of associated high upfront investments also largely depends on uncertain future energy costs (Jackson, 2010).

In this case outsourcing, involving an energy service company (ESCo), can provide a solution (Bennett, 2006; Hartmann et al., 2014; Helle, 1997; Roehrich et al., 2014). This outsourcing process involves a shift in governance structure from hierarchies (in-house provision) to markets (Pint and Baldwin, 1997; Toffel, 2002). This paper focuses on energy performance contracts that include guaranteed savings for the client (EPCs) as a sub-category of energy service contracts (Nolden et al., 2015; Sorrell, 2007). The ESCo assumes control over the secondary energy conversion and control equipment that converts primary energy streams into useful energy such as thermostats, boilers or lamps as part of an EPC (Sorrell, 2007, 2005). This allows the ESCo to identify, deliver and maintain savings using guarantees for certain standards (e.g. lighting) at an operational cost typically lower than its customers' current or projected energy bill. Capital investment by the ESCo will be recovered by energy savings as well as other savings such as maintenance costs. The retrofitting activities are financed using debt and a forfeiting mechanism that allows ESCos to benefit from their clients' credibility or directly through client debt. The assets installed can either be accounted for on the balance sheet of the client or the ESCo. Risks associated with long payback periods for retrofits may favour ESCo solutions and associated guarantees (Hannon et al., 2013; Marino et al., 2011; Sorrell, 2007).

To date, research has focused primarily on two aspects of outsourcing through energy service contracting. Using expert survey techniques scholars have highlighted overall drivers and barriers for the ongoing ESCo market development primarily in the US and Europe (Bertoldi et al., 2006; Bertoldi et al., 2014; Marino et al., 2011; Vine, 2005; Hannon et al., 2015; Nolden and Sorrell, 2016). Using in-depth case studies, scholars also analysed business models of ESCos such as EPC and the role of ESCos in the wider energy system (transition) (Pätäri and Sinkkonen, 2014; Hannon and Bolton, 2015; Hannon et al., 2013; Haas et al., 2008; Aasen et al., 2016). Complementing both streams of literature, we develop hypotheses about the relationship between a local authority and an ESCo.

### 2.1. Barriers to retrofitting as potential drivers for an ESCo solution

Prior qualitative research has pointed towards a potential suitability of energy service contracting to address barriers currently hindering the diffusion of innovative end-use energy demand reduction technologies (Polzin et al., 2015; Steinberger et al., 2009; Aasen et al., 2016). Technological factors (e.g. quality and durability), economic factors (high upfront costs and uncertain future energy

<sup>1</sup> EUCos typically engage in energy generation and supply. They may also engage in distribution and transmission (Hannon et al. (2013), p.1036).

<sup>2</sup> In the German context MUCo refers specifically to local 'Stadtwerke', which tend to provide a wide range of utilities such as gas, electricity and municipal waste management. Strong local embedding ensures that these MUCos enjoy near monopolies on most supply and waste streams which can provide incentives for integrated solutions (Betsill and Bulkeley, 2006).

costs), competency factors and institutional factors (such as the maintenance backlog) determine whether outsourcing using a third-party contractor is considered (Roehrich et al., 2014; Steinberger et al., 2009; Aasen et al., 2016; Wilson et al., 2012; Sorrell et al., 2004).

Improving the energy performance of public properties requires significant amounts of upfront investments into energy-related technologies that typically have a long payback period (Suhonen and Okkonen, 2013). One of the main reasons for public actors to engage with a private contractor (ESCo) is therefore the reduction of the overall financial burden (limited budgets) as energy and cost savings are typically guaranteed (Polzin et al., 2015; Sorrell, 2007; Sorrell et al., 2004; Pätäri and Sinkkonen, 2014; Uyarra et al., 2014). Hence our first hypothesis relates to savings by using EPC:

**H1a.** Financial constraints encourage outsourcing.

Second, limited competencies prevent local authorities from procuring innovative (green) goods and services which poses a significant barrier for retrofitting (Polzin et al., 2015; Edquist and Zabala-Iturriagoitia, 2012; Uyarra et al., 2014). These competencies were not necessary in the past as more efficient energy technologies evolved slowly. If municipalities lack in-house competencies and capacities to carry out retrofits, this might be a case in point for sourcing these from a third party:

**H1b.** Personnel capacity constraints encourage outsourcing.

Third, management of the retrofitting process requires enhanced capabilities and capacities. One way of acquiring these skills is by engagement. Prior research has highlighted that positive experience with outsourcing and corresponding trust leads to increased awareness, a positive attitude towards energy service contracting and an increased likelihood of considering this form of outsourcing (Backlund and Eidenskog, 2013; Marino et al., 2011; Hannon and Bolton, 2015; Pätäri and Sinkkonen, 2014). Correspondingly our hypothesis reads as follows:

**H1c.** Existing partnerships encourage outsourcing.

Fourth, in the retrofitting process of municipal infrastructure, the assessment and management of risk represents a crucial task (Jackson, 2010; Uyarra et al., 2014; Sorrell, 2007). Uncertainties regarding payback periods for energy efficiency projects may be amplified by volatile energy prices and unpredictable regulation of the energy market etc. (Toffel, 2002; Sorrell, 2005). Hannon and Bolton (2015) argue that the degree of risk-aversion determines the establishment of a partnership with a local ESCo. Consequently we hypothesize:

**H1d.** The higher the perceived risks of achieving the savings generated by the retrofitting measures, the higher the tendency towards outsourcing.

In line with addressing barriers for retrofitting as possible drivers for an EPC solution, we hypothesize that alleviating financial constraints and personnel constraints as well as addressing the corresponding risks are also the explicitly stated main drivers for local authorities to engage in an EPC (Polzin et al., 2015; Hannon and Bolton, 2015; Aasen et al., 2016). Hence the following hypotheses read:

**H2a.** Reason to engage in energy performance contracting is the minimisation of financial exposure.

**H2b.** Reason to engage in energy performance contracting is the minimisation of personnel.

**H2c.** Reason to engage in energy performance contracting is the minimisation of risk.

## 2.2. Barriers to EPC in the public sector

Where EPCs are suitable for the delivery of energy services in the public sector, as is the case with street lighting, prior qualitative research has highlighted factors that are restricting the diffusion of EPC (Polzin et al., 2015). Missing personnel capacity to manage the contract is one. A recent case study of Norwegian municipalities revealed that committed public sector decision makers could facilitate EPC retrofitting solutions and correspondingly increase the likelihood of outsourcing solutions to be considered (Aasen et al., 2016). In the absence of those capacities we hypothesize that:

**H3a.** Missing capacity and competencies to engage with EPC poses a severe barrier to EPC diffusion.

Furthermore, Polzin et al. (2015), Pätäri and Sinkkonen (2014) and Marino et al. (2011) summarised barriers relating to contract design. These include the missing flexibility and legal complexities in a long-term ESCo contract and a perceived unfair balance of interests also aggravated by bad experiences with prior outsourcing efforts. Aasen et al. (2016) found flexible contracts to be a significant driver in the municipal context in Norway. More specifically they refer to the possibility of addressing maintenance backlogs through EPCs. Standardised contracts that reduce flexibility, on the other hand, reduce transaction costs. This has been a significant driver in the municipal context in the UK and Germany.<sup>3</sup> In the UK it is often assumed that the sole purpose of an EPC is to address maintenance and retrofit backlogs. Resulting from the discussion we hypothesize that from a municipal point of view, the absence of flexibility acts as a barrier:

**H3b.** Disadvantageous contract design (such as lack of balance of interests and flexibility) hinders local authority engagement in EPC.

