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Abstract

Energy efficiency is widely recognized as a cost-effective strategy to meet energy demand. The U.S. energy service company (ESCO) industry generates significant energy savings and other benefits through installing and maintaining energy efficiency, renewable and other types of projects. In this study, we evaluate factors that may explain trends in the economic performance of U.S. ESCO projects by analyzing project level data for ~7,000 U.S. ESCO industry projects. We find that real project investment levels normalized for floor area have increased over time in ESCO projects across market segments. However, the dollar value of energy savings and other reported benefits have not kept pace with increases in real project investment levels over time. The latter have increased 100%-500% in various market segments from 1990 to 2017. We conduct an econometric analysis to decompose the drivers of these underlying trends. Number of measures and a changing mix of conservation measures are the primary factors that correlate with the long-term increase in project investment levels. However, our analysis is only able to account for less than 50% of the increase in real investment levels. We discuss additional factors, and conclude discussing policy implications and outlining long-term research needs.

1. Introduction

The U.S. energy services company (ESCO) industry provides energy savings and other benefits through comprehensive building retrofits, efficient equipment installation and other energy services. This private-sector industry has a 40-year track record of providing cost-effective energy efficiency, primarily to customers in the public and institutional sectors. The ESCO industry delivers significant incremental energy savings each year. In 2012, ESCO-implemented projects delivered energy savings (electricity, gas and other resources) of approximately 224 million MMBtu or about 1% of total annual energy consumption for all U.S. commercial buildings (Carvallo et al., 2015).

Larsen et al. (2012) define an ESCO as:

> *"A company that provides energy-efficiency-related and other value-added services and for which performance contracting is a core part of its energy-efficiency services business. In a performance contract, the ESCO guarantees energy and/or dollar savings for the project and ESCO compensation is therefore linked in some fashion to the performance of the project."*

ESCOs deliver cost and energy savings primarily through the energy savings performance contract (ESPC) business model. ESPCs are long-term contracts between ESCOs and end-use customers that enable customers to finance large energy efficiency, onsite generation, and other types of energy projects without the need for significant up-front capital. In an ESPC, the ESCO typically guarantees that the project will generate a specified annual stream of savings sufficient to pay back the project installation and financing costs. ESPC distinguishes ESCOS from other energy efficiency service providers that may install efficient equipment, but not provide performance guarantees. Nearly three-quarters of 2014 ESCO industry revenue came from performance contracting (Stuart et al., 2016). Non-ESPC agreements, such as fee-for-service or design-build[1] projects, made up about 15% of revenue; power purchase agreements (PPA), consulting and other services made up 10% of industry revenue (Stuart et al., 2016).

Public policy has also played an influential role in the development of the U.S. ESCO industry, specifically its popularity in the public/institutional sector (Goldman et al., 2005; IEA, 2017a). First, nearly all states and the federal government have enabled performance-based contracts through legislation that authorizes institutional sector entities to enter into long-term contracts with ESCOs. In these arrangements, capital investments in high efficiency equipment, controls, lighting, renewables and onsite generation are repaid through energy and operational savings over the expected lifetime of the project. Second, ESCOs have also utilized and leveraged financial incentives (e.g., rebates) offered by many U.S. electric and gas utilities for installation of high-efficiency equipment which can shorten the payback times for customers for high-efficiency and renewable energy investments. Utility rebates were particularly important in the earliest years of the ESCO industry in order to help overcome customers concerns regarding installation and technical performance of high efficiency equipment.

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[1] In a design-build project, the ESCO provides such services as energy auditing, project design and construction management, typically for a fixed fee, and does not contractually guarantee a specific level of energy or cost savings.

Past studies suggest a changing environment for the U.S. ESCO industry. Larsen et al. (2012) found that project investment levels were increasing somewhat faster than benefits in ESCO projects implemented between 1990 and 2008. Since that time, a range of economic conditions and government policies has affected the ESCO industry: the 2008 financial crisis, the American Reinvestment and Recovery Act (ARRA) of 2009[2], and Presidential mandates[3]. Stuart et al. (2018) reported that after 20 years of growth, ESCO industry revenue appeared to flatten between 2011 and 2014 at $5.3 billion (nominal $) and that the financial crisis, ARRA, and other factors may partly explain the trend.

A key objective of this paper is to address an important gap in recent research on the economics of energy efficiency, specifically U.S. ESCO industry projects, by exploring factors that may explain trends in project investment levels over time. We categorize ESCO projects into five contiguous vintages that reflect macro-economic trends, significant changes in electricity sector policies, and ESCO industry maturity (see Table 1).[4]

Table 1. ESCO industry vintages used in this paper

Vintage	Description
1990-1997	ESCOs mature as performance contractors. Public policy programs support the ESCO industry in consolidating its performance contracting business model (e.g., ESPC legislation passed in many states).
1998-2003	Electricity industry restructuring and retail competition creates a perceived opportunity for utilities to establish and/or buy many ESCOs. The California crisis brings this expansion to a halt, fundamentally altering the composition and structure of the ESCO industry
2004-2007	ESCO activity is positively influenced by resurgence in state-level energy efficiency policies as well as re-authorization of ESPCs by the federal government (Larsen et al., 2012).
2008-2011	This period includes the financial and economic crisis of 2008-2009 and subsequent years in which the U.S. economy experienced a severe recession and high unemployment. Federal stimulus packages increase ESCO activity in institutional sector (Goldman et al., 2011), but their reduced focus on performance contracting counters some of this effect (Stuart et al., 2018).
2012-2017	Between 2012 and 2017, post-recession economic growth is slow and the cost of capital (i.e. interest rates) are low, which encourages long-term commitments. Additional federal policy stimulus boosts ESCO activity.

A primary motivation for this research is that the long-term viability of a private sector efficiency services industry depends on its ability to deliver cost-effective projects that are highly valued by end users. This paper is intended to inform U.S. policymakers, ESCO industry executives, end-users, and other stakeholders interested in continuing to foster a robust private sector energy efficiency services

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[2] ARRA provided billions of dollars to federal, state and local government agencies for energy efficiency projects.

[3] The main presidential mandate under the Obama administration called for the federal government to acquire $4 billion in energy service performance contracting (ESPC) between 2013 and 2016.

[4] It is important to note that ESCO industry growth is somewhat correlated with growth in GDP.

industry. Analysis of trends in the U.S. ESCO industry may also be useful for policymakers and stakeholders in Asia, Europe, and other emerging markets.

The remainder of this report is organized as follows. Section 2 includes a literature review of ESCO industry development, market barriers and potential policy drivers. Section 3 describes our data sources and overall methodological approach. Section 4 provides descriptive statistics of key ESCO project variables. In section 5, we investigate potential ESCO project investment level drivers and their relative influence on investment trends using a regression model. Section 6 summarizes our findings, explores the impacts of cost increase in ESCO project economics, and identifies future research needs.

2. Research on ESCO industry, project economics and market trends

Most literature on the U.S. and international ESCO industries has focused on emerging ESCO models, broad market trends, and barriers to end users engaging in ESPC (e.g. Bertoldi et al., 2014, 2007; Bertoldi and Boza-Kiss, 2017; Hilke and Ryan, 2012; Marino et al., 2011; Nakagami and Murakoshi, 2010; Okay and Akman, 2010; Pätäri and Sinkkonen, 2014; Vine, 2005; Vine et al., 1999). A number of studies focus on barriers to ESCO industry development and potential policy drivers in specific European countries, for example Soroye and Nilsson (2010) and Kindström et al. (2017) in Sweden, and Pätäri and Sinkkonen (2014) and Pätäri et al. (2016) in Finland. In the UK, Hannon and Bolton (2015) and Hannon et al. (2013) examined public policy to support ESCO activity. Polzin et al. (2016) reported on the role of ESCOs in overcoming barriers to retrofitting public street lighting in Germany. The IEA (2017, 2016) includes updates on ESCO market activity in China, India, the European Union and the U.S.

In terms of economic analysis of ESCO projects, the majority of studies to date do not rely on empirical research and field evidence, but instead focus on economic concepts (e.g. Jaffe et al., 2004), theoretical models (e.g. Faggianelli et al., 2017; Robinson et al., 2015) or engineering estimates of investment levels and potential savings (e.g., McKinsey & Company, 2009). Hilke and Ryan (2012) noted that there is a lack of data and empirical evaluations of energy efficiency policies that would enable broad evaluation of impacts and benefit-cost ratio comparisons.

Available empirical analyses of the economic performance of energy efficiency projects in the U.S. have focused primarily on the evaluation of utility program portfolios rather than project level economics. For example, Hoffman et al. (2017, 2015) and (Molina, 2014) accessed annual data reported by utility program administrators to state public utility commissions to estimate the cost of delivering electric kWh savings for U.S. ratepayer-funded energy efficiency programs at the portfolio and program level, but not at the individual project level. Gillingham and Palmer (2014) reviewed empirical evidence on outcomes of three U.S. energy efficiency program and policy approaches including information, financial incentives and energy efficiency standards.

Most European empirical studies of energy efficiency economics focus on the programmatic- or sectoral levels. For example, Rosenow and Bayer (2017) conducted a cost-benefit analysis of the EU Energy

Efficiency Obligations[5] program at large. O'Malley et al. (2003) applied publicly available energy and policy data and conducted surveys to examine barriers to all available cost-effective[6] energy efficiency in three Irish market sectors: mechanical engineering, brewing, and the higher education sector. Very few U.S. or international studies have conducted empirical analyses of efficiency project investment levels and savings for the markets served by ESCOs. One study that has analyzed project trends reported that project investment levels (and by turn simple payback times) were increasing faster than the rate of inflation in Japan (Nakagami and Murakoshi, 2010). Those findings are consistent with Larsen et al. (2012).

Finally, other studies may have provided empirical analysis of project economics, but did not examine trends over time. For example, Burlig et al. (2017) used machine learning techniques to estimate aggregate realized savings from energy efficiency projects in CA K-12 schools implemented during 2008-2014. However, their analysis is constrained to the K-12 schools market in California and covers a narrow period.

3. Data sources and methods

This study analyzes ESCO-implemented project and measure level data from two datasets: the LBNL/NAESCO database of projects and the eProject Builder (ePB)[7] online database system. The LBNL/NAESCO database has served as the basis for a number of reports about the U.S. ESCO industry (Bharvirkar et al., 2008; Goldman et al., 2005, 2002; Larsen et al., 2012). This is the first time that measure level information from the ePB system is used in a formal analysis. We also draw from information on ESCO industry and market trends in aggregate from previous LBNL reports (Goldman et al., 2005; Satchwell et al., 2010; Stuart et al., 2018, 2013) and a review of ESCO and energy efficiency project economics literature.

3.1 LBNL/NAESCO database

LBNL has collected information from ESCO-implemented projects for more than two decades. The majority of the projects come from the accreditation process of the National Association of Energy Service Companies (NAESCO)—a national trade association for the ESCO industry. As part of this process, ESCOs seeking national accreditation submit applications that include detailed information from recently developed projects.[8] A small percentage of projects (<10%) in the database have been provided by state agencies that manage energy efficiency programs and the U.S. Department of

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[5] The EU Energy Efficiency Directive requires EU states to establish energy efficiency obligation (EEO) schemes. EEOs are resource standards for energy efficiency that require energy companies (e.g., utilities) to achieve annual energy savings of 1.5% of annual sales to end-use customers (European Commission, 2012).

[6] The authors define "cost-effective" as projects where the investment in energy efficiency provides a better rate of return than the cost of capital to the organization.

[7] See https://eprojectbuilder.lbl.gov/

[8] LBNL has limited information to determine whether the submitted projects are representative of all of the ESCOs' projects; thus, we do not assume that these data comprise a random sample from the population of U.S. ESCO projects. In our analyses, we report "typical" findings, such as median values and interquartile ranges for the available data, similar to Larsen et al. (2012) and Goldman et al. (2005). Average or mean values may produce different results, as they may be influenced by a few large projects that dominate the result.

Energy's Federal Energy Management Program (FEMP). Data typically includes project investment levels; estimated, guaranteed, and at least one year of verified savings data (physical and monetary); a list of the energy conservation measures installed, and information on project facility characteristics such as floor area or location. Appendix A.6 provides more detail about the data fields included in the database.

The LBNL/NAESCO database includes 6,314 projects implemented from 1982 to 2017, with the vast majority of the projects (> 98%) installed after 1990. This database contains projects representing over $16 billion (2016$) in total project investment levels without financing costs. The majority of U.S. ESCO activity has historically occurred in the MUSH markets (municipal and state governments, universities/colleges, K-12 schools, and healthcare facilities). In recent years, these markets combined have constituted ~65% of ESCO industry revenue (Hopper et al., 2007; Satchwell et al., 2010; Stuart et al., 2018, 2014). The LBNL/NAESCO database shows a similar breakdown: MUSH market projects account for about 70% of aggregate project investment levels. The federal market represents another 25% of all investment in the database, which is consistent with the sector's 21% share of ESCO industry revenue (Stuart et al., 2018). The private sector makes up about 8% of investment in the database, which is also consistent with its share of ESCO industry revenue (see Table 2).