Finally, due to the variety of governance structures for street lighting provision specifically in Germany, incumbent (existing) legal arrangements with an EUCo or a MUCo prevent the use of ESCo solutions. These contracts allow the public body to benefit from private sector organisational effectiveness and efficiency to carry out the services while at the same time retaining strategic control. The municipality may even choose (partial) ownership over the third party that carries out retrofits and provides energy services (Hannon and Bolton, 2015). However, these contracts usually do not include a performance-based element associated with EPCs, which incentivizes the third party to use efficient retrofitting technologies. Additionally, MUCos and EUCos often also produce and sell electricity which

<sup>3</sup> The UK Department of Energy and Climate Change (Mayor of London 2014) as well as SBI (2013) in Germany have recently published a standardised contract on their websites to help reduce transaction costs further.

conflicts with the goal of higher savings. Locking clients into long-term arrangements has also been identified as a major barrier for new ESCo companies in other contexts such as the UK (Polzin et al., 2015; Hannon et al., 2013), hence:

**H3c.** Existing long-term contracts or partnerships prevent the use of an ESCo solution.

### 2.3. Competencies, capacities and tools to conduct an EPC

In order to address the above mentioned barriers to the use of EPC, the literature also identified a range of drivers that facilitate the tendering, implementation and management of EPC. Using an outsourcing solution requires enhanced competencies on the client side such as open book and energy cost information that allows the definition of a baseline and the corresponding procedures for measurement and verification (Marino et al., 2011; Pätäri and Sinkkonen, 2014; Aasen et al., 2016). ESCos perform significantly better if the tenders are not over-specified (which lead to the implementation of particular products or the choice of particular suppliers) (Polzin et al., 2015; Uyarra et al., 2014). Hence, transparent cost management favours considering an EPC solution.

**H4a.** Detailed energy cost information leads to a higher tendency towards outsourcing.

On the other hand, if municipalities acquire or already possess the necessary competencies and capacities regarding both innovative technologies and their implementation as well as tendering schemes to carry out the retrofit, we hypothesize that this would lead to a lower propensity of considering an outsourcing solution (Polzin et al., 2015; Sorrell, 2007).

**H4b.** Technical knowledge leads to a lower tendency towards outsourcing.

To improve competencies on the client side, the use of tools to implement the retrofitting process, including planning, tendering and implementation of the modernisation increases the chances of an EPC solution to be considered. On the other hand, acquiring the necessary competencies could also lead to a higher propensity of conducting an in-house modernisation as products and tenders may be better evaluated (Hartmann et al., 2014; Roehrich and Lewis, 2014). Accordingly we develop two concurring hypotheses:

**H5a.** Using tools for the modernisation lead to a higher tendency towards outsourcing.

**H5b.** Using tools for the modernisation lead to a lower tendency towards outsourcing.

### 2.4. The role of consultants in EPC

If neither competencies nor capacities are present in-house, prior research suggest the positive role of facilitators to handle the complexity of the whole retrofitting process lifecycle, ranging from the (neutral) tendering process, implementation of the project as well as measurement and verification. One has to distinguish between purely technical consultants, focusing on implementing the retrofits and process oriented consultants that facilitate the procurement process. These agents mostly consult on

behalf of a client, act as an intermediary between the ESCo and the client, ensure competition between the different kinds of suppliers and facilitate the implementation of the project. Thus they can play an important and enabling role (Bleyl et al., 2013; Polzin et al., 2015; Lemon et al., 2015).

**H6.** Using an energy consultant or facilitator leads to a higher tendency towards outsourcing.

## 3. Methodology

### 3.1. Research context

To uncover the factors affecting the municipal use of EPC for retrofitting we analysed public lighting infrastructure retrofits with LED lamps in German municipalities. German municipalities are typically short in budgets with total municipal debt amounting to €133.6bn in 2013 (Difu, 2014; DStGB, 2014). Investing in energy efficiency can alleviate financial constraints and help municipalities meet climate change targets (Bennett, 2006; dena, 2015; Hartmann et al., 2014; Hendricks, 2014) but overburdening debt often limits capacities to seek and engage in energy efficiency projects.

At the same time the lighting industry has recently undergone major shifts from traditional lamps towards LED with significant savings in terms of energy and costs (IEA, 2013). As a result, application of this technology is proving to be challenging for both manufacturers and customers (Sanderson and Simons, 2014; Smink et al., 2015; Bergek and Onufrey, 2014), despite forecasts of LED market shares increasing from less than 10% to 70% by 2020 (McKinsey, 2012).

The example of Germany is particularly revealing as municipal independence and its federal state structure have lent themselves to the establishment of diverse governance mechanisms for the provision of street lighting services, including an emerging ESCo market for lighting. 27% of municipalities provide street lighting in-house, 35% outsourced the management to EUCos, another 10% to MUCos and 25% partially outsourced services such as maintenance. 3% of municipalities use ESCo solutions to manage their street lighting (dena, 2012). Additionally, the German government launched an energy service contracting initiative by providing standardised contracts (SBI, 2013; BMBF, 2014).

### 3.2. Survey design

To derive a quantitative research design and model for this study, we conducted an extensive literature review (see Section 2) and a qualitative study, interviewing 40 experts participating in the process of retrofitting public street lighting (with LED) and confronted with the choice between different modes of governance (including energy service contracting) (Polzin et al., 2015). This set-up allowed us to combine drivers and barriers for the use of EPC based on the literature with context-dependent results from our previous qualitative study. Hence we derived indicators for the above mentioned hypotheses.

The overall aims of this study were to gather data on Germany's street lighting inventory, to analyse trends regarding retrofitting, to identify drivers and barriers in the retrofitting process and to evaluate the possible role of



contracting to derive implications and policy advice for a municipal “Energiewende” in Germany and beyond.

### 3.3. Data collection, sample and data processing

To develop an empirical perspective on the determinants of EPC take-up in the public sector, our data collection captured the view of public clients on public property retrofitting (in this case: public street lighting). Hence we developed a survey based on the theoretical framework (Section 2) and the qualitative study (Polzin et al., 2015). Combining qualitative and quantitative elements in a study is considered a mixed method approach (Creswell and Clark, 2010).

An important aspect to be taken into account, when using this methodological approach, is the potential presence of common method bias (i.e. gathering all information for this analysis via a survey). This type of bias generally affects survey data (Podsakoff et al., 2003). Following Testa et al. (2016) we adopted several measures to reduce the bias. We started by minimising item ambiguity in the questionnaire, which included avoiding vague concepts, complicated syntax and unfamiliar terms. We deliberately kept questions simple, specific and concise. A pretest with selected municipalities validated the survey and the wording of the questions. We also guaranteed the respondents anonymity.

The questionnaire consisted of items relating to governance structure, management of street lighting, street lighting inventory, retrofitting (technologies used, drivers and barriers) and energy service contracting (EPC approach, drivers, and barriers) as well as information on street lighting expertise, tools, consultation and financial support mechanisms. For a detailed list of questions please consult the Appendix A. In the period from May 2014 – July 2014, German local government institutions were surveyed using a fully structured website based online survey (34 questions in 12 groups). Thereby we gathered key performance indicators and the level of agreement with statements was determined using a 5 point likert scale, ranging from 1, strongly disagree, to 5, strongly agree. The questionnaire was distributed via reliable channels such as the association for German municipalities (Deutscher Städte und Gemeindebund – DStGB) to obtain a stratified sample. In total there are 11,197 municipal entities in Germany that are distributed across 16 federal states. In total we gathered 2971 responses. Among these were 1298 completed surveys, which represents a response rate of 11.6% and a completion rate of 43.7%. This sample is representative in terms of sizes and states (see Table 1).

### 3.4. Model

Drawing from the hypotheses derived in Section 2 we developed a model for the analysis. The components of the model (Fig. 1) are described in the following sections.