Table 2. ESCO project investment level in the LBNL/NAESCO database by market segment (1990-2017)

Market segment	**ESCO project cost (M$ 2016)**	**Share of total investment in LBNL/NAESCO database (%)**
Federal Govt.	$ 3,732	23 %
State/Local Govt.	$ 3,217	20 %
Univ./Colleges	$ 2,361	14 %
K-12 Schools	$ 4,988	30 %
Healthcare	$781	5 %
Private Sector	$ 1,305	8 %
All Sectors	**$ 16,384**	**100%**

We perform several quality control analyses on and organization of the LBNL/NAESCO database raw data. First, we exclude projects that qualify as outliers; that were developed before 1990[9]; or that lack basic information on project characteristics (e.g., market segment, investment level, or location). Second, we classify project installation date into five different vintages as described earlier. Third, we follow earlier ESCO industry studies and assign each project to one of seven possible dominant retrofit

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[9] We excluded projects installed prior to 1990 because the U.S. ESCO industry was in its infancy and does not really represent the industry as only very few ESCOs were submitting their accreditation data.

strategies (DRS): onsite generation, lighting-only, major HVAC, minor HVAC, motors and drives, non-energy, and water conservation. Each DRS represents a group of measures that have similar investment intensity and that serves to characterize a project. Finally, ESCOs report the dollar value of energy and water savings in their projects. However, ESCOs use very different methods to estimate these savings and key input values and assumptions are often not transparent (e.g., assumed escalation rates in electricity and fuel prices). Thus, we develop and implement a method to recalculate the dollar value of energy and water savings with standardized retail prices for each ESCO project. See Appendix subsections 1, 2, and 3 for a detailed explanation of the methods and outcomes of the quality control and data manipulation process.

3.2 eProject Builder (ePB) database

ePB is a secure, online database that enables ESCOs and their customers to upload and track data for their energy savings performance contracting and other energy projects through the life of the contract term. ePB standardizes the collection of detailed project- and measure level information including measure investment levels, proposed and verified physical and monetary savings, and details about project financing. From a structural perspective, a key difference between ePB and the LBNL/NAESCO database is that ePB contains energy conservation measure (ECM) level investment levels and annual savings information. The LBNL/NAESCO database contains investment levels and annual savings at the project level only.

The ePB system was first released in June 2014 includes ~500 projects representing $4 billion (nominal dollars) in overall project investment levels. About 75% of the projects in the ePB database are federal market projects; thus, the data in ePB are not representative of all market segments served by the ESCO industry. The ePB database includes projects implemented from 1998 to 2017, which is a shorter time horizon than the LBNL/NAESCO database of projects (1982- 2017). Finally, about a third of the projects in ePB are also included in the LBNL/NAESCO database.

Given these limitations, we do not use ePB data for direct economic analyses, but as a support to specific analyses within this study. For example, the detailed ECM level data is useful for examining ECM level trends in savings and investment levels in federal projects whose effects may extend beyond the federal government market segment.

3.3 Analytical Approach

A central objective of this paper is to understand the extent to which various factors may contribute to trends in ESCO project investment levels over time. To explore this issue, we implement an Oaxaca-Blinder (O-B) decomposition to understand how much of the variation in the outcome variable – investment levels – is due to either changes in variables that influence project cost or changes in the sensitivity of project cost to these variables.

The O-B decomposition was introduced independently by Blinder (1973) and Oaxaca (1973) as a way to decompose the sources of differences in two groups. The labor economics literature commonly employs O-B decomposition to unearth sources of differences in wage levels among groups differentiated by gender, race, or other similar indicator. The two-fold O-B decomposition splits the difference in outcomes in two terms (Hlavac, 2018):

$$\Delta\bar{Y} = \underbrace{(\bar{X}_A - \bar{X}_B)'\hat{\beta}_R}_{\text{explained}} + \underbrace{\underbrace{\bar{X}'_A(\hat{\beta}_A - \hat{\beta}_R)}_{\text{unexplained A}} + \underbrace{\bar{X}'_B(\hat{\beta}_R - \hat{\beta}_B)}_{\text{unexplained B}}}_{\text{unexplained}} \tag{1}$$

In this equation, A and B correspond to the groups, and R corresponds to a reference group that can be formed by weighing A and B in different ways.[10] The explained term captures the impact on the outcome of changes of a given variable across groups. For example, assume that we are examining two groups (male and female), that the outcome is wage levels, and the variable is years of education. The explained term would capture how much wage difference is attributed to differences in years of education across the two groups. The reference regression coefficient, β_R, is calculated from the whole sample. The unexplained term captures the impact on the outcome of changes in the regression coefficient across groups. In this example, it would show how the gap in wages might be due to discrimination. The unexplained term can also reflect the impact of unobserved variables. The unexplained term can be divided further in the portion that relates to group A, and the one that relates to group B.[11] The advantage of the O-B method is that it quantifies the share of the change in the outcome (e.g. wage level) that is attributable to explanatory variables, or unexplained. A formal explanation of the O-B decomposition method can be found in Jann (2008).

A few energy-related studies have used the O-B decomposition to estimate the impact of demographic and preference changes on energy consumption (see Levinson, 2014; Morikawa, 2012). In this paper we follow the insight from Leard et al. (2019) and assign an older and a newer vintage to each of the two groups A and B. Then, the explained portion will capture the share of investment level change due to variation over time of each potential driver such as project savings, floor area, or types of measures installed.

4. Descriptive statistics and trends

This section provides a succinct overview of trends for key factors that are reported in the LBNL/NAESCO database that may correlate with trends in the economics to customers of ESCO projects. More information on ESCO industry and market trends can be found in the latest LBNL State of the U.S. ESCO Industry (Carvallo et al., 2018).

4.1 Key performance metrics

Table 3 summarizes information on the median cost, savings and contract features of ESCO projects in various market segments during the last decade (2008-2017). Median investment levels (in absolute terms) for ESCO projects are much higher in the federal sector than in any other market segment (\$5.3M vs. \$1.3-3.5M). However, this is primarily due to the larger size of federal facilities being retrofitted compared to the size of facilities in other market segments. Thus, when we normalize

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[10] The reference is formed by weighting coefficients for the regressions of groups A and B, or by pooling both groups together and running a "reference" regression. For more details see Neumark (1988) and Cotton (1988)

[11] This split is accomplished by comparing the regression coefficient of group A and B against the reference coefficient.

median project investment values by the floor area that is retrofitted in a facility, we find that project investment levels per square foot are approximately 50% higher in the MUSH market segment compared to federal government facilities.

Projects typically save 20% to 40% of annual baseline consumption depending on market segment. In contrast, normalized savings levels—expressed as savings per square foot—are relatively similar across markets. Investment level differences and savings level similarities translate to typical payback times that vary from 8 years for private sector projects to 12-13 years for public sector projects (e.g. federal and state/local governments). This difference reflects the fact that most private sector customers have higher investment hurdle rates than customers in the public/institutional sector market (Goldman et. al 2002).

Table 3. Typical values for key project performance metrics (2008-2017)

Key metric	Federal Govt.	Healthcare	K-12 Schools	Private	State/Local Govt.	Univ./Colleges
Floor area (MM sqf)	1 (n=140)	0.3 (n=82)	0.3 (n=778)	0.2 (n=73)	0.2 (n=405)	0.4 (n=220)
Investment level (MM $2016)	$5.3 (n=187)	$2.1 (n=95)	$2.3 (n=730)	$1.3 (n=138)	$2.7 (n=416)	$3.5 (n=222)
Investment per sqf ($2016/sqf)	$6.8 (n=108)	$8.9 (n=69)	$8 (n=709)	$5.1 (n=70)	$9.3 (n=359)	$6.5 (n=189)
Annual cost savings (MM $2016)	$0.3 (n=138)	$0.3 (n=63)	$0.2 (n=693)	$0.1 (n=54)	$0.2 (n=415)	$0.3 (n=194)
Annual cost savings per sqf ($2016/sqf)	$0.7 (n=98)	$0.7 (n=61)	$0.5 (n=678)	$0.5 (n=48)	$0.8 (n=368)	$0.7 (n=172)
Energy savings as % of utility bill (%)	38% (n=14)	19% (n=27)	18% (n=408)	19% (n=21)	21% (n=200)	20% (n=83)
Contract length (years)	13 (n=213)	9 (n=77)	14 (n=711)	11 (n=20)	13 (n=423)	11 (n=197)
Simple payback time (years)	12 (n=130)	9 (n=53)	13 (n=647)	8 (n=52)	12 (n=359)	11 (n=170)

4.2 Trends in project benefits

Project benefits— annual energy and non-energy dollar savings—have generally increased in the past three decades (see Figure 1). Federal and state/local government markets savings have increased by 300% and 100% in the last three decades, respectively. Typical savings have stabilized in the remaining market sectors at around $ 0.5/sqf. Saving levels have historically been lower in the K-12 schools, university/colleges, and private markets.

4.3 Trends in project investment levels

Larsen et al. (2012) observed that project investment levels were increasing faster than project savings over the 1990-2008 timeframe. Table 4 summarizes median values for project investment levels by market segment and vintage. Median absolute project investment levels have increased by more than 500% in the federal, healthcare and private sectors between the earliest and most recent vintages. Project investment levels have grown nearly 1,000% in the state/local government market segment, from a median of $0.6 million in the earliest vintage (1990-1998) to a median of over $6 million in the most recent vintage (2012-2017). Investment levels in the K-12 schools and university/college projects have increased ~200% between the first and most recent vintages. The university/college market segment has the highest median project investment levels of any market in the most recent vintage with a median project investment level of ~$7 million.

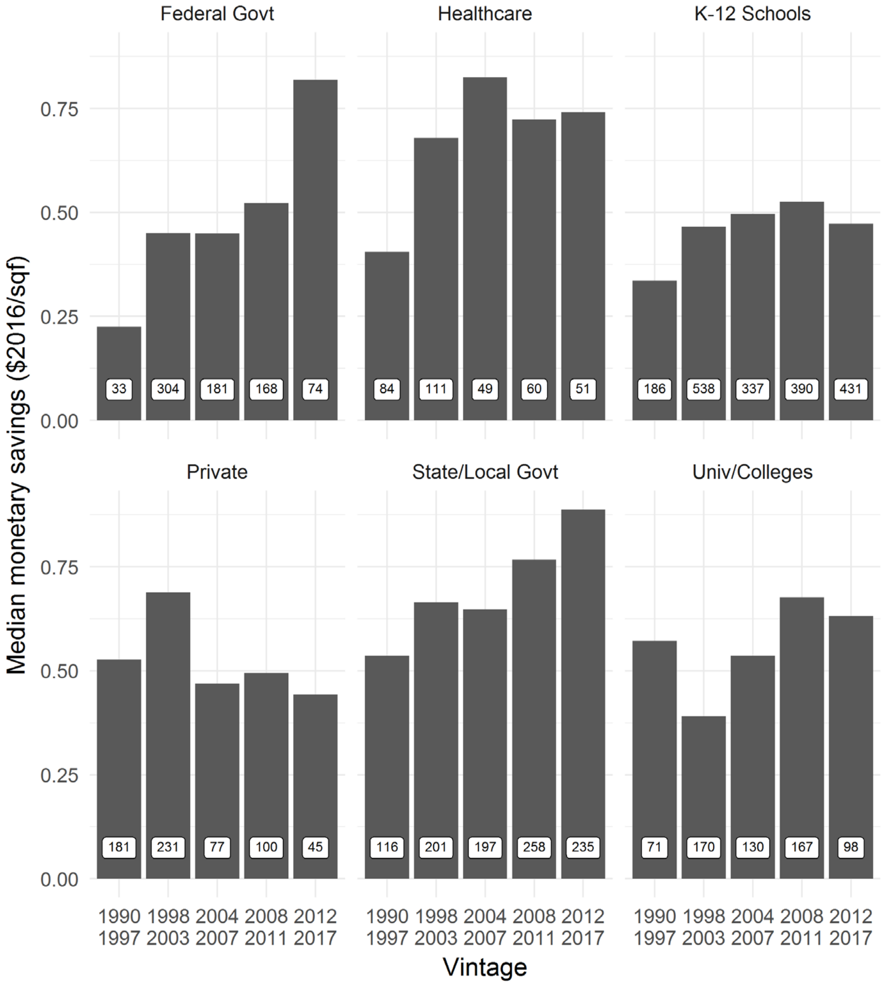

Figure 1. Trends in normalized typical monetary savings by source

As we look at trends in project investment over the last three decades, it is important to understand the influence of public policy and economic drivers. For example, during the 2008-2012 period, ESCOs that were developing projects responded to the very large economic stimulus provided by the American Recovery and Reinvestment Act (ARRA) as well as the impacts of a very severe economic recession. Median project investment levels increased substantially in the ARRA period for the federal government sector, whereas there were significant decreases for the private sector during this same period. These findings likely reflect the expanded federal activity buoyed by ARRA and austerity in the private sector amidst economic uncertainty and a slower-than-expected economic recovery. It should be noted that median project investment levels increased substantially in the most recent vintage—the post-ARRA period (2012-2017) — for the state/local government, K-12 schools and university/college market segments. This trend may reflect project investments made by these customers to address ongoing deferred maintenance issues as reported by Larsen et al. (2012).