#### 3.4.1. Dependent variable

To analyse the determinants which encourage municipalities to sign-up to an EPC we use the *active consideration* of this governance mode for modernising their street lighting (see Fig. 1). This gives a better understanding of drivers and barriers to engagement as actual use of EPC is

**Table 1**  
Response rates across the sample.

| Size              | Inhabitants      | Population <sup>a</sup> | Responses   | Response rate (%) |
|-------------------|------------------|-------------------------|-------------|-------------------|
| <b>Very small</b> | < 5000           | 8323                    | 362         | 4.3               |
| <b>Small</b>      | 5000 < 50,000    | 2692                    | 799         | 29.7              |
| <b>Medium</b>     | 50,000 < 100,000 | 106                     | 79          | 74.5              |
| <b>Large</b>      | > 100,000        | 76                      | 58          | 76.3              |
| <b>Total:</b>     |                  | <b>11,197</b>           | <b>1298</b> | <b>11.6</b>       |

<sup>a</sup> German federal statistical office/statista.com (2012/2013).

rather limited (see Section 3.1). EPC is considered a niche application in most countries (Bertoldi et al., 2014; Marino et al., 2011; Transparense, 2013; Combines, 2014).

#### 3.4.2. Independent variables

The independent variables consist of scales with multiple items that relate to the hypotheses outlined in the theoretical framework. They include barriers to retrofitting (such as missing personnel capacity, inadequate financial resources for infrastructure etc.), drivers for contracting (minimising personnel, investments and risks), barriers for EPC (personnel capacity, missing flexibility, bad experiences in the past, unfair balance of interests, other legal partnerships, veto from regulatory authorities) as well as the usage of tools and consulting. Finally we include demographic factors that influence the decision of a municipality to engage in EPC, such as financial constraints (measured as the presence of a formal state of budget control) and inhabitants (size) that also serve as *control variables* (see Fig. 1).

### 3.5. Econometric procedures

To study the willingness of municipalities to engage in EPC as a categorical/binary outcome the use of a logistic regression is appropriate (Hair, 2010; Kutner et al., 2005; Cohen et al., 2009; Wooldridge et al., 2009). It enables the calculation of the propensity of a certain case belonging to one or the other category based on discriminant Z scores. These scores are influenced by characteristics of the independent variables. Logistic regression does not require the strict assumptions of multivariate normality (i.e. normally distributed variables) as well as equal variance-covariance matrices. The error term of the underlying distribution does not follow the normal but the binominal distribution, invalidating most tests based on the normal distribution. It behaves similar to multivariate regression for metric dependent variables and can incorporate metric and non-metric variables as well as non-linear effects (Hair, 2010; Cohen et al., 2009).

Logistic regression requires a number of assumptions. With regard to sample size, prior literature recommend sample sizes greater than 400, which is the case in our analysis (Hosmer and Lemeshow, 2000). Similarly, the independent variables exhibit the characteristics of heteroskedasticity (i.e. they have a common variance), which the logistic regression is capable of dealing with.

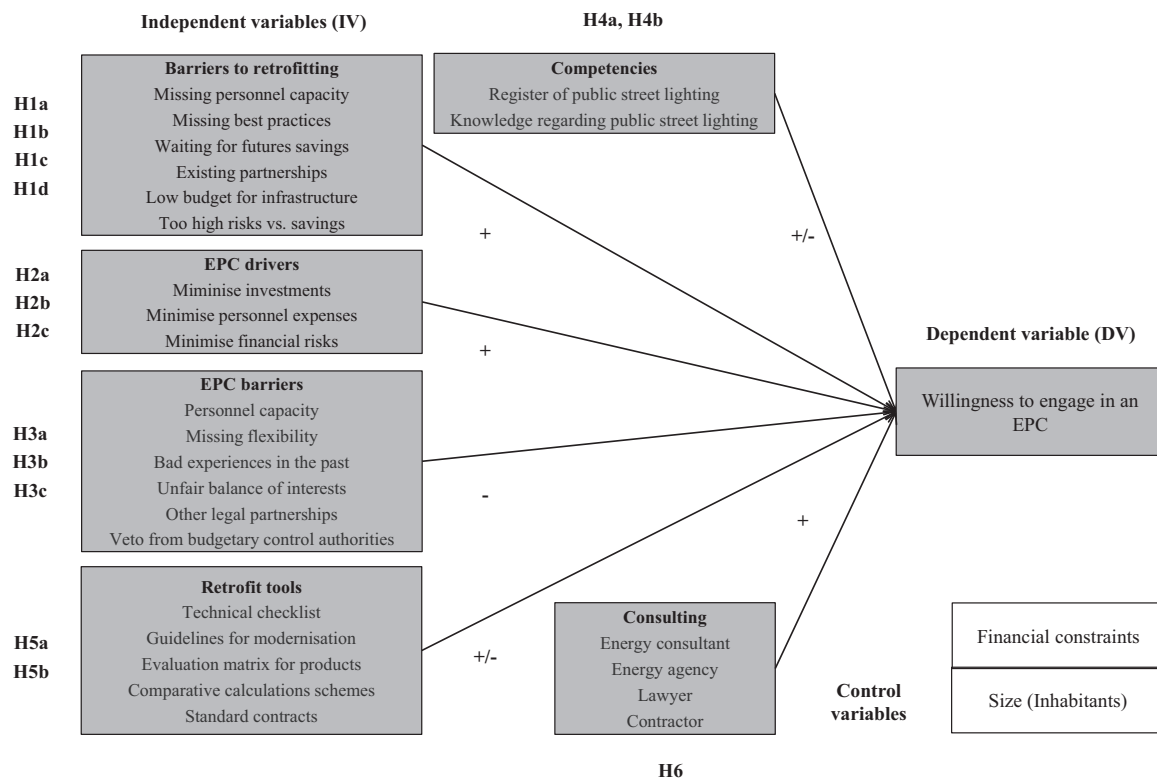


Fig. 1. Model of the quantitative regression analysis.

## 4. Results and discussion

### 4.1. Descriptive results

The descriptive statistics (see Table A.1) give an overview of the nature of our data (for a detailed descriptive analysis see also von Flotow and Polzin, 2015).<sup>4</sup> The drivers and barriers variables have been evaluated on a 5 point likert scale, which corresponds to the values in the table. Financial support variables represent the share of street lighting that has been modernised using the specific support. All other variables have been assessed as categorical or binary variables.

In the full sample, 20% of the municipalities experience financial constraints. Among the barriers to retrofitting the lack of funds for adjacent infrastructure and personnel capacity are the most salient. 224 of the municipalities consider engaging in an EPC while 68 local authorities actively employ EPCs for street lighting. Potential drivers for EPC are equally important for municipalities whereas among the barriers to EPC, the lack of flexibility and missing flexibility rank first. Municipalities commonly engage directly with energy consultants and energy agencies while direct engagement with lawyers and ESCos is less common. In the retrofitting process comparative calculations and guidelines are most prevalent as tools.

<sup>4</sup> More granular supporting data cannot be made openly available due to ethical concerns (privacy of the respondents). Further information about the data and conditions for access are available at the Sustainable Business Institute (SBI) Contact: www.sbi21.de.)

Comparing the sub-samples of municipalities that consider or already use EPC with the full sample reveals some interesting differences, although the general patterns are similar. On the one hand, barriers to retrofitting are perceived as more severe among municipalities that consider/use EPC. On the other hand, drivers for EPC are evaluated as more important whereas the barriers to EPC are perceived as less severe. Municipalities with a tendency towards EPC or usage tend to engage more with lawyers and ESCos compared to consultants which might be expected. Also the adoption of standard contracts as tools is higher among these local authorities. Interestingly, among the EPC users, tools for modernisation are less common. Additionally we gathered data about the ownership and management situation of street lighting in municipalities. 78% of local authorities that responded to the survey own their street lighting. This makes them free to choose between in-house management (30%) with some outsourcing services (21%), a national EUCo (28%), a local MUCo (15%) and a third-party contractor (ESCO) (3%) using EPC.