Table 4. Median project investment levels without financing charges by market sector and vintage

	Median project investment levels (million 2016$)						
Market segment	**1990 - 1997**	**1998 - 2003**	**2004 - 2007**	**2008 - 2011**	**2012 - 2017**	**Growth between first and last vintage (%)**	**Growth between second and last vintage (%)**
Federal government	$0.8	$2.9	$3.3	$5.3	$5.5	588%	90%
Healthcare	$0.5	$1.2	$2.5	$2.7	$3.0	500%	150%
K-12 Schools	$1.6	$1.4	$2.0	$2.1	$4.9	206%	250%
Private	$0.4	$0.6	$1.8	$1.0	$2.9	625%	383%
State/Local government	$0.6	$1.5	$2.1	$2.0	$6.2	933%	313%
University/Colleges	$2.5	$1.7	$2.6	$3.4	$7.3	192%	329%

Trends in absolute level of project investment can be driven, in part, by changes in the size of the facilities being retrofitted. All market segments report significant increases in normalized project investment levels since the earliest vintage (the 1990-1997 period), although K-12 schools, universities/colleges and private sector project investment levels per square foot have been plateauing in more recent vintages.

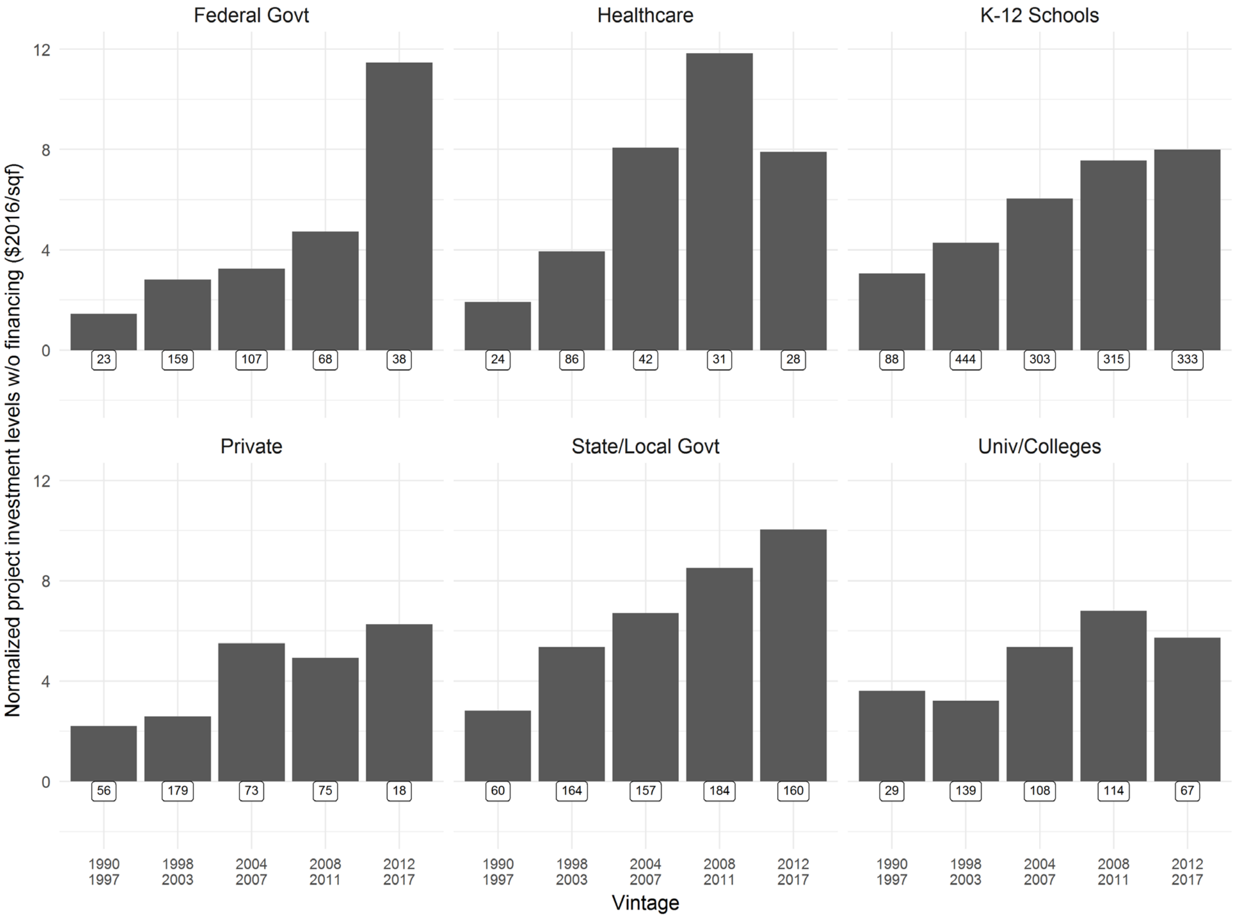

Figure 2. Trends in normalized project investment levels

We compare these overall project investment level trends with specific ECM level investment trends for the nine most frequently reported measures within the ePB database (see Figure 3). We estimate normalized investment levels by dividing inflation corrected investment levels by floor area of the retrofitted space (there is no ECM-specific floor area information). The ePB database includes a relatively larger share of projects for the two most recent vintages (2008-2011 and 2012-2017). In general, we find that normalized ECM investment levels have doubled or tripled for most ECMs since the 2008-2011 period. This finding suggests that there appears to be *both* measure level and overall project level factors concurrently affecting the long-term increase in project investment levels.

Figure 3. ECM normalized investment levels for the most frequently reported measures in ePB

5. Contribution of factors that affect project investment level trends

Based on previous research and discussions with ESCOs, we hypothesize that the level of project investment is correlated with the following factors:

- An increase in ESPC projects that are more expensive per square foot than non-ESPC projects;
- A changing mix of project measures with the increasing presence of more capital-intensive measures (e.g., onsite generation, roof replacement) which we characterize by defining a dominant retrofit strategy for each project;
- An increase in energy savings; and
- An increasingly comprehensive mix of measures in projects.

We hypothesize that projects that produce higher absolute energy savings (MMBtu) would also have higher absolute investment levels due to the effort involved in designing and implementing a retrofit project that is expected to yield greater energy savings.[12] There is evidence that more capital-intensive technologies can produce more customer savings (DOE, 2017).

We also included census sub-region as a categorical variable in earlier models, but it was not a statistically significant variable and thus excluded from the final regression results. Discussion with ESCOs revealed that labor and materials costs might also affect project investment levels. Labor costs for contractors do vary somewhat by region (e.g. higher in New England and California compared to the Midwest and South). However, institutional sector customers (Federal and state government) are required by law to pay prevailing union wages in implementing projects; thus wage differentials between high-cost and low cost regions of the U.S. are not as great as in private sector projects, which are a small part of the ESCO market. We do not include labor or materials factors because that information is not reported with project level data in the LBNL/NAESCO database. However, we do examine the evolution of these variables in the discussion section to assess to what extent they may relate to the unexplained term in the O-B decomposition.

5.1 Modeling ESCO project investment levels

We employ the following econometric model to study the relationship between project investment levels and other project factors[13]:

$$inv_{i,t} = \beta_1 + \beta_2 \cdot ESPC_{i,t} + \beta_3 \cdot retrofit_{strat_{i,t}} + \beta_4 \cdot floorarea_{i,t} + \beta_5 \cdot savings_{i,t} + \beta_6 \cdot num_{measures_{i,t}} + \varepsilon_{i,t} \tag{2}$$

In this model, the subscripts *i* and *t* represent project and vintage of installation year, respectively; *inv* is the absolute project investment in \$2016; *ESPC* indicates whether the project was developed using a performance contract; *retrofit_strat* indicates the dominant retrofit strategy that characterizes the project (i.e., project *composition*); *floorarea* is the surface area of the retrofitted facilities measured in ft^2; *savings* are physical energy savings measured in MMBtu[14]; and *num_measures* is the number of installed conservation measures (i.e., project *comprehensiveness*). See Appendix A.4 for additional details about the method, implementation, and results.

5.2 Oaxaca-Blinder decomposition results

We run a O-B decomposition in R using the *oaxaca* package (Hlavac, 2018). When running a two-fold decomposition, there is a choice on the selection of the reference group used to measures changes

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[12] We exclude physical water savings from the savings variable because water units (gallons) cannot be readily converted to energy units (MMBtu). Physical water savings also tend to produce lower monetary savings than energy savings and they are less prevalent across ESCO projects than energy savings.

[13] We analyze the potential multicollinearity between the continuous variables in our specification: floor area, savings, comprehensiveness, and investment levels. We calculate variance inflation factors (VIF) to test for collinearity among explanatory variables. We run the analysis for each market segment and find no collinearity among the variables of interest. More details can be found in Appendix A.4.2.2

[14] We use physical resource savings instead of monetary savings to isolate from the effect of commodity prices that are not under the control of the project developer and hence should be unrelated to project investment levels.

across groups and changes of regression coefficients. We employ the method proposed by Neumark (1988) using a pooled regression across our sample of projects.

The O-B decomposition is set up by selecting projects that belong to either the first or the last vintage in our sample. We use 1990-2000 as the early vintage because it reflects the maturation of the ESCO industry in the 1990s and the initial euphoria during electricity industry restructuring that retail competition would lead to significant growth in the ESCO industry. This choice for first vintage for the O-B decomposition also has sample size advantages compared to the first vintage defined in Table 1. The most recent vintage is still 2012-2017. We then assign each project to group A (last vintage) or group B (first vintage). We create dummy variables to identify the dominant retrofit strategy in each project and omit “Lighting-only” to prevent perfect multicollinearity.

Group B, the first vintage, has 600 projects with complete data, while group A has 394 projects. The mean project investment level is $2.10 million and $4.68 million for group B and A, respectively. The mean difference in project investment levels to be explained with the O-B decomposition is then $2.58 million, which is approximately 120% and consistent with market level metrics (see Table 4).

5.2.1 Regression results for floor area and resource savings

Table 5 summarizes the regression results for groups A and B. Coefficients for floor area and resource savings (the two continuous factors) are consistently significant and positive, as intuition suggests. Projects that retrofit a larger footprint and that have higher savings correlate with higher investment levels. Coefficients across groups have remained stable for floor area, but more than doubled for savings. The latter means that an additional unit of savings correlates with 2.5 times higher investment levels in the recent vintage compared to the older vintage. This is consistent with a low-hanging fruit phenomenon: achieving one unit of savings in recent projects requires more than twice as much investment as in older ones.

Table 5. Group A and B regression coefficients for O-B decomposition

Type of factor	Group	Factor name	First vintage (Group B)	Last vintage (Group A)
Continuous		Floor area	1.06*** (0.14)	1.67*** (0.26)
Continuous		Resource savings (MMBtu)	41*** (6.96)	100*** (11)
Discrete		Comprehensiveness (number of different project measures)	147493*** (28142)	16758 (29954)
Categorical	Contract type (base: non-ESPC)	ESPC	515346* (226425)	-1809359* (712301)
Categorical	Dominant Retrofit Strategy (base: Lighting only)	Major HVAC	1258561*** (334223)	3042969* (1186177)
		Minor HVAC	-428084 (293882)	653645 (1198332)
		Motors and drives	-461213 (315032)	101266 (1361321)
		Non-energy	518296* (313541)	2175361* (1180040)
		Onsite generation	2801293*** (536411)	4397355*** (1258157)
		Water conservation	-874058 (837882)	3439504* (2018833)
Continuous		Constant	-388427 (245605)	1843584 (1187116)
		Number of observations	600	394
		Adjusted R^{2}	0.3975	0.4036

Standard errors in parentheses; *, **, and *** significant at 5%, 1%, and 0.1% respectively.

Accounting for project level savings – rather than measure level savings - may obscure the contribution that specific ECMs have to investment levels. There is no measure level data in the LBNL/NAESCO database, but there are projected savings and investment level data at the measure level in the ePB dataset. We run a simplified regression of investment levels over savings controlling by market segment and ESCO using the ePB dataset over a sample of the most prevalent ECMs (see Table 6).

Table 6. Regression coefficients for energy savings from selected ECM Categories using ePB measure level data

ECM Category	Measure Count	Coefficient for savings
Lighting Improvements	642	0.137*
Building Automation Systems/Energy Management Control Systems (EMCS)	528	19.72***
Heating, Ventilating, and Air Conditioning	485	2.65*
Water and Sewer Conservation Systems	305	4.23
Chiller Plant Improvements	241	12.97***
Boiler Plant Improvements	236	9.35*
Chilled Water, Hot Water, and Steam Distribution Systems	201	27.75***
Building Envelope Modifications	154	-0.25
Renewable Energy Systems	151	115.59***

The regression coefficients for the more common ECMs in Table 6 are generally lower than the project-level energy savings coefficients in Table 5. The project level coefficients range between 41 and 100 and the ECM level coefficients between 0.14 and 150. This is expected because savings are additive, which means that the coefficients for resource savings in Table 5 should be the mean sum of coefficients from all ECMs installed. Projects will be composed of a mix of measures and hence a mix of energy savings potential.

5.2.2 Regression results for ESPC, comprehensiveness, and DRS

ESPC shows a remarkable change over time. In the first vintage, a performance-based contract (i.e., ESPC) correlates with increased project investment levels. This may be explained by higher transaction costs related to RFP processes and long development cycles; M&V required for verifying guaranteed savings; and building the costs of the ESCOs' performance risk into project investment (Tetreault and Regenthal, 2011). Reliance on ESPC correlates with reductions in project investment in the most recent vintage compared to non-ESPC, which is generally unexpected. This could be explained by the maturity and refinement of ESCO performance contracting business models, which have been used by ESCOs for more than 20 years in the U.S. Indeed, the performance requirements for ESPC projects in some market segments (e.g., MUSH) have eased over time, with durations[15] that are shorter than the full contract term (e.g. 1-3 years). This change has reduced the performance risk premium of ESPC projects in recent vintages. We must always consider that data may not be fully representative, especially if sample sizes are low as in this case[16].