These results confirm prior research that highlighted EPC as a niche application for general public infrastructure retrofits (Marino et al., 2011; Pätäri and Sinkkonen, 2014; Hannon et al., 2013; Sorrell, 2005). Interestingly, when it comes to retrofitting specific infrastructures (i.e. street lighting), local authorities exhibit a greater tendency to rely more on outsourcing. Hence within the process of retrofitting, 5% of the municipalities rely on an EPC to manage the street lighting. This may be the result of lower transaction costs associated with outsourcing specific infrastructures and

individual technology retrofits compared to more intricate and interdependent technologies. Mapping possible individual or unique combinations of technologies (e.g. insulations, boiler and lighting) in a comprehensive energy service contract (comprising several technologies) would increase the cost of monitoring. Also, light bulbs, compared to other energy efficiency technologies (such as insulation), can be easily removed and collected once the client cannot pay the contracting fee. This reduces the risk of opportunism on the side of the client.

Table A.2 provides the aggregated correlation matrix for the dependent and independent variables. A full correlation table is included in the supplementary material of this article (Appendix B). There is a higher degree of correlation between the independent variables that represent a common theme (i.e. barriers to EPC). However, there is lower correlation between items across constructs (e.g. ‘barriers to retrofitting’). Hence multicollinearity between the explanatory variables is not an issue.

#### 4.2. Drivers and barriers for EPC in a municipal setting (logistic regression results)

Table 2 shows the results of our logistic regression, determining the categories of Considering energy service contracts for modernisation activities (1 or 0). The magnitude of the coefficients as well as the significance levels are shown. In addition the overall effectiveness of the model is assessed using Chi<sup>2</sup> and (McFadden) pseudo R<sup>2</sup> results. The sample size of 1016, which was obtained through the removal of cases with missing answers from the initial sample, provides a robust basis for the assessments of individual variables. Our fitted model can significantly predict the outcome (i.e. whether or not a municipality considers EPC) – see Chi<sup>2</sup> statistic significant at the 0.01 level. The fitted model further explains over a quarter of the variance, i.e. reasons why a municipality considers an EPC solution for retrofitting – see McFadden's pseudo R<sup>2</sup> of 0.28 (Long and Freese, 2006).

Below, we discuss our results in light of the hypotheses derived above and thereby contribute to the literature on EPC in the public sector.

##### 4.2.1. Barriers to retrofitting as potential drivers for an ESCo solution

Our results show that financial constraints represent a significant driver for municipalities to engage with a private ESCo (Table 2, line 2). This confirms hypothesis H1a. Hence EPC could be a means to alleviate budgetary constraints by reducing the financial burden in terms of energy costs. We further hypothesised personnel constraints to carry out the retrofitting as being a major driver for a local authority to consider engagement with an ESCo for modernisation. Retrofitting activities require capacities to evaluate technologies and products and to design an implementation strategy (H1b). Our results also warrant the acceptance of this hypothesis (Table 2, line 4). Our results therefore quantitatively confirm earlier work in the context of municipal modernisation (Polzin et al., 2015; Pätäri and Sinkkonen, 2014; Marino et al., 2011; Aasen et al., 2016).

In addition, the estimations show that EPC is considered a means to holistically modernise infrastructure (Table 2, line 9). In this respect we go beyond extant work (Pätäri

**Table 2**  
Results of the logistic regression analysis.

| Nr. | Considering EPC  | Coef.           | (Std. Err.)   |
|-----|--|-----------------|---------------|
| 1   | <b>Inhabitants</b>   | <b>0.27*</b>    | <b>(0.15)</b> |
| 2   | <b>Financial constraints</b>                                 | <b>0.68***</b>  | <b>(0.22)</b> |
| 3   | <b>Register streetlight present</b>                          | <b>0.24*</b>    | <b>(0.14)</b> |
| 4   | <b>Barriers to retrofitting: Personnel capacity</b>          | <b>0.23***</b>  | <b>(0.09)</b> |
| 5   | Barriers to retrofitting: Missing best practices             | 0.12            | (0.10)        |
| 6   | Barriers to retrofitting: Waiting for future savings         | 0.14            | (0.11)        |
| 7   | <b>Barriers to retrofitting: Existing partnerships</b>       | <b>0.30***</b>  | <b>(0.10)</b> |
| 8   | <b>Barriers to retrofitting: Risks outweigh the savings</b>  | <b>−0.20*</b>   | <b>(0.12)</b> |
| 9   | <b>Barriers to retrofitting: No funds for infrastructure</b> | <b>0.17**</b>   | <b>(0.09)</b> |
| 10  | <b>Drivers for EPC: Minimising investment</b>                | <b>0.97***</b>  | <b>(0.20)</b> |
| 11  | <b>Drivers for EPC: Minimising financial risk</b>            | <b>0.85***</b>  | <b>(0.20)</b> |
| 12  | <b>Drivers for EPC: Minimising personnel</b>                 | <b>0.35***</b>  | <b>(0.20)</b> |
| 13  | <b>Barriers to EPC: Personnel capacity</b>                   | <b>−0.23***</b> | <b>(0.10)</b> |
| 14  | Barriers to EPC: Lack of flexibility                         | 0.08            | (0.12)        |
| 15  | Barriers to EPC: Bad experience outsourcing                  | −0.14           | (0.12)        |
| 16  | Barriers to EPC: No balance of interests                     | −0.14           | (0.14)        |
| 17  | <b>Barriers to EPC: Existing legal partnerships</b>          | <b>−0.37***</b> | <b>(0.09)</b> |
| 18  | Barriers to EPC: Veto from budgetary control authorities     | −0.05           | (0.12)        |
| 19  | <b>Consulting: Energy consultant</b>                         | <b>−0.42**</b>  | <b>(0.22)</b> |
| 20  | <b>Consulting: Lawyer</b>                                    | <b>0.69**</b>   | <b>(0.33)</b> |
| 21  | <b>Consulting: ESCo</b>                                      | <b>2.44***</b>  | <b>(0.41)</b> |
| 22  | Consulting: Energy agency                                    | 0.25            | (0.28)        |
| 23  | Knowledge street lighting                                    | −0.03           | (0.18)        |
| 24  | Tools: Guidelines  | −0.17           | (0.23)        |
| 25  | Tools: Checklist   | −0.00           | (0.27)        |
| 26  | Tools: Evaluation matrix                                     | −0.00           | (0.28)        |
| 27  | Tools: Comparative calculations                              | 0.05            | (0.22)        |
| 28  | <b>Tools: Standard contracts</b>                             | <b>2.39***</b>  | <b>(0.66)</b> |
| 29  | Financial support: Kreditanstalt für Wiederaufbau            | 0.013           | (0.56)        |
| 30  | <b>Financial support: National Climate Initiative</b>        | <b>−1.05***</b> | <b>(0.40)</b> |
| 31  | Financial support: State level                               | −1.80           | (1.13)        |
| 32  | Financial support: Local level                               | −0.72           | (1.57)        |
| 33  | Financial support: Other                                     | −0.96           | (0.75)        |
|     | <b>_cons</b>   | <b>−2.84***</b> | <b>(0.76)</b> |
|     | N (observations)   | 1016            |               |
|     | Initial −2LL   | 707.97          |               |
|     | Model Chi <sup>2</sup> (d.f.)                                | 274.09 (33)***  |               |
|     | McFadden's pseudo R <sup>2</sup>                             | 0.28            |               |

Notes: \*\*\*, \*\*, denote significance at 1%, 5% and 10% significance levels, respectively; Logit command was used (Stata 13.1)

and Sinkkonen, 2014; Marino et al., 2011; Aasen et al., 2016). Missing funds to improve complementary infrastructure for lighting significantly drives the willingness to consider an EPC. This aligns well with our results showing that minimising investments, related risks and personnel would be/are the main reasons for considering an outsourcing solution.