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[15] In performance contracting, project performance is assessed during a specific evaluation period. This duration has been shortening in time, according to our conversations with ESCO stakeholders.

[16] We tested a few different specifications for equation (1), excluding some variables and removing outliers. In all cases, the coefficient for ESPC in the recent vintage was negative.

Comprehensiveness in ESCO projects can represent the number and types of measures installed. Larsen et al. (2012, p.24) define comprehensiveness as:

"Installation of multiple measures that address the full range of energy efficiency and, in some cases, supply opportunities in an individual building as well as any interactive effects among system components or building systems."

In this analysis, we define comprehensiveness as the number of *different types* of measures. This definition provides a readily quantifiable metric necessary for the purposes of regression analysis. Regression coefficient for comprehensiveness is statistically significant in the first vintage only. Results suggest that project investment levels increase by about $0.15 million for each additional measure installed. While not significant, the coefficient for the recent vintage is an order of magnitude lower. The effect of and changes in comprehensiveness may potentially be explained by the fact that investment levels are driven more by the specific *types* of measures installed than the number and diversity of measures.

The types of measures installed are measured through the dummy variables that represent one of seven possible dominant retrofit strategies that a project can implement. Results show that major HVAC, non-energy, and onsite generation are statistically significant and positive. This is expected because the baseline is lighting-only measures, which are typically the least capital-intensive retrofit strategy (see Figure 3). Their relative impact in investment is also reasonable: an onsite generation DRS correlates with higher investment levels than major HVAC DRS, which in turn correlates with higher investment levels than non-energy DRS.

The three strategies mentioned above have significantly increased their impact on investment levels over time which can be seen by comparing the coefficients for groups B and A. For example, onsite generation projects were $2.8 million more expensive than lighting-only projects in the first vintage, but they are $4.4 million more expensive in the last vintage. Since we do not have information on the capacity of the onsite generation projects, one plausible hypothesis is that customers have been deploying larger generation systems in their premises over time. This is supported by the distributed PV system size trends reported by Barbose and Darghouth (2016). In the case of major HVAC retrofits, investment levels increased from $1.3 million to $ 3 million for these systems over time. A plausible explanation could be related to deeper and more complex HVAC retrofits, although part of that variation would be captured by the comprehensiveness variable. Another plausible explanation is that HVAC systems have become more expensive, perhaps due to an increase in materials costs. We explore this hypothesis further in the discussion and conclusion section.

5.2.3 O-B decomposition results

The O-B decomposition results are reported in Table 7. We report results using both pooled regressions. The "no indicator" one does not use the group indicator (i.e. the vintage) as a covariate; the "indicator" one does include this covariate. The literature has generally preferred to employ the no indicator method proposed by Neumark (1988), but we report both for comprehensiveness.

Table 7. O-B decomposition of investment level differences for two weighting methods

	Pooled, no indicator		Pooled, indicator	
	Explained	Unexplained	Explained	Unexplained
Floor area	-1%	14%	-1%	14%
Resource savings (MMBtu)	2%	25%	2%	25%
Comprehensiveness (number of different project measures)	12%	-37%	7%	-32%
ESPC Contract	1%	-82%	0%	-81%
Major HVAC	5%	1%	8%	-2%
Minor HVAC	2%	-4%	0%	-2%
Motors and drives	7%	-6%	2%	0%
Non-energy	1%	1%	5%	-3%
Onsite generation	9%	-2%	10%	-3%
Water conservation	0%	1%	0%	1%
Lighting-only	7%	-6%	0%	0%
Constant	0%	148%	0%	148%
Total share	46%	54%	34%	66%

Results show that the changes in modeled variables – floor area, savings, comprehensiveness, composition (i.e., dominant retrofit strategy), and a performance contract – are able to explain between 34% and 46% of the increase in project investment levels over time, depending on the pooling method. This means that between 54% and 65% of the increase in investment levels remains unexplained. This fraction could be explained by structural changes in project development that underlie the data, or is explained by unobserved factors that have changed over time that are not tracked in our data.

Among the explained portion, changes in the dominant retrofit strategy utilized in ESCO projects explain about 25-30% of increase in project investment levels. This is due to the increased deployment of onsite generation (9%-10% of variation in investment levels) and major HVAC (5%-8% of variation) over time (see also Figure A.5.2 in Appendix). Changes in the comprehensiveness of ESCO projects (i.e., the number of installed measures) also have high impact and explain between 7% and 12% of the increase in project investment levels. However, comprehensiveness was not statistically significant for the recent vintage regression (see Table 5). Changes in floor area, resource savings, and ESPC contribute marginally to increases in project investment levels over time, largely because these variables have not changed significantly between the earliest and most recent vintages.

The unexplained term is challenging to understand when groups are formed by two vintages[17]. Technically, this term represents changes in the regression coefficients over time. A regression

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[17] Furthermore, the unexplained term can be difficult to measure and understand in general. See for example the discussion in Elder et al. (2010)

coefficient represents how much the outcome variable changes as a response to variation in the independent variable, controlling by the other variables in the model. In the labor economics literature, when groups are based on race or gender, the unexplained term is usually assumed to represent gender or racial discrimination in the labor market. This is because the regression coefficient is describing a structural property of the labor market, which treats one group compared to another group differently.

In this study, we split groups by vintage to explain trends in project investment levels. Then, changes of the regression coefficients may describe structural changes over time in project design, development, construction, and operation that are not captured in the variables used in the regression. For example, we had hypothesized earlier that savings may be affected by a low-hanging fruit phenomenon. This means that a unit of savings correlates with a larger change in investment in recent years compared to the first vintage, which may reflect that achieving savings is becoming more costly. This is consistent with the findings in Table 7, which indicate that 25% of investment level increase is related to change in the regression coefficient of resource savings, not to changes in savings per se. To directly track the low-hanging fruit phenomenon and include this variable as an explained term, we would need an objective metric for ease of savings in buildings. To our knowledge, this metric is unavailable and potentially difficult to produce.

The high contribution to investment level *decrease* of ESPC models in the unexplained term is worth discussing. The low explained contribution of ESPC to project investment level increase suggests that there has not been dramatic changes in industry-level use of ESPC over time. The unexplained term for ESPC suggests that there are unobserved properties of ESPC projects that have made them less investment intensive over time than non-ESPC projects.

6. Other factors that may affect project investment levels

The unexplained fraction of the O-B decomposition can reflect unobserved factors that are not part of the ESCO data. We explore a few relevant factors in this section chosen based on discussion with ESCO stakeholders.

First, changes in financing costs (e.g. interest rates) over time may influence project investment levels. A reduction in interest rates makes the cost of capital less expensive, which can lead to increases in project investment as less money has to be spent in financing and debt and more money can be used for the cost of the installation. The LBNL/NAESCO database cannot be used to test this hypothesis because of data quality and availability issues (e.g. many ESCOs report project costs and exclude financing costs over the contract term). However, we use reported project interest rates from ePB to run a simple regression against ePB project investment and find that they are negatively correlated: *lower interest rates are correlated with higher investment levels*.[18] Nominal interest rates have decreased substantially and remained low over the last decade (St Louis FED, 2018). It follows that part

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[18] ESPC legislation in many states stipulates the maximum payback time for an ESCO project (often including financing costs). Thus, if interest rates are lower (which leads to lower financing costs), ESCOs can propose and install a more comprehensive set of measures with higher installation costs and still meet the customer’s constraint on maximum payback time.

of the recent ESCO project investment level increase may be correlated with the decrease in interest rates.

Second, inclusion of more non-energy measures (NEMs) by ESCOs in projects as well as changes to internal ESCO cost components (e.g., labor, materials, and markup) may also explain increases in project investment levels over time. Non-energy measures (NEMs) are generally more capital intensive than ECMs (Larsen et al. 2012). An increase in adoption of non-energy measures over time could be correlated with higher investment levels. There is evidence that ESCO customers have increased the use of ESPC for capital and facility improvement needs (Stuart et al., 2016). This increase is partly informed by tighter capital budgets in the state/local government and constraints in the use of appropriations in the federal government (Gilligan, 2018). Institutional customers then use ESPC to fulfill their capital improvement needs by combining a larger number of NEMs with ECMs in energy efficiency projects. To test this hypothesis, we would need NEM level cost data, which is not available in the LBNL/NAESCO database.

Third, there is little or no publicly available information on the actual cost structure of past ESCO projects. In its simplest form, direct project investment levels can be decomposed into internal labor costs, materials expenditures, and a project level markup that includes indirect costs, overhead, and profit. For purposes of this analysis, we exclude financing costs that are charged by 3rd party financial institutions that finance ESPC projects as well as any incentives/rebates that were offered by utility energy efficiency programs and accessed by ESCOs and/or customers. Changes in any of these three, unobservable internal cost components—labor, materials, and markup—can help explain absolute project investment level increases that have been captured in the temporal trend component of the regression analysis.

To examine these factors more deeply, we evaluate U.S. Bureau of Labor Statistics data and find that costs for labor pertinent to the ESCO workforce have increased less than 10% during the analysis period of 1990-2017 (BLS, 2017). We also find that costs for equipment and materials such as HVAC has increased around 30% over the analysis time frame (St Louis Fed Reserve, 2017), but that costs for other equipment such as photovoltaic (PV) systems has decreased by about 80% over the same time frame (Barbose and Darghouth, 2016). We also evaluate markup information from projects in the ePB database and find that this investment level component has remained essentially stable over the past twenty years.

There is inconclusive evidence that trends in materials and equipment costs in ESCO projects are a significant factor that partially explains the long-term trend in project investment level increases captured in the unexplained term of the O-B decomposition. We also find that it is unlikely that ESCO labor costs and markup are a significant factor in the long-term increase in project investment levels. However, there is still a need of project-level data for these different factors to include them as observed variables in the O-B decomposition framework.

7. Conclusion

Recent research has suggested that the economic performance of projects installed by ESCOs may be changing over time. We perform analyses to characterize and understand what may explain these trends by leveraging two detailed databases which include ~7,000 U.S. ESCO industry projects: the LBNL/NAESCO database of ESCO projects and eProject Builder (ePB) system. The LBNL/NAESCO database has served as the basis of a number of LBNL reports about the U.S. ESCO industry. This is the first time that we incorporate measure level information from the ePB system into our analysis of ESCO project economic performance.

We find that projects are becoming larger (in terms of floor area and investment levels) and more comprehensive, are generating more savings, and installing more capital intensive measures. The trend has led to steady increases in normalized project investment levels ($\$/ft^2$) across markets and relatively modest increases in normalized savings over time ($savings/ft^2$). Median project investment have increased by 192 to 933% in various market sectors between the earliest and most recent vintage. Normalized monetary and physical energy savings have increased or remained stable following the deployment of projects that are more comprehensive and new technologies.

We conduct the first Oaxaca-Blinder decomposition over U.S. ESCO projects, which explains between 34% and 46% of the investment level increases, depending on method. Number of measures and project composition (mix of measure types) are the main variables that explain investment level increases. Virtually all the explained variation comes from these two factors. Floor area and savings have marginally contributed to investment level increase in the last three decades. Results for the role of ESPC are inconclusive with the data at hand. We explore the unexplained fraction of investment level increase by studying factors that are not explicitly reported in the LBNL/NAESCO database, such as labor, material costs, and markup. Their trends suggest little influence in explaining investment level increases, but further formal analysis is required to test these factors as hypotheses.

The long-term trend in project investment levels clearly has an impact on project economics from the customers' perspective. Larsen et al. (2012) reported a decrease in project benefit-cost ratios across a number of market segments, but noted that there were a number of non-energy benefits that were not considered in their estimates. We report a similar finding—reported project benefits are growing at a slower rate than the trend in project investment levels. This finding implies that customer benefit-cost ratios are likely to have declined over time while project simple payback times have increased. It should be noted that long-term increases in simple payback times have also been reported by other sources (e.g., State of the U.S. ESCO Industry). It is important to reiterate that—as was the case with Larsen et al. (2012)—there appears to be a significant amount of unreported non-energy benefits that are a component of the value proposition for customers and ESCOs.

We have also noted the role of public policies in enhancing and influencing the development of the U.S. ESCO industry (e.g., state and federal legislation encouraging ESPC, utility energy efficiency programs). Our analysis of ESCO project results by market sector illustrates the impact of these public policies in the sense that ESCO activity in the U.S. has been most successful in public/institutional markets compared to private sector and healthcare customers (e.g. greater market penetration, higher savings levels, more comprehensive projects). The fact that nearly all states and the federal government have adopted ESPC legislation means that the impact of public policies is most clearly seen across market segments rather than across states (e.g., public/institutional customers that are included in legislation vs. those market segments that are not covered).[19]

These results suggest several future research directions. First, this is the first attempt to identify ESCO project investment level structure using a data-driven approach. This technique has several shortcomings that are reflected in explaining less than 50% of the increase in investment levels in the past three decades. There is a need to better understand the cost structure of ESCO firms and projects by collecting quantitative and qualitative data and to expand on past research on ESCO workforce costs (Goldman et al., 2010). For example, contracting costs may be very specific to the ESCO industry and its trends may not be well represented by blue-collar labor costs. We need a deeper understanding of changes in ESCO labor composition and cost structure in the last two or three decades to test this hypothesis. One specific research effort may involve harnessing the power of eProject Builder to conduct a deep analysis of projects completed by the federal government—to learn more about the components that drive overall project investment levels, ongoing monitoring of savings, and other emerging trends.

There has also been an increase in non-energy measures and benefits within contracts, but also a recognition that many other non-energy benefits are difficult to monetize and include in a contractual framework (Carvallo et al., 2018). Previous studies that have analyzed ESCO project economics suggest that there is a substantial number of projects that may be producing non-energy benefits to their customers (e.g., see Larsen et al., 2012). There is a need to identify the types of non-energy benefits that customers of ESCOs are considering in their project assessments and develop techniques to incorporate them more formally in a cost-effectiveness framework.

Despite these challenges, the U.S. energy service company industry has produced significant energy savings, largely in institutional and public facilities, by installing and maintaining energy efficient equipment and other cost and resource-saving measures. Given the significant remaining market potential of this industry, it is important to continue to understand project investment levels and the associated benefits over time. Improving the understanding of project level economics will enable local/state/federal stakeholders to make decisions that are more informed and, ultimately, unlock the full potential of this growing industry.

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[19] There are some differences between in the authorizing legislation for ESPC at the Federal level vs. state governments (e.g. maximum payback time, terms and conditions, solicitation processes) and among states (e.g., institutional/public market segments covered by legislation in each state).

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Technical Appendix

A.1. Pre-analysis quality control

This section describes the data preparation process prior to analysis.

Project selection

We exclude projects in the LBNL-NAESCO database that contain extreme outliers[20], that were developed before 1990, or that lack basic data values, e.g., date, location, or market identifiers. Moreover, not all projects report the requisite fields required for each analysis (e.g., a project may be missing information on investment levels, savings or floor area). Table A.1.1 shows the number and share of projects that contain key variables used in this study. 54%-87% of projects report any of the variables of interest (e.g. 67% of projects include floor area (ft2)). Only 42% of projects contain all of the listed variables. Sample sizes for results in this paper vary depending on the number of projects that contain the requisite data for the specific analysis.

Table A.1.1. LBNL/NAESCO database: overview of project sample sizes

		Project count	Share of total projects
Full database	Pre-screening	6,314	100%
	Post-screening	5,510	87%
Selected variables	Date completed	5,510	87%
	Project investment levels	4,957	79%
	Floor area	4,204	67%
	Total MMBtu savings (actual, guaranteed, or projected)	3,429	54%
	Total dollar savings	4,385	69%
	Contract type	5,329	84%
	Contract length	4,587	73%
	Installed measure(s)	5,510	87%
	Contains all selected variables	2,649	42%

Cleaning and standardization

Previous LBNL research noted that the information reported by ESCOs varies in terms of quality and completion (Larsen et al. 2012). To address quality issues, we implemented a methodology to improve

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[20] Extreme outliers are data points that are so far outside the norm that they are likely erroneous.

the accuracy and consistency of project level information used in our analyses. The quality control and quality assurance process involves two key processes:

1. Screen projects for missing and/or questionable data:
    - Remove projects that lack key data fields necessary for time trend analyses (e.g., U.S. state, project completion year, market segment)
    - Exclude projects installed before 1990 when the ESCO market was nascent
    - Exclude projects from outside the U.S.
    - Perform an outlier analysis to identify projects for exclusion from specific economic and energy analyses
2. Classify and standardize data:
    - Calculate the monetary value of energy (electricity, gas, oil) and water savings with standardized retail prices for commercial/institutional or industrial customers. We use standardized retail prices because ESCOs often do not provide information on retail rates or tariffs or assumptions regarding future electricity and fuel prices when they report monetary savings from projects.
    - Classify projects that fall in specific time periods (i.e., vintages)
    - Assign each project to a dominant retrofit strategy (e.g., major HVAC, onsite generation)
    - Convert all nominal dollar values into real terms ($2016)

We describe specific classification and standardization methods in the following subsections.

Vintages

This study focuses primarily on evaluating ESCO project level economic trends over time. Accordingly, we categorize projects into five contiguous vintages. This report includes the first three vintages from Larsen et al. (2012) plus two additional vintages for the 2008-2017 period. We define vintages according to the following criteria:

- 1990-1997: "ESCOs mature as performance contractors." During this period, the nascent ESCO industry from the early 1980s developed into a relatively mature industry focused on performance contracting which distinguishes them from HVAC or lighting contractors. The extensive deployment of utility ratepayer-funded energy efficiency and demand side management programs provided additional support to a growing ESCO industry (Larsen et al., 2012).
- 1998-2003: "Electricity Industry Restructuring and Retail Competition." During this period, efforts to restructure the electricity sector affected the ESCO industry. Many utilities either established ESCOs or acquired small existing ESCOs as part of a strategy that allowed them to provide energy services in states that allowed retail competition (e.g., retail energy services companies could provide energy commodity and services). Electricity restructuring and retail

electric completion stalled primarily because of the California electricity crisis in 2000/2001. The promise of a robust, national retail energy services market receded as part of the fallout from the California electricity crisis. Many utilities then sold off their ESCO subsidiaries and other ESCOs consolidated and merged, which fundamentally affected the structure of the ESCO industry (Larsen et al., 2012).

- 2004-2007: "Resurgence." ESCO activity was positively influenced by resurgence in state level energy efficiency policies as well as re-authorization of ESPCs by the federal government (Larsen et al., 2012).
- 2008-2011: "Recession" This period includes the financial crisis of 2007 and subsequent years in which the U.S. economy experienced a severe recession and high unemployment. ARRA, designed to spur economic growth, provided a massive, short-term (3 years) boost of funding for energy efficiency investment in public and institutional facilities. ARRA directed federal, state and local agencies to invest the funds quickly, and many agencies complied by addressing a backlog of "shovel-ready" energy efficiency projects in their facilities (Goldman et al., 2011). Some ESCOs reported that an expected boost in the performance contracting market did not materialize, because under time pressure, agencies often used ARRA funds to pay directly for short-payback efficiency measures, rather than entering into ESPC contracts for more comprehensive projects (Stuart et al., 2018).
- 2012-2017: "Post-Recession" Between 2012 and 2017, overall economic growth was slow and the cost of capital (i.e. interest rates) was low. The President's Performance Contracting Challenge (PPCC) called for federal agencies to implement $4 billion in ESPC (Harada, 2016). Federal agencies exceeded the goal, awarding 340 projects valued at over $4.2 billion (Harada, 2016), which provided a boost to the ESCO industry.

Dominant retrofit strategies

Following earlier studies (Hopper et al., 2005; Larsen et al., 2012), we assign each project to a dominant retrofit strategy (DRS). The DRS corresponds to a general category of measures that typically influences the project's investment levels and savings. Each DRS represents a grouping of measures that can be characterized by a dominant retrofit strategy in which selected measures (e.g., new HVAC equipment, onsite generation, only lighting) may influence investment (and savings) levels.

Previous research categorized projects in the database into six DRS categories: lighting-only, minor HVAC, major HVAC, onsite generation, non-energy, and other (Larsen et al. 2012). For this paper, we create two additional dominant retrofit strategies—motors and drives, and water conservation—that better characterize the dominant mix of measures installed in certain projects. Table A.1.2 provides a summary of the retrofit strategies, their assignment logic, and characteristics of each energy conservation measure (ECM) and non-energy measure (NEM). Section A2 in this appendix provides a detailed description of the methodology used to assign projects to DRS.

Table A.1.2. LBNL defined dominant retrofit strategy classification (adapted from Larsen et al. 2012)

LBNL dominant retrofit strategy (DRS)	Criteria	Example of ECM and/or NEM included in this category
Lighting-only	Projects include only this type of measure	Technologies installed include only various lighting efficiency measures and controls.
Minor HVAC	Normalized project investment of \$5/ft^2 or less.	Technologies installed include less-capital intensive HVAC measures and controls (and exclude major HVAC equipment) and may include lighting and other measures.
Major HVAC	Normalized project investment of \$5/ft^2 or more.	Technologies installed include major HVAC equipment replacements (e.g., boilers, chillers, cooling towers, HVAC distribution system improvements) and may include other HVAC control, high-efficiency lighting, and motors measures.
Onsite generation	Projects include onsite generation technology	Technologies include installation of onsite generation equipment and may include other energy efficiency measures (e.g., lighting, HVAC equipment and controls, motor efficiency measures). Onsite generation includes diesel backup generators, distributed PV systems, and biomass gasifiers, among others.
Motors and drives	Normalized project investment of 5 \$/ft^2 or less.	Technologies installed include industrial process equipment not directly related to HVAC, such as variable speed drives, pumps and priming systems, and electric motors.
Water conservation	Majority of dollar savings are from water savings	Technologies installed include an array of water conservation measures that include low flow showers, faucets, urinals, and toilets, as well as meters and leak detection equipment.
Non-energy	Normalized project investment of \$7/ft^2 or more. Majority of dollar savings are non-energy savings.	Technologies installed include roof or ceiling replacement, asbestos abatement (i.e., measures that are not installed primarily for their energy savings, but may have other types of savings), and projects may include other efficiency measures (e.g., lighting or HVAC upgrades).
Other	Projects include only these types of measures	Technologies installed include installation of energy-efficient equipment such as vending machines, laundry or office equipment, high-efficiency refrigeration, staff training and utility tariff negotiation. These individual measures may also be included in other retrofit strategies (except lighting-only); projects categorized as "Other" retrofit strategy only installed these types of measures.

Standardization of dollar value of energy savings

ESCOs may calculate and report monetary savings in many different ways, which complicates the comparison of project economics. To make the savings data comparable, we recalculate monetary value of savings by multiplying reported physical resource savings (electricity, natural gas, oil, and water) by standardized commodity prices. We follow the same dollar savings recalculation method developed in Larsen et al. (2012) for gas, oil and water savings. However, in this paper we refine the methodology for electricity savings by calculating energy and demand charges savings separately.

Reported savings information requires a considerable amount of processing due to variations in the underlying data. For example, the monetary value of resource savings often varies over the lifetime of a project. We estimate an average annual savings equivalent by dividing the stream of monetary savings by the number of years of the performance contract. Projects may also report non-resource[21] savings—most commonly operations and maintenance (O&M) savings or capital cost avoidance. In these cases, we add the non-resource savings to the annual monetary resource savings to produce an estimate of the dollar value of savings from an ESCO project.

Mean measure lifetime

We utilize the same methodology to estimating mean measure lifetime for project measures specified in Appendix C of Larsen et al. (2012).

A.2. Dominant retrofit strategy (DRS) methodology

The current methodology to assign a DRS to a given project is based on the presence of a single type of measure and a hierarchical prioritization (see Appendix A.7 in Larsen et al. (2012) for details). In the original method, there are six possible DRS: Onsite Generation, Non-Energy, Major HVAC, Minor HVAC, Lighting-only, and Other. The methodology used in Hopper et al. (2005) used the same DRS but had a more refined approach to distinguish Major and Minor HVAC projects through a measure-specific cost analysis (see Appendix B in Hopper et al. (2005)).

Our preliminary analysis suggested that an important cost driver was the mix of energy conservation measures and non-energy measures being installed, which we measure through the DRSs. Improving the accuracy of the DRS classification is critical for this paper. The main concerns we are trying to address with the DRS classification review are excessive projects classified in the ‘Onsite generation’ and ‘Major HVAC’ categories, which have higher priority in the current hierarchical structure. In parallel, we address the reduced number of projects classified in lower priority DRS by developing a quantitative approach that we describe below.

First, we create the “Water conservation” and “Motors and drives” DRSs. Water conservation projects are low cost and their savings are relatively easy to measure. These projects were originally bundled in the “Non-energy” DRS, which includes expensive measures with little to no measurable savings. Motors

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[21] Non-resource savings, often called non-energy benefits, are cost savings that accrue to ESCO projects from other sources besides energy and water use reduction and demand charge savings.

and drives types of measures are associated with industrial or commercial processes that are neither Major not Minor HVAC. There are enough motor and drives measures implemented to include these in their own DRS.

Second, we analyze each DRS to propose possible new classification criteria.

A.2.1 Onsite generation projects

These projects are expected to be dominated by a single measure related to deployment of backup generation or renewable energy systems. We use a similar approach to Hopper et al. (2005) to better assess the actual contribution of an onsite generation measure to the overall project cost. Ultimately, we want to test whether onsite generation measures make projects more expensive or if more expensive projects include onsite generation but their costs may be driven by another strategy or a mix of them.

To test this, we use ePB data for federal government Indefinite Delivery/Indefinite Quantity (IDIQ) projects to determine the cost per unit of floor area for 20 measure categories. The measure category “renewable energy systems” has 44 projects developed in 2008-2017 with price and floor area data. Most of the measures installed in this category correspond to solar PV systems. The median cost of this measure is about 1 $/sqf and the 80% percentile value is about 3 $/sqf (all ePB monetary values in nominal dollars).

We compare these values to the median value for cost per unit of floor area for “Onsite Generation” projects in the LBNL database that use the original DRS classification. We find that these projects present median values of 7 to 13 $/sqf in recent vintages. For further analysis, we split these projects in two bins depending on the proportion of measures that is an “onsite generation” measure. If a project has 20% or less of its measures identified as onsite generation, it is classified as “lower presence”. For projects with a high presence of this measure – that is, projects that are most likely dominated by onsite generation measures because there are few or no other measures installed – the median cost is about 13$/sqf. Projects with lower presence of this measure have median costs closer to 10 $/sqf.