Existing partnerships also have a significant effect on the willingness to consider energy service contracts as a possible means of outsourcing (Table 2, line 7) (H1c). On the one hand, experience with outsourcing leads to a positive attitude towards an EPC as trust had been established (Backlund and Eidskog, 2013; Marino et al., 2011; Aasen et al., 2016). On the other hand, legal commitments (in the form of maintenance contracts or commitments to MUCos etc.) prevent municipalities from considering alternatives such as EPC (see Table 2, line 17, relating to hypothesis H3c).

Furthermore, engaging in energy efficiency projects, particularly with ESCos, relates to the perception of risks (Table 2, line 8). According to our results, perceived high risks of retrofitting do not lead to a higher willingness to engage with an ESCo to mitigate these risks and thereby reject hypothesis H1d (Jackson, 2010; Hannon and Bolton, 2015; Uyarra et al., 2014). On the contrary, we show that the lower the perceived risk of a modernisation project, the higher the willingness to consider an energy service solution, which is in line with previous research (Hannon and Bolton, 2015). Still, this result necessitates further interpretation, as it contradicts results related to hypothesis H2b (see Table 2, line 11). One could argue that these conflicting results point to the fact that municipalities do not fully understand the risks related to the retrofitting process, which an EPC solution could partially address. Nevertheless, municipalities generally perceive outsourcing as a means to reduce risks (Pätäri and Sinkkonen, 2014).

Some barriers to modernisation such as personnel and financial constraints as well as missing funds for retrofitting the adjacent infrastructure for lighting could apparently be mitigated by an EPC. Others, such as waiting for technological improvements in end-use energy demand reduction technologies could not (see Table 2, lines 5–6) (Polzin et al., 2015; Steinberger et al., 2009).

We also evaluated the three most important reasons for engaging in an energy service contract in the literature: Minimising financial exposure, personnel and risks (Polzin et al., 2015; Hannon and Bolton, 2015). According to our estimations these all comprise highly relevant factors (see Table 2, lines 10–12), with the financial argument being most important, followed by reducing risks. Reducing the personnel burden was considered a less important driver for the outsourcing solution. Our results differ from prior research on municipal motivations to sign up to an EPC which highlighted reductions in personnel as a more important driver (Polzin et al., 2015; Hannon and Bolton, 2015) (H2a–c).

#### 4.2.2. Barriers to EPC in the public sector

As mentioned above, only 3% of German municipalities use EPC. In other European countries EPC also represents a niche application (Combes, 2014; Transparense, 2013), which points towards the existence of strong interdependencies between actors and a conservative institutional environment. This 'lock-in' may be a reason for the slow diffusion of LED lighting, end-use energy demand reduction technologies in general and/or ESCo solutions. Municipalities lacking sufficient in-house expertise do not appear to fully grasp the risks associated with the application of new technologies as they would otherwise be more inclined to outsource these risks to third parties. Our study provides important insights into the assessment of energy service contracts from the client side. Although an EPC may reduce the need for in-house capacity to retrofit lighting infrastructure, skilled personnel is nevertheless needed to manage the contract with the private ESCo. Thus our results highlight missing personnel for the management of an EPC as a significant barrier (H3a). According to our estimations, neither the missing flexibility in an EPC, perceived unfair balance of interests (H3b), nor bad experience with sale-and-leaseback or other public-private-partnerships (PPP) in the past (H3c),

are significant barriers for municipal representatives to consider contracting as an alternative way of sourcing (Table 2, lines 13–18). We contribute to the discussion of flexible vs. standardised contracts to enhance EPC diffusion by highlighting that flexibility of including maintenance measures in an EPC is a success factor (Aasen et al., 2016). Too much flexibility however increases transaction costs and would render municipal application unlikely (Polzin et al., 2015; Sorrell, 2007).

#### 4.2.3. Competencies, capacities and tools to conduct an EPC

We theorised about the required capacities and competencies to consider energy service contracts. Prior research highlighted the definition of a baseline and corresponding procedures for measurement and verification as drivers for an EPC solution (H4a) (Hartmann et al., 2014; Marino et al., 2011; Pätäri and Sinkkonen, 2014). Our estimations differentiate these works into two separate components, namely a measurement system for energy consumption and tools which support the overall EPC process. In-house street lighting expertise and most tools that are considered beneficial for the retrofitting process and an energy service solution do not exhibit a significant positive impact on the likelihood to consider EPC as a means for implementing the modernisation (see Table 2, lines 23–27). It appears likely that sufficient in-house expertise encourages in-house solutions. Still, the use of standard contracts that carry a built in balance of interest between municipality and guaranteed savings exhibits a strong significant probability to consider EPC. Finally, detailed energy cost information (in this case a complete inventory of the lighting infrastructure) for measurement and verification makes the consideration of an energy service solution more likely as ESCos can build upon these numbers and calculate the business case more easily (Table 2, line 3) (H4b). We thereby quantitatively confirm earlier work (Pätäri and Sinkkonen, 2014; Aasen et al., 2016).

Furthermore, we had concurring hypotheses regarding the use of specific tools for an EPC solution and modernisation in general. In this regard our results highlight concrete means of reducing the legal complexity of EPC as significant (Pätäri and Sinkkonen, 2014; Marino et al., 2011). Standard contracts that could achieve this aim have a highly significant positive influence on the consideration of contracting as a possible means of outsourcing (Table 2, line 28). Hence we can partly accept hypothesis H5a. This result further supports the argument of standardised contracts as a means to reduce transaction costs of EPC (Sorrell, 2007; Polzin et al., 2015). Other tools (Table 2, lines 24–27) neither precluded the consideration of contracting (as in-house modernisation would be more attractive when the necessary tools are at hand) nor further raised awareness for this form of outsourcing (H5b).

#### 4.2.4. The role of consultants in EPC

Prior research suggested the positive role of facilitators to cope with the complexity of the retrofitting process such as planning, tendering, implementation and monitoring (H6) (Bleyl et al., 2013; Polzin et al., 2015; Lemon et al., 2015; Nolden and Sorrell, 2016). Our estimations provide useful insights into this debate. Consulting an ESCo or a lawyer in the modernisation process leads towards a



higher propensity of considering an EPC solution while energy consultants tend to negatively influence this probability and consulting an energy agency has no statistically significant effect (Table 2, lines 19–22). This could be due to the fact that municipalities engaging with an energy consultant source the necessary resources to conduct the retrofitting on their own. Energy consultants might also consider themselves as technology and implementation companions, not as holistic process or procurement advisors, which is likely to neglect outsourcing options or legal competencies. Thus we can mostly reject our hypothesis H6. However, prior qualitative evidence point towards a knowledge deficit of energy consultants with regard to outsourcing and energy service solution and a positive role of energy agencies (Polzin et al., 2015).

In addition to the theorised results our estimations provide supplementary insights. Regarding the relationship between the size of the municipality and the use of EPC our results contradict prior research findings (see Table 2, line 1). Whereas Aasen et al. (2016) proposed no relationship between the size of the municipality and the likelihood to engage in EPC, we highlight a slightly positive significant influence. Hence the larger the municipality, the higher the willingness to consider an EPC solution.

Finally, our study emphasises the need to design support schemes that do not exclude an EPC solution (Table 2, line 30). In Germany the support measures did not include the possibility of engaging with a third-party, which leads to a significant negative probability of municipalities even considering an EPC solution if subsidies need to be rejected in return. With these results we complement recent work that highlighted a conducive policy framework as a major determinant for ESCo market development (Hannon et al., 2015; Marino et al., 2011; Bertoldi et al., 2014).

#### 4.3. Robustness checks

We conducted a number of robustness checks to check the consistency of our results. Firstly, we checked for multi-collinearity i.e. the correlation among explanatory/independent variables. Investigating the variance inflation factors (VIFs) reveals no multicollinearity, given the mean VIF of 1.25 and all individual values are below 2 which is well below the critical value of 5 (see Kutner et al. (2005)). Second, we ran our model using probit regression technique. The estimator displayed consistent results. Third, we aggregated the variables (barriers for retrofitting, drivers and barriers for EPC, consulting, tools and financial support) and ran a logistic regression again. The analysis displayed overall consistent results regarding the direction of and the height of the coefficients. Overall barriers to retrofitting positively increase the likelihood of considering EPC while drivers and barriers to EPC exhibit a positive respectively negative influence on the consideration of EPC. When aggregated, the usage of tools loses its explanatory power, consulting becomes overall positive and financial support schemes have an overall negative influence (see Table A.3 in the Appendix A).

## 5. Conclusions and policy implications

Accelerating the uptake of EPCs for retrofitting among public actors such as municipalities is economically and

socially desirable as it bears a huge (mostly untapped) potential for reducing carbon emissions and energy dependency as well as providing a relief for public budgets. However, this does not necessarily mean that EPC is always the most cost effective solution as this depends on competencies, capacities and existing partnerships. Total costs of EPC could be higher than of an in-house solution especially if the municipality has the technical, procurement and risk analysis capabilities in house (which is partly the case for larger cities). Hence, for an effective and efficient retrofitting, it is necessary to increase market transparency but also municipal capacity and competency to allow for a rational choice among in-house and outsourcing options.

The aim of this study was to quantify determinants for the consideration of energy service contracts as a means to modernising public properties (in this case public street lighting). Complementing prior research that has either dealt with barriers to ESCo market deployment on the supra-national level (Bertoldi et al., 2006; Marino et al., 2011; Bertoldi et al., 2014; Vine, 2005) or explored drivers and barriers in case studies covering the UK, Finland, Norway and Germany (Pätäri and Sinkkonen, 2014; Hannon and Bolton, 2015; Hannon et al., 2013; Polzin et al., 2015; Aasen et al., 2016; Nolden and Sorrell, 2016), this analysis evaluates drivers and barriers of an EPC solution in a large survey among German municipalities.

We can conclude that several barriers to retrofitting such as existing partnerships, missing financial resources for the modernisation of complementary infrastructure, missing personnel capacity as well as overall financial constraints lead to a higher propensity of considering an EPC solution. This corresponds well with the overall aim of the municipalities to reduce both the financial burden of investments and associated risks. Specific barriers to EPC lie in missing management capacity (both in terms of quantity and quality) and existing legal arrangements such as other modes of governance (especially long-term contracts with EUCos).

Most tools and expertise for the retrofitting process do not represent drivers for an EPC solution. However, engaging ESCos and lawyers as consultants in the retrofitting process increases the likelihood of considering energy service contracts. Energy consultants, on the other hand, may reduce the likelihood of municipalities to consider an EPC solution, possibly as a result of limited expertise and experience in this domain. Finally, support schemes for public sector retrofits should not preclude the use of energy service contract models (as they did in the German case) in order to fully make use of beneficial aspects of private sector engagement and to alleviate financial constraints in the long run.

#### 5.1. Implications for policy makers and ESCos

The estimations based on this survey have implications for decision makers in the public sector on the local, national or supranational level. Policy makers are the actors setting the regulations for market transparency, encouraging efficient retrofitting to address climate and budgetary concerns on the one hand and implementing retrofits on the other.

On a national level, our results show that there is the need to enhance expertise of facilitators and to effectively develop a more diverse energy service market for retrofitting. It is important to distinguish between different types of facilitators. Whereas technical facilitators that support the retrofitting process are well established, process facilitators that accompany the procurement (including the decision regarding outsourcing) could be better supported. Evidence from the UK suggests that process facilitators, particularly regarding the procurement process, can contribute to the reduction of transaction costs associated with EPCs (Nolden et al., 2015; Nolden and Sorrell, 2016).

Public authorities in the EU are subject to public procurement law, for which long-term EPC as a combination of goods and services might be challenging. Introducing statutory obligations for tendering to include more market-based solutions may improve choice and competition among governance models (Polzin et al., 2015). In addition, legislation at the EU level could be streamlined regarding the criteria for categorizing EPCs as a good or a service. These criteria should be then diffused among the municipalities. Additionally, accounting rules treating EPC as debt should be changed to address municipal budgetary issues. EPC provides the opportunity to modernise infrastructure while lowering the financial burden in the long run.

Reducing the (legal) complexity of an EPC solution through by promoting standard contracts is highly recommended to accelerate appropriate uptake of EPCs in the public sector. Although the flexibility of including maintenance services might have beneficial effects, the overall contract should be standardised, with balance of interests between the local authority and the ESCo accounted for. Standardisation reduces transaction costs relating to designing and negotiating the contract, which initiatives by the Department for Energy and Climate Change in the UK and SBI in Germany also show (SBI, 2013; Mayor of London, 2014). A solution to this trade-off may lie in modular contracts that offer different options such as maintenance, measurement and verification, supply of energy, contract duration or transfer of ownership to a special purpose vehicle (during or after the EPC).

Above all, capacity and competencies at the local level, both to implement modernisation processes and, where applicable, to consider possible ways of outsourcing, are considering crucial. Hence, policy makers should support the municipalities in gathering important information required for a neutral tender in which an EPC may be considered. We recommend the enhanced diffusion of best practices and guidelines, especially regarding the criteria to design tenders (see also Polzin et al. (2015)). Finally, support schemes that target the modernisation of public properties should not exclude an EPC solution to fully engage the private sector. On the other hand, public incentives for ESCo solutions could be combined with a white certificate system that specifies savings at the client level to be achieved by utilities and network carriers.

The research reported here also has implications for ESCos targeting the public property and infrastructure market. First and foremost, the ESCo has to be aware of the fact that municipalities considering an EPC solution

aim at reducing the financial and personnel burden for retrofitting as well as related risk in the long run while at the same time having limited personnel to manage the ESCo solution. To be economically viable, the total costs of an EPC (including production, transaction and finance costs – see Sorrell (2005) and Polzin et al. (2015)) need to be below the current and projected energy bill and the calculation should be readily accessible to municipal representatives. Second, to reduce (perceived) legal complexity our results strongly encourage the use of standard contracts that have a built in guarantee for savings and a fair balance of interest. However, these factors did not significantly influence the propensity of considering energy service contracts for retrofitting in the first place.

## 5.2. Limitations and future research

The authors of this research article acknowledge limitations that stem from the cross-sectional nature of the data and the focus on only one market and possible application for end-use energy demand reduction technologies. Hence future research might firstly expand this research by analysing the possibility for servitization of a combination of retrofit technologies, especially with regard to legal complexity and associated challenges. Secondly, scholars could conduct longitudinal analyses to see how determinants of an EPC solution in the public sector change over time. Additionally a survey based analyses could be conducted in other institutional settings to allow comparisons with research reported here. It is also unclear what a municipal loss of control over technologies such as lighting imply in the long run, particularly if flexibility regarding lighting hours is to be taken into account.