We run the previous analysis for projects that only install onsite generation measures and find a median cost of 13 $/sqf for 26 projects. This value is about 10 times higher than the one in ePB projects for this measure type. Comparing the ePB single measure cost with the LBNL database cost suggests the onsite generation measure may not be the dominant strategy when present in these projects. However, using the LBNL database values only suggests that onsite generation project costs are indeed dominated by that measure, regardless of the number of other measures implemented.

We propose no changes in the onsite generation DRS assignment. The analysis supports the logic that even in projects with low presence of onsite generation measures the project costs seem to be driven by it.

A.2.2 Major HVAC

Major HVAC is one of the highest priority DRS. This translates to higher chance of misclassifying projects as Major HVAC in lieu of other DRS that could deploy a similar mix of measure that is dominated by a different strategy.

We run a similar analysis for projects classified as "Major HVAC" based on number of measures. We find about 90 projects that have 60% or more of their installed measures classified as "Major HVAC". The median normalized cost for these projects is around 7.5-8 $/sqf. Projects with between 20% and 50% of measures identified as Major HVAC have median costs of about 5.5 $/sqf. Projects below this threshold have normalized costs of about 3.5 $/sqf.

This gradual decline in normalized cost as a function of the relative presence of Major HVAC measures suggests a cutoff or threshold to classify a project with a Major HVAC DRS.

We analyze ePB data to find normalized values for typical Major HVAC measures such as boiler and chiller improvements and general HVAC. If we assume the joint presence of these three measures is equivalent to a major HVAC project, we find a median normalized cost of about 2.5-3 $/sqf (median costs of ~ 1 $/sqf for boiler and chiller and ~ 0.5 $/sqf for general HVAC). The ePB values are consistent with the cost cutoff criteria determined in Hopper et al. (2005) for Major HVAC technologies.

The difference may also be explained by the fact that a Major HVAC project is composed from several measures of that type. We find that projects with relatively high presence of Major HVAC measures typically install 4 to 5 measures on a typical project. This would suggest an average cost per measure of 1-1.5 $/sqf, closer to ePB measure level values.

We propose setting a cutoff for Major HVAC projects at about 5 $/sqf. Projects identified as Major HVAC with a normalized cost below this level will be classified as "Minor HVAC" if they do not include motors and drives measures or "Motors and drives" if they do. This follows the same logic proposed in Hopper et al. (2005), with the extension for the new motors and drives DRS.

A.2.3 Non-energy projects

Non-energy projects are classified based on the presence of specific measures. There are 723 projects (13%) in the database that are classified as non-energy based on their measures only. However, we find that there is a significant amount of projects (~500) that are not classified as non-energy whose non-energy dollar savings are larger than their energy savings. We know that many non-energy projects and measures may not report non-energy savings because it is hard to measure and verify them. However, we classify projects with a high proportion of non-energy savings into the non-energy DRS. We propose that projects with a share of non-energy dollar savings that exceed 50% or more of total savings are classified as non-energy projects.

A.2.4 Water conservation projects

About 70 projects in the database (1.3%) are classified as water conservation project as the DRS. However, it should be noted that more than 2000 projects implement some type of water conservation measures. Among this group, we find that ~380 projects are not classified as water conservation even though the dollar value of water savings is 50% or more of total dollar savings. Following the same criteria as in non-energy savings, we propose that projects with a share of water dollar savings that are 50% or more of total savings are classified as water conservation projects.

A.2.5 Remaining DRS

The Motors and Drives and Minor HVAC DRSs are implicitly reclassified based on the Major HVAC cost threshold analysis. We make no changes to the Lighting Only DRS, as its classification is straightforward.

A.2.6 Classification changes

We compare the original and resulting classifications (Table A.2.1). The main result is redistribution from Major HVAC projects into Minor HVAC and motors and drives, plus non-energy. Median normalized costs for Minor and Major HVAC projects are much more differentiated now, which suggests the quantitative threshold implemented works as intended.

Table A.2.1. Count and share of project comparison between original and new DRS classification method.

	New method		Larsen et al. (2012)	
	Count	Share	Count	Share
Non-energy	1398	25%	979	18%
Major HVAC	1136	21%	1960	36%
Minor HVAC	922	17%	667	12%
Lighting-only	532	10%	570	10%
Unknown	481	9%	543	10%
Motors and drives	432	8%	227	4%
Onsite generation	413	7%	438	8%
Water conservation	144	3%	70	1%
Other	52	1%	56	1%

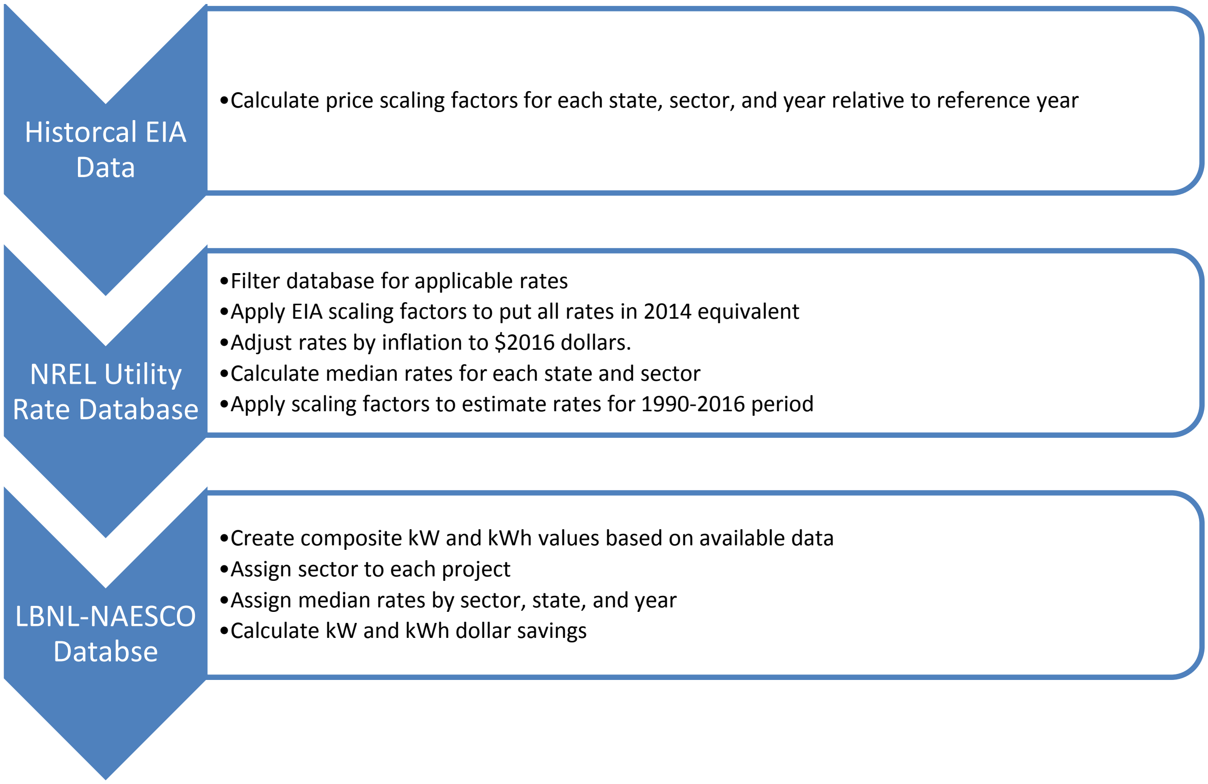
A.3. Electricity dollar savings methodology

This section presents the original and new method devised in this paper to estimate electricity dollar savings from ESCO projects.

A.3.1 Previous method to estimate the dollar value of electricity savings

Historically, we calculated the dollar value of electricity savings from ESCO projects using both reported physical project savings and historical electricity price data from the EIA (e.g., Larsen et al. 2012). EIA provides state level-electric retail prices for a range of market sectors and utility service types over the period 1990-2015. However, these prices are not commodity rates. They are, in fact, gross utility revenues from energy and demand rates; services charges; taxes; and surcharges averaged over residential, commercial, and industrial sector sales. The prices are reported in dollars per kWh ($/kWh). For this reason, we cannot estimate the value of energy and demand reductions independently of each other. For projects that have large peak demand reductions, we may be under-estimating monetary benefits. For projects that do not report demand charge savings, we may be over-estimating monetary energy savings.

A.3.2 New method to estimate the dollar value of electricity savings


Historcal EIA Data

- Calculate price scaling factors for each state, sector, and year relative to reference year

NREL Utility Rate Database

- Filter database for applicable rates
- Apply EIA scaling factors to put all rates in 2014 equivalent
- Adjust rates by inflation to $2016 dollars.
- Calculate median rates for each state and sector
- Apply scaling factors to estimate rates for 1990-2016 period

LBNL-NAESCO Databse

- Create composite kW and kWh values based on available data
- Assign sector to each project
- Assign median rates by sector, state, and year
- Calculate kW and kWh dollar savings

We developed a methodology that employs actual utility energy and demand rates in order to address this gap in demand valuation and overall bias in electricity savings calculations. The NREL Utility Rate Database contains more than 26,000 commercial and industrial rates from nearly 3,000 utilities across the U.S. Rates are reported for four sectors—Industrial, Commercial, Residential, and Street Lighting—and in two voltage delivery levels. Some demand rates vary with the time of day, so the data is classified according to “periods” during which a particular rate prevails. These rates may also have multiple tiers, with higher tiers representing the time when demand exceeds a specified threshold. Unfortunately, we do not know when project demand reductions occur, so we cannot assume a particular rate period is correct for a given project. To address this, we utilize the most common demand rate available in the schedules, which also happens to be the lowest rate compared to other periods. We believe that using a more conservative approach (i.e., lowest rates) reduces concern about picking the incorrect rate based on limited/no information on the actual timing of the demand reduction.

The first step in calculating the rates involves filtering the NREL Utility Rate Database to remove rates not applicable to ESCO projects. These rates include those for agriculture, electric vehicles, and transmission projects. The NREL database does not specify whether rates are bundled or delivery-only, but a preliminary analysis of energy rates found a very low incidence of delivery-only rates. Since delivery-only rates would not contain the energy portion that drives prices, we exclude energy rates less than $.03 ($/kWh). We also remove demand rates less than $0 ($/kW) as they are likely a result of data entry errors. Filtering the NREL database removed 30% of the reported rates available in the 2011-2017 period. We adjusted all of the applicable rates to 2016 dollars.

The NREL utility rate database has limited time-series coverage - ~80% of its rates are from 2010 to 2017, but ~ 70% of projects in the LBNL-NAESCO database were installed before this period. The volatility of commodity prices precludes the use of such recent rates over a broad time-series. We address this limitation by scaling the NREL rates with historical utility prices from EIA.

We populate a rate time-series for all sectors and states for the period 1990-2016 that accounts for state level price changes. As noted earlier, the EIA data we use are not rates, but prices calculated as total utility collections divided by sales. We begin by calculating average prices for each state and sector and year in our study period. We then take each price and divide it by the price from the same state and sector from a reference year. We use 2014 as this reference year because it is the year with the most rates in the NREL database.

The scaling occurs in two stages. First we scale all of the rates in the NREL database to the reference year and calculate median energy and demand rates for commercial, industrial, and residential sectors in each state. We use medians to identify rates because of the variation in rates both across and within utilities. Then, we multiply each of these median rates by the appropriate scaling factor for a given state, sector, and year. This procedure results in a time series of rates modulated with the price trends contained in the EIA data.

In parallel, we assign projects in the LBNL-NAESCO database to one of two rate classes (commercial or industrial) based on the reported market segments. We designate industrial and military projects as industrial, housing projects as ‘Residential’ and all others as ‘Commercial’. Finally, we assign the applicable commercial (industrial) rates to each LBNL-NAESCO project.

ESCOs report physical energy and demand reductions as either “actual”, “guaranteed”, or “projected”. To maximize sample size, we create composite energy and demand savings fields populated with these three categories according to a hierarchy of preference. We use actual savings whenever possible, but use guaranteed when actual savings are not available. Finally, we use projected savings when neither guaranteed savings nor actual savings are available. We adjust projected savings using historical ratios between projected and actual savings. We perform a quality control check over reported demand charge savings by comparing them with the reported base kW when available, discarding values with unusually high or low percentage savings. Finally, we calculate a demand and energy dollar savings for projects in the LBNL-NAESCO database.

Based on our analysis, we assume demand savings are reported as peak demand savings. Since demand charges are expressed in $/kW-month we multiply the savings by 12 to express them as an annual equivalent. Finally, we multiply the composite energy field by the assigned rate to estimate dollar savings and add it to the demand charge savings.

A.4. Regression analysis and results

In this section, we expand on the regression specification and its results.

A.4.1 Specification

The main reason for using a multivariate regression approach is to disentangle the how the types and number of measures in project affect its overall cost. We employ the following econometric model to study the relationship between project investment levels and other project factors:

$$inv_{i,t} = \beta_1 + \beta_2 \cdot ESPC_{i,t} + \beta_3 \cdot retrofit_{strat_{i,t}} + \beta_4 \cdot floorarea_{i,t} + \beta_5 \cdot savings_{i,t} + \beta_6 \cdot num_{measures_{i,t}} + \varepsilon_{i,t}$$

Where *i* is the developer and *t* is the group for the Oaxaca-Blinder (O-B) decomposition. We use the following categorical variables:

- "ESPC" is a dummy binary variable set to 1 for performance contracting projects.
- "retrofit_strat" corresponds to one of the 7 dominant retrofit strategy described in Table A.1.2 (projects classified as "Other" and "Unknown" are omitted from the analysis). We use the Lighting Only strategy as the reference.