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## Appendix A

Questionnaire (translated from German)

### Demographics

1. How many inhabitants does your municipality have? (< 5.000, 5.000 < 50.000, 50.000 < 100.000, > 100.000).
2. Is municipality controlled by a supervisory agency with budgetary powers (financial constraints) (yes/no).
3. In which federal state is your municipality located? (16 German states).

### Lighting (current state)

4. How does the ownership structure look like? (ownership municipality, ownership EUCo/MUCo, possession municipality, possession EUCo/MUCo, partly privatized, completely privatized, other).
  5. Who manages the street lighting? (own management, partly outsourced, management by municipal utility, management by utility company, energy service contracting, other).
  6. Are the information about the state of the lighting system stored in a register (energy consumption, age, type of lamp, power, hours of operation)? (yes/no/partially).
  7. How many lamps of the following types are you currently using? (High pressure mercury vapor lamps (MVL), sodium-vapor lamps (SVL), metal halide lamps (MHL), (compact) fluorescent lamps, LED lamps).
  8. Besides street lighting, where are you also deploying LED in your municipality? (sports facilities, indoor lighting, decorative lighting for places of interest, other).
- Retrofitting of lighting**
9. Have you modernised (in the last ten years), do you modernise or do you plan to modernise the street lighting installations? (yes/no).
  10. To what extent do you use LED technology for your modernisation activities? (none (0%) rarely (0–20%), medium (20–50%), by the majority (50–80%), predominantly (> 80%).
  11. Why are you not using LED technology for your modernisation? (too complex, too expensive, not mature enough, already converted to SVL, we prefer to wait, bad experiences with LED retrofits, other).
  12. To what extent do you use SVL technology for your modernisation activities? (none (0%) rarely (0–20%), medium (20–50%), by the majority (50–80%), predominantly (> 80%).
  13. Why are you not using SVL/MHL technology for your modernisation? (too complex, too expensive, not mature enough, we prefer to wait, bad experiences with LED retrofits, other).
- Drivers for retrofitting**
14. What are the most important preconditions or success factors for a successful modernisation of public street lighting? (very high technical understanding (for the development of a modernisation plan and to conduct the corresponding tendering and evaluation of different offers, predictability of profitability of the retrofitting measures, support of independent consultants (for example, energy agencies, energy consultants, lawyers etc., participation of the population).
  15. Additional drivers/preconditions.
- Barriers to retrofitting**
16. What are the main barriers for modernisation activities? (the personnel capacity for the modernisation plan and the tendering process is not available, there is far too little positive experiences with respect to the success of the modernisation measures or use of LED in other municipalities, future technologies might offer even more savings offer; a modernisation at the present time would come too early, there are concession contracts or partnerships that preclude a modernisation, the EU eco-design directive does not change the availability of traditional light bulbs for the foreseeable future, the necessary financial resources for the modernisation of the adjacent infrastructure (masts, cables, etc.) are not available, there are too high risks vs. potential savings).
  17. Additional barriers.
- Energy service contracts**
18. Are you considering energy performance contracting for street lighting? (yes/no).
  19. Are you actually using EPC? (yes/no).
  20. Which form of energy service contract are you using? (energy performance contract, energy service contract without guaranteed savings, energy supply contract with guaranteed savings, energy supply contract).
- Drivers of energy service contracts**
21. What are/would be the reasons to source your street lighting out to a third-party contractor? (Minimising the investment and the necessary borrowing, minimising the financial risk (long-term calculable costs for energy-saving effect and light quality, transfer of default risk to the Contractor), minimising the current staffing and other resources of the local authority for the operation and planning of the municipal street lighting).
  22. What are the success factors of an ESCo solution? (manufacturer-independent support / consulting (for example, by consultants, lawyers or energy agencies), neutral tenders (regarding the products), early involvement of the local politicians, administration and population, transparency of the contract and a balance of interests, comprehensibility or simplicity of the contracts, guaranteed savings).
  23. Additional drivers.
- Barriers to energy service contracts**
24. What are the barriers for an EPC solution? (the required capacity for preparation, tendering and evaluation of the offers is not available, the possibility of flexible control during the contract duration is not feasible, there are too many bad experiences with public-private partnerships, cross-border leases etc., a fair balancing of interests between private sector and municipal interests is no possible, existing concession contracts or old lighting contracts hinder us, an approval of the energy service contract by the budgetary control authority (due to forfeiting) is difficult).
  25. Additional barriers.
- Consulting**
26. Which consulting services are you using? (energy consultant, energy agency, lawyer, contractor).
  27. Which (independent) consultant can you recommend?
  28. Why are you not using any consulting services? (too expensive, unknown, not required, other) Competencies and tools.
  29. How would you rate your knowledge/skills regarding street lighting? (poor, good, very good).
  30. Which of the following tools are you using? (technical checklist, guidelines for modernisation, evaluation matrix for products, comparative calculations schemes, standard contracts).
- Regulatory framework**
31. Which part of your street lighting have you modernised using the following financial support measures? (Kreditanstalt für Wiederaufbau (federal level), National Climate Initiative (federal level), state level, local level, other).
  32. What are the reasons not using any financial support mechanisms? (too expensive, unknown, not required, other).
- End**
33. Would you be willing to participate in a case study dealing with modernisation activities and energy service contracting?
  34. Here you can leave your email address if you like to receive the results of this survey and additional information or materials.