In addition, we use the following numerical variables:

- "floorarea" corresponds to the average floor area retrofitted for the pooled projects. We hypothesize that larger projects are more expensive.
- "savings" corresponds to the average physical energy savings in MMBTu achieved by the pooled projects. We hypothesize that projects with higher savings are more expensive.
- "num_measures" corresponds to the average count of measures installed for the pooled projects. This is a measure of comprehensiveness. We hypothesize that more comprehensive projects are more expensive.

We use non-logged variables to make the coefficients directly represent the increase in absolute project cost. We tested a logged version of all numerical variables – the three listed above plus the dependent variable – with similar results. This assumption is validated when studying the distribution of residuals (see Figures A.4.1 and A.4.2).

We include ESCO fixed effects in our specification to account for the idiosyncratic effect that a given ESCO may have on specific projects. For example, a large ESCO (ESCO A) may capture economies of scale that a smaller ESCO (ESCO B) does not. Controlling for other factors, projects developed by ESCO A would be cheaper than projects developed by ESCO B would be. We can capture this with this fixed effect and therefore not attribute this variation in cost to one of the explanatory variables. Note that in doing so, we assume that ESCOs are unchanged in time, which is not completely accurate as they have grown and merged with other ESCOs.

A.4.2 Results analysis

A.4.2.1 Residual plots

Residual plots for groups A (last vintage) and B (first vintage) are shown below

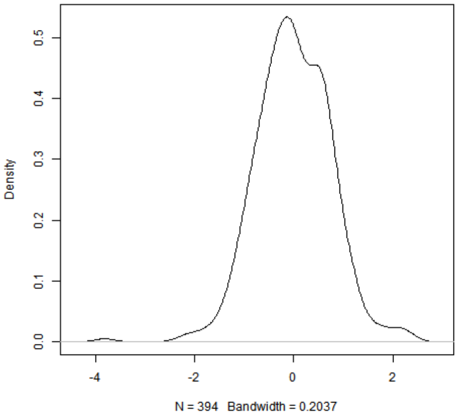


Figure A.4.1. Residual plot for last vintage (Group A) regression

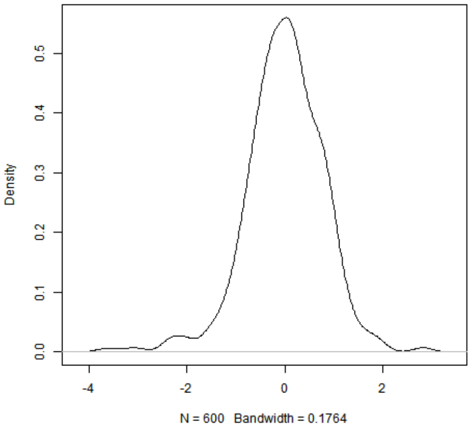


Figure A.4.2. Residual plot for first vintage (Group B) regression

A.4.2.2 Multicollinearity

We analyze the potential multicollinearity between the continuous and categorical variables in our specification: floor area, savings, comprehensiveness, and investment levels, plus six of the seven DRS dummy variables (remove Lighting-only to prevent perfect collinearity). We calculate variance inflation factors (VIF) to test for collinearity among explanatory variables. VIFs are constructed by running a regression of each explanatory variable on the remaining variables and using the R^2 value to construct the factor (O'brien, 2007). Higher levels of VIF – in the order of 5 to 10 – will signal multicollinearity is present.

We run the analysis for the industry as a whole and find no collinearity among the covariates of interest.

Table A.4.1. Variance inflation factor results

Covariate	VIF
Floor area	1.37
Resource savings (MMBtu)	1.47
Comprehensiveness (number of different project measures)	1.39
Cost	1.68
ESPC	1.13
Major HVAC	2.65
Minor HVAC	2.29
Motors and drives	1.99
Non-energy	2.97
Onsite generation	1.78
Water conservation	1.11

A.4.3 Analysis of other factors that may affect project investment levels

There is little if any publicly-available information on the actual cost structure of ESCO projects. The LBNL/NAESCO database contains sufficient project level financial information to determine total implementation expenditures with and without financing, but no information about various expenditures that make up the total project investment levels. In its simplest form, direct project investment levels without financing (and excluding any incentives offered by utilities for high efficiency measures) can be decomposed into labor and materials costs, and a markup that includes indirect costs, overhead and profit. Changes in any of these three cost components – labor, materials, and markup – could also help explain increases in project investment levels that are not captured in the regression analysis based on reported factors.

In this section, we examine trends in labor and materials costs for which there are publicly available data, and use the findings as a proxy for ESCO project labor and materials cost trends. To the best of our knowledge, there is no data that can act as a proxy for markup so we make no attempt to estimate it. However, we use data from the ePB database to look for some evidence of markup trends over time.

A.4.3.1 Real labor costs have grown less than 10% during the analysis period

In earlier research, ESCO executives reported that labor costs were the most significant contributor to rising project investment levels (Larsen et al. 2012). To quantitatively test this hypothesis, we use data from the U.S. Bureau of Labor Statistics (BLS) on employment compensation for private industry workers in the construction sector as a proxy for direct skilled labor costs in the ESCO industry (BLS, 2017). We believe this subgroup adequately represents the technical skills of labor employed in the installation of energy efficiency projects. We considered other types of blue-collar labor employment cost indexes and verified that conclusions remain unchanged.

Labor costs associated to this subgroup have grown approximately 8% in real terms from 2001 (the earliest year with available data) to 2017 (see Figure A.4.3). The impact of these labor cost increases on ESCO project economics depends on ESCO and project cost structures and their evolution over time, however we lack the data to model them. However, given the relatively modest increases, it is likely the contribution of labor costs to ESCO project investment level increases is relatively small.

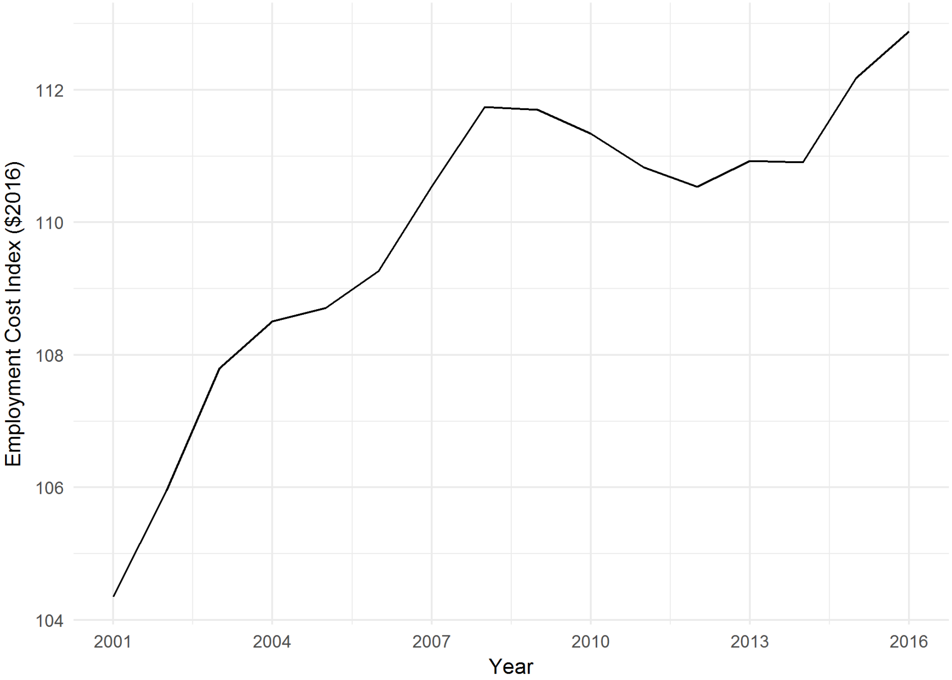


Figure A.4.3. Real compensation growth for private industry construction skilled labor across the U.S. for the period 2001-2017

A.4.3.2 Materials and equipment cost variation is mixed and their effect is undetermined

Materials cost trends might also help explain the rise in project investment levels reported in earlier sections. Assessing the impact of the cost of materials and equipment is not straightforward due to the wide variety of materials and equipment used in ESCO projects. Moreover, while we know the measure composition for projects in our dataset, we do not know the relative weight of the different measures installed, in terms of their investment level or contribution to resource savings. This means that even if we account for a diversity of materials and/or equipment price indexes, we do not have a straightforward way to apply these indexes to project data. Finally, we do not know how much of the project investment level consists of materials as opposed to other components such as labor and markup. Thus we are unable to assess the impact of certain equipment or material cost increases on overall project investment levels.

We can, however, measure temporal trends in materials costs and compare those to temporal trends from our findings. We use the Producer Price Index (PPI) by Industry reported by the Economic Research Division of the Federal Reserve Bank of St. Louis (St Louis Fed Reserve, 2017). We examine the

HVAC and commercial refrigeration equipment, measures commonly installed in ESCO projects. We use the GDP deflator employed in our previous calculations on the nominal PPI values to remove the effect of inflation and estimate the index in real 2016 dollars.

The information for HVAC is only available from 2003 to 2016. Real HVAC prices grew steadily from 2003 to about 2008-2009, when the great recession hit. From that point on, real HVAC prices stagnated (see Figure A.4.4). To extend the data over our entire period of analysis (1997-2017) we estimate the average growth trend for the 2003-2009 HVAC price data points and extrapolate back to 1997.

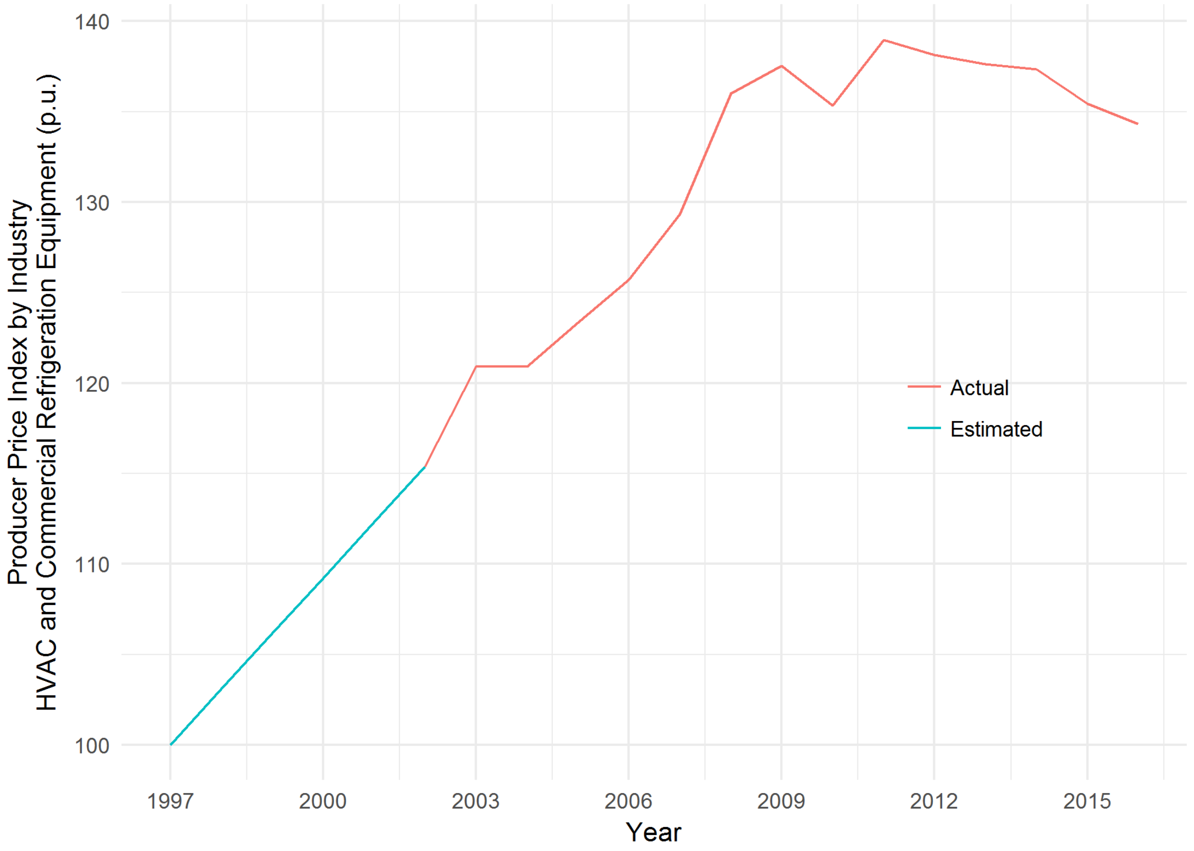


Figure A.4.4. Real HVAC price index for 1997-2002 (estimated) and 2003-2016 (observed)

Using this approach, we estimate that real HVAC prices have increased about 35% since the first vintage (1990-1997). Depending on project cost structure, HVAC prices may help explain part of the ESCO project investment levels increases during the 1997-2008 period (the first three vintages). HVAC price trends, however, cannot explain the investment level increases during the ARRA and post-ARRA periods because during those periods HVAC prices remained virtually flat.

In contrast, costs for other equipment installed by ESCOs such as photovoltaic (PV) systems have decreased significantly during our analysis period. Median costs for PV systems of a capacity below 500 kW – the most usual size installed by ESCO customers – decreased from $12/W in 1998 to around $4/W in 2015 (Barbose and Darghouth, 2016). The declining costs of PV would be expected to have pushed project investment levels downward, reducing overall ESCO project investment level increases.

.4.3.3 Markup has probably remained stable and not affected investment level increases

Markup can include indirect costs, overhead and profit margin, among other expenses. There is evidence for an increased markup in small and medium firms in the U.S. in recent years (Loecker and Eeckhout, 2017). However, in fully competitive markets firms would have little incentive to increase markup because increasing markup would increase prices for customers and decrease competitive advantage. We might expect to observe little change in markup over time, particularly in markets with high product or service commodification, in which there is little differentiation in terms of the product or service provided. In contrast, ESCO projects are quite customized and involve significant transaction costs for developing tailored proposals and maintaining client relationships (Stuart et al., 2016).

A potential increase in markup does not necessarily relate to lack of competition. Evidence suggests that ESCOs may be facing increasing competition from other energy efficiency providers (e.g., HVAC or lighting companies) and distributed renewable energy installers, which may be driving higher client acquisition and retention costs (Stuart et al., 2016).

Unfortunately, there is no markup data or any proxy for it in the LBNL/NAESCO database. However, the eProject Builder (ePB) database includes a markup percentage field for each project. In ePB, markup is comprised of ESCO overhead and profit, applied as a single blanket percentage across all of the implemented ECMs and NEMs. Median project markup is approximately 23% to 25%, and has remained relatively stable across the four vintages for which there are available data (from 1998 to 2017). While markup may be a significant portion of total ESCO project investment levels, it does not appear to contribute to project investment levels increases over time because it has remained unchanged during the analysis period.

As discussed in Section 4 of the manuscript, nearly all of the projects in ePB are federal sector projects, so the results are only applicable to this market segment. It is possible that the markup percentages differ in other market sectors. However, based on the stability of federal project markups, we believe it is unlikely that changes in project markup for any market sector contribute significantly to overall ESCO industry project investment level changes.

A.4.4 Additional notes

A.4.4.1 Selection bias

The LBNL/NAESCO database is populated with projects from the NAESCO accreditation process. ESCOs submit detailed data for a sample of projects developed in the years prior to the accreditation. Guidelines suggest projects should provide a good overview of the ESCO activity, but do not require projects to be selected in any particular way. It is possible that ESCOs cherry-pick the projects they send into accreditation

A.5. Additional figures

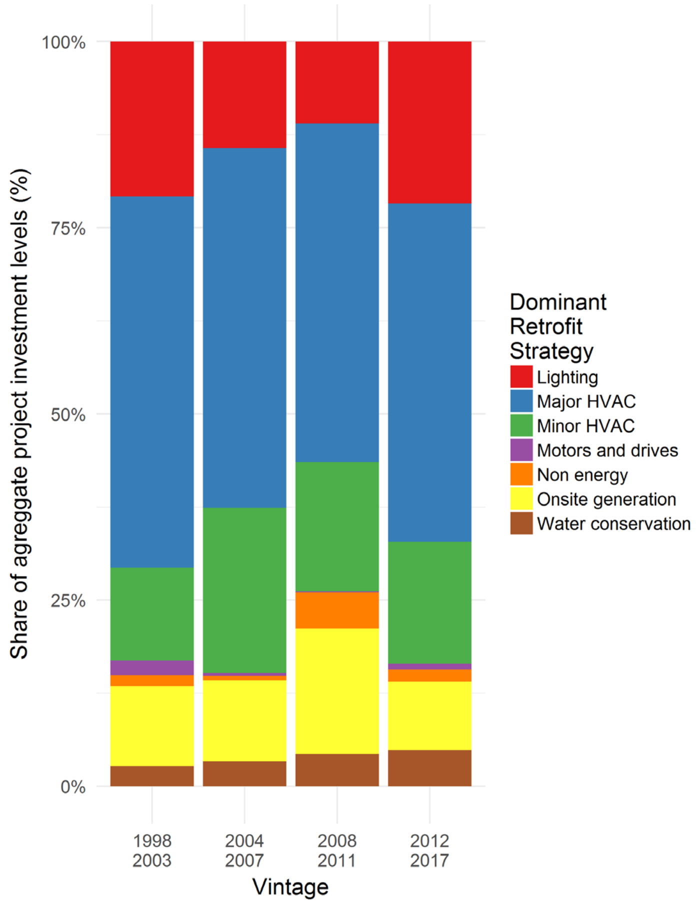


Figure A.5.1. Share of investment by vintage using ECM level data from ePB database.

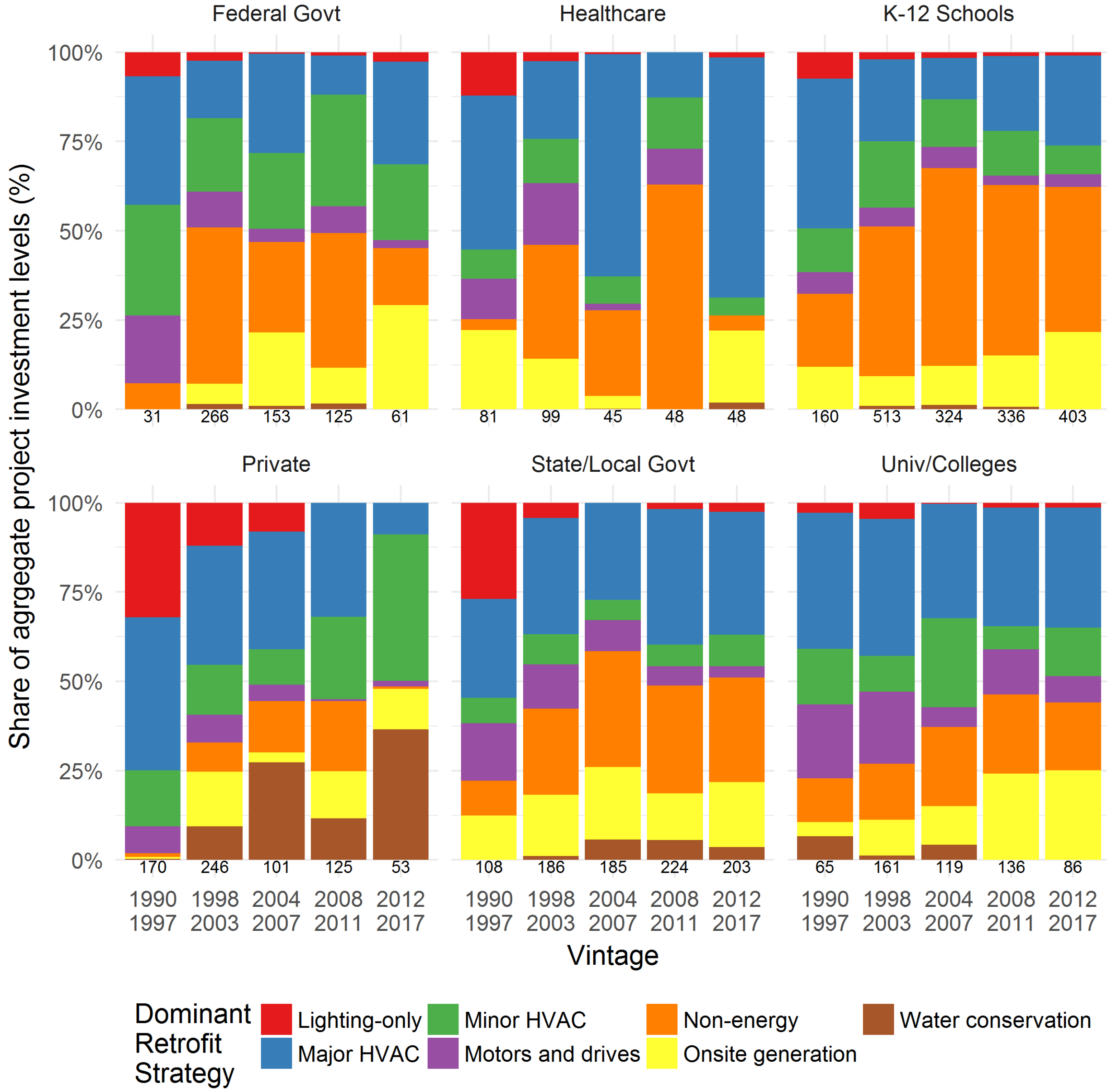
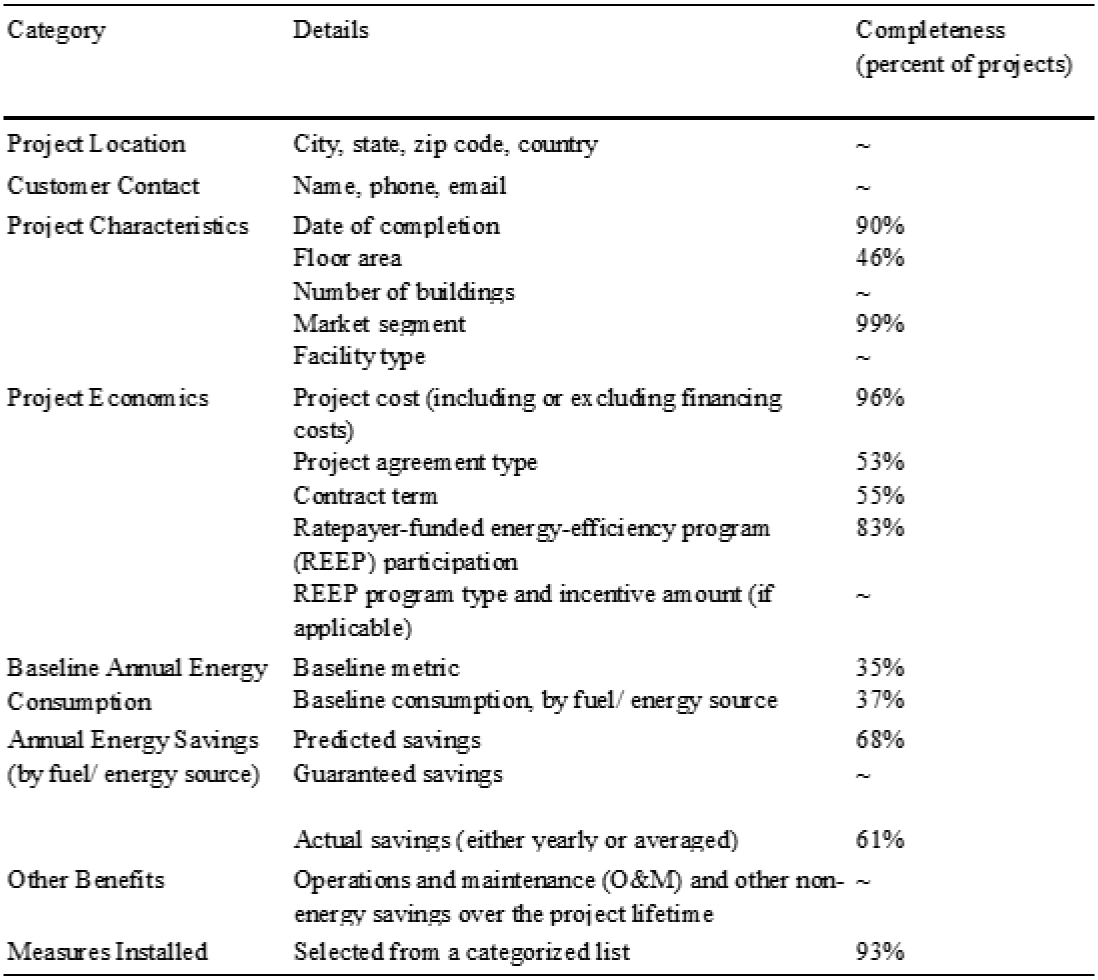


Figure A.5.2. Share of investment by vintage, market, and DRS.

A.6. LBNL/NAESCO data fields

Table A.6.1 – taken from Goldman et al. (2005) – describes the data collected for projects uploaded into the LBNL/NAESCO database. The table also includes the share of projects that satisfactorily report each field.

Table A.6.1. Data fields collected for LBNL/NAESCO database projects



Category	Details	Completeness (percent of projects)
Project Location	City, state, zip code, country	~
Customer Contact	Name, phone, email	~
Project Characteristics	Date of completion	90%
	Floor area	46%
	Number of buildings	~
	Market segment	99%
	Facility type	~
Project Economics	Project cost (including or excluding financing costs)	96%
	Project agreement type	53%
	Contract term	55%
	Ratepayer-funded energy-efficiency program (REEP) participation	83%
	REEP program type and incentive amount (if applicable)	~
Baseline Annual Energy Consumption	Baseline metric	35%
	Baseline consumption, by fuel/ energy source	37%
Annual Energy Savings (by fuel/ energy source)	Predicted savings	68%
	Guaranteed savings	~
	Actual savings (either yearly or averaged)	61%
Other Benefits	Operations and maintenance (O&M) and other non-energy savings over the project lifetime	~
Measures Installed	Selected from a categorized list	93%

A.7. Appendix references

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