**Table A.1**  
Descriptive statistics.

| Nr.       | Variable                        | Obs. | Mean  | Std. Dev. | Min. | Max. | Agreement (% of 1 or 4 and 5) | Measurement  |
|-----------|---------------------------------|------|-------|-----------|------|------|-------------------------------|--|
| <b>1</b>  | <b>Consideration EPC</b>        | 1227 | 0.18  | 0.39      | 0    | 1    | 18.26                         | Dummy variable   |
| 2         | Inhabitants                     | 1298 | 1.87  | 0.71      | 1    | 4    | n.a.                          | < 5.000 (1), 5.000 < 50.000 (2), 50.000 < 100.000 (3), > 100.000 (4) |
| 3         | Financial constraints           | 1073 | 0.20  | 0.40      | 0    | 1    | 19.94                         | Dummy variable   |
| 4         | Register streetlight present    | 1298 | 1.31  | 0.76      | 0    | 2    | n.a.                          | Yes (2), partially (1), No (0)                                       |
| <b>5</b>  | <b>Barriers to retrofitting</b> | 1298 | 17.24 | 4.7       | 7    | 35   | n.a.                          | Aggregated variable  |
| 6         | Personnel capacity              | 1298 | 2.30  | 1.32      | 1    | 5    | 39.06                         | Likert scale 1–5   |
| 7         | Missing best practices          | 1298 | 2.39  | 1.18      | 1    | 5    | 20.26                         | Likert scale 1–5   |
| 8         | Waiting for future savings      | 1298 | 2.32  | 1.05      | 1    | 5    | 14.18                         | Likert scale 1–5   |
| 9         | Existing partnerships           | 1298 | 1.63  | 1.10      | 1    | 5    | 9.40                          | Likert scale 1–5   |
| 10        | Risks outweigh the savings      | 1298 | 3.25  | 1.33      | 1    | 5    | 11.48                         | Likert scale 1–5   |
| 11        | No funds for infrastructure     | 1298 | 2.24  | 1.04      | 1    | 5    | 51.93                         | Likert scale 1–5   |
| <b>12</b> | <b>Drivers for EPC</b>          | 1227 | 1.21  | 0.88      | 0    | 3    | n.a.                          | Aggregated variable  |
| 13        | Minimising investment           | 1227 | 0.39  | 0.49      | 0    | 1    | 38.63                         | Dummy variable   |
| 14        | Minimising financial risks      | 1227 | 0.36  | 0.48      | 0    | 1    | 35.94                         | Dummy variable   |
| 15        | Minimising personnel            | 1227 | 0.46  | 0.50      | 0    | 1    | 46.05                         | Dummy variable   |
| <b>16</b> | <b>Barriers to EPC</b>          | 1227 | 1.87  | 3.83      | 6    | 30   | n.a.                          | Aggregated variable  |
| 17        | Personnel capacity              | 1227 | 3.21  | 1.21      | 1    | 5    | 41.73                         | Likert scale 1–5   |
| 18        | Lack of flexibility             | 1227 | 3.52  | 0.98      | 1    | 5    | 52.65                         | Likert scale 1–5   |
| 19        | Bad experience outsourcing      | 1227 | 3.30  | 1.02      | 1    | 5    | 39.12                         | Likert scale 1–5   |
| 20        | No balance of interests         | 1227 | 3.29  | 0.91      | 1    | 5    | 37.16                         | Likert scale 1–5   |
| 21        | Existing legal partnerships     | 1227 | 2.51  | 1.31      | 1    | 5    | 23.06                         | Likert scale 1–5   |
| 22        | Surveillance authorities        | 1227 | 2.83  | 0.92      | 1    | 5    | 15.4                          | Likert scale 1–5   |
| <b>23</b> | <b>Consulting</b>               | 1298 | 0.64  | 0.80      | 0    | 4    | n.a.                          | Aggregated variable  |
| 24        | Energy consultant               | 1298 | 0.39  | 0.49      | 0    | 1    | 38.91                         | Dummy variable   |
| 25        | Lawyer                          | 1298 | 0.06  | 0.24      | 0    | 1    | 6.39                          | Dummy variable   |
| 26        | ESCo                            | 1298 | 0.04  | 0.21      | 0    | 1    | 4.62                          | Dummy variable   |
| 27        | Energy agency                   | 1298 | 0.147 | 0.34      | 0    | 1    | 13.79                         | Dummy variable   |
| 28        | Knowledge about street lighting | 1298 | 1.94  | 0.64      | 1    | 3    | n.a.                          | Poor (1), moderate (2), very good (3)                                |
| <b>29</b> | <b>Tools</b>                    | 1227 | 1.0   | 1.1       | 0    | 5    | n.a.                          | Aggregated variable  |
| 30        | Guidelines                      | 1227 | 0.27  | 0.44      | 0    | 1    | 27.14                         | Dummy variable   |
| 31        | Checklist                       | 1227 | 0.21  | 0.41      | 0    | 1    | 21.43                         | Dummy variable   |
| 32        | Evaluation matrix               | 1227 | 0.19  | 0.39      | 0    | 1    | 18.83                         | Dummy variable   |
| 33        | Comparative calculations        | 1227 | 0.35  | 0.48      | 0    | 1    | 34.88                         | Dummy variable   |
| 34        | Standard contracts              | 1227 | 0.03  | 0.16      | 0    | 1    | 2.53                          | Dummy variable   |
| <b>35</b> | <b>Financial support</b>        | 1298 | 0.33  | 0.38      | 0    | 3    | n.a.                          | Aggregated variable  |
| 36        | Kreditanstalt für Wiederaufbau  | 1298 | 0.06  | 0.18      | 0    | 1    | n.a.                          | % of retrofitted street lighting financed                            |
| 37        | National Climate Initiative     | 1298 | 0.20  | 0.29      | 0    | 1    | n.a.                          | % of retrofitted street lighting financed                            |
| 38        | State level                     | 1298 | 0.03  | 0.12      | 0    | 1    | n.a.                          | % of retrofitted street lighting financed                            |
| 39        | Local level                     | 1298 | 0.01  | 0.09      | 0    | 1    | n.a.                          | % of retrofitted street lighting financed                            |
| 40        | Other                           | 1298 | 0.03  | 0.13      | 0    | 1    | n.a.                          | % of retrofitted street lighting financed                            |

**Table A.2**  
Correlation matrix (aggregated measures).

|           | 1        | 2        | 3       | 4        | 5        | 12       | 16       | 23      | 28      | 29   | 35   |
|-----------|----------|----------|---------|----------|----------|----------|----------|---------|---------|------|------|
| <b>1</b>  | 1.00     |          |         |          |          |          |          |         |         |      |      |
| <b>2</b>  | 0.12***  | 1.00     |         |          |          |          |          |         |         |      |      |
| <b>3</b>  | 0.17***  | 0.18***  | 1.00    |          |          |          |          |         |         |      |      |
| <b>4</b>  | 0.05     | 0.25***  | 0.10*** | 1.00     |          |          |          |         |         |      |      |
| <b>5</b>  | 0.10***  | 0.00     | −0.01   | −0.10*** | 1.00     |          |          |         |         |      |      |
| <b>12</b> | 0.24***  | −0.01    | 0.05    | −0.07**  | 0.14***  | 1.00     |          |         |         |      |      |
| <b>16</b> | −0.15*** | −0.02    | −0.04   | 0.02     | 0.31***  | −0.02    | 1.00     |         |         |      |      |
| <b>23</b> | 0.16***  | 0.02     | 0.10*** | 0.11***  | −0.03    | 0.09***  | −0.07**  | 1.00    |         |      |      |
| <b>28</b> | −0.03    | 0.26***  | 0.00    | 0.20***  | −0.28*** | −0.12*** | −0.08*** | −0.03   | 1.00    |      |      |
| <b>29</b> | 0.02     | 0.18***  | 0.07**  | 0.17**   | −0.11*** | −0.02    | −0.01    | 0.09*** | 0.23*** | 1.00 |      |
| <b>35</b> | −0.12*** | −0.11*** | −0.05   | 0.04     | −0.19*** | −0.02    | −0.04    | 0.08*** | 0.08*** | 0.04 | 1.00 |

Notes: Category numbers stem from Table A.1; \*\*\*, \*\*, denote significance at 1% and 5% significance levels, respectively.



**Table A.3**

Logistic regression results (aggregated measures).

| Consideration contracting        | Coef.           | (Std. Err.)   |
|----------------------------------|-----------------|---------------|
| <b>Inhabitants</b>               | <b>0.34***</b>  | <b>(0.14)</b> |
| <b>Financial constraints</b>     | <b>0.73***</b>  | <b>(0.20)</b> |
| Register streetlight             | 0.16            | (0.13)        |
| Knowledge street lighting        | −0.02           | (0.16)        |
| <b>Barriers retrofitting</b>     | <b>0.10***</b>  | <b>(0.02)</b> |
| <b>Drivers EPC</b>               | <b>0.73***</b>  | <b>(0.10)</b> |
| <b>Barriers EPC</b>              | <b>−0.16***</b> | <b>(0.03)</b> |
| Tools                            | 0.03            | (0.09)        |
| <b>Financial support schemes</b> | <b>−0.87***</b> | <b>(0.27)</b> |
| <b>Consulting</b>                | <b>0.31***</b>  | <b>(0.11)</b> |
| <b>_cons</b>                     | <b>−2.4***</b>  | <b>(0.68)</b> |
| N (observations)                 | 1016            |               |
| Initial −2LL                     | 810.31          |               |
| Model Chi <sup>2</sup> (d.f.)    | 171.76 (10)***  |               |
| McFadden's pseudo R <sup>2</sup> | 0.17            |               |

\*\*\* Denotes significance at 1% level; Logit command was used (Stata 13.1).

## Appendix B. Supplementary material

Supplementary data associated with this article can be found in the online version at <http://dx.doi.org/10.1016/j.enpol.2016.03.049>.

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