

CICERO Report 2013:01

Performance-based Potential for Residential Energy Efficiency

Jason W. Hoyle

January 2013

CICERO

Center for International Climate
and Environmental Research - Oslo

P.O. Box 1129 Blindern

N-0318 Oslo, Norway

Phone: +47 22 85 87 50

Fax: +47 22 85 87 51

E-mail: admin@cicero.uio.no

Web: www.cicero.uio.no

**Center for Economic Research & Policy Analysis
Research Institute for the Environment, Energy, and Economics
Appalachian State University
P.O. Box 32131
Boone, NC 28608-2131 USA**

Tittel: Performance-based Potential for Residential Energy Efficiency

Forfatter(e): Jason W. Hoyle
CICERO Report 2012:02
32 sider

Finansieringskilde: Norges Forskningsråd

Prosjekt: ESPARR
Prosjektleder: Hege Westskog
Kvalitetsansvarlig: Knut H Alfsen
Nøkkelord:

Sammendrag: Energisparekontrakter (EPCer) har vist seg å være en effektiv mekanisme for å øke energieffektiviteten i nesten alle sektorer av økonomien siden de ble introdusert for nesten 30 år siden. I sin moderne form planlegges og gjennomføres EPC av eksperter med spesialisert teknisk kunnskap og finansieres av kommersielle långivere. EPC muliggjør reduksjon av risiko og bruk av tid og ressurser for å oppnå energisparing for byggeier. Denne rapporten gir en oversikt over erfaringer fra USA når det gjelder EPC og diskuterer muligheter og barrierer for bruk av EPC i boligsektoren hvor EPC nærmest har vært fraværende. Boligsektoren varierer på flere viktige måter fra de markedssegmenter hvor EPC har hatt suksess. Faktorer som høy grad av heterogenitet i energibruken, relativt lite energiforbruk per bolig, begrenset tilgang til informasjon om energiforbruk og innsparingspotensial og markedsineffektivitet som begrenser verdien av effektiviserings tiltak har stått i veien for bruk av EPC i boligsektoren. Imidlertid kan kombinasjonen av nye teknologiske fremskritt ved automatisert målingssystemer, fleksible finansieringsalternativer og en økt inkludering av energieffektiviseringsløsninger som en del av konkurransen i energimarkedet bidra til at EPC liknende løsninger kan benyttes også i boligsektoren.

Språk: Engelsk

Rapporten kan bestilles fra:
CICERO Senter for klimaforskning
P.B. 1129 Blindern
0318 Oslo

Eller lastes ned fra:
<http://www.cicero.uio.no>

Title: Performance-based Potential for Residential Energy Efficiency

Author(s): Jason W. Hoyle
CICERO Report 2012:02
32 pages
Financed by: Norwegian Research Council

Project: ESPARR
Project manager: Hege Westskog
Quality manager: Knut H Alfsen
Keywords:

Abstract: Energy performance contracts (EPCs) have proven an effective mechanism for increasing energy efficiency in nearly all sectors of the economy since their introduction nearly 30 years ago. In the modern form, activities undertaken as part of an EPC are scoped and implemented by experts with specialized technical knowledge, financed by commercial lenders, and enable a facility owner to limit risk and investment of time and resources while receiving the rewards of improved energy performance. This report provides a review of the experiences of the US with EPCs and discusses the possibilities for the residential sector to utilize EPCs. Notably absent from the EPC market is the residential segment. Historically, research has shown that the residential sector varies in several key ways from markets segments where EPCs have proven successful, including: high degree of heterogeneity of energy use characteristics among and within households, comparatively small quantity of energy consumed per residence, limited access to information about energy consumption and savings potential, and market inefficiencies that constrain the value of efficiency measures. However, the combination of recent technological advances in automated metering infrastructure, flexible financing options, and the expansion of competitive wholesale electricity markets to include energy efficiency as a biddable supply-side resource present an opportunity for EPC-like efforts to successfully engage the residential sector, albeit following a different model than has been used in EPCs traditionally.

Language of report: English

The report may be ordered from:
CICERO (Center for International Climate and Environmental Research – Oslo)
PO Box 1129 Blindern
0318 Oslo, NORWAY

Or be downloaded from:
<http://www.cicero.uio.no>

Innhold

- I. Purpose 1
- II. Introduction 2
 - A. TERMINOLOGY..... 2
 - B. ORIGIN OF THE EPC..... 2
- III. Energy Service Companies & Performance Contracts..... 5
 - A. TYPES OF ESCOS..... 5
 - B. TYPES OF EPCS 5
 - C. MEASURES IMPLEMENTED AND SAVINGS FROM EPCS..... 6
 - D. CONTRACTING FOR ENERGY SAVINGS 9
- IV. Development, Design, and Operation of EPCs 12
 - A. LESSONS LEARNED FROM THE GROWTH OF EPCS 12
 - B. EVOLUTION OF ENERGY EFFICIENCY EFFORTS 14
 - C. INTERACTION BETWEEN ENERGY EFFICIENCY BARRIERS & EPCS 17
- V. Prospects for the Future of Performance-based Energy Savings Contracts in Housing..... 19
 - A. ENERGY SAVINGS IN HOUSING: BARRIERS & OPPORTUNITIES 19
 - B. TWO KEYS TO APPROACHING RESIDENTIAL ENERGY EFFICIENCY 24
- VI. Conclusion..... 26
- VII. Works Cited..... 27

Acknowledgements

The author extends his gratitude to the following people for their assistance, feedback and contribution of other support: Aaron Hrozencik (Appalachian State University) for exhaustive research assistance; Todd Cherry (Appalachian State University) for directing the project and scoping assistance; and Tor Håkon Inderberg (Fridtjof Nansen Institute - Norway), Tanja Winther, Hege Westskog, Marianne Aasen (Center for International Climate and Environmental Research – Oslo) and participants in the reference group for the ESPARR-project for supporting the project and providing comments, feedback and valuable suggestions. Errors are the responsibility of the author.

This work described herein was funded by the Research Council of Norway through the project “Energy Savings - from Regulation to Realization” (ESPARR) under contract No. 12-0263.

I. Purpose

This report is intended to provide insight into energy performance contracts (EPCs) in the United States. by addressing the following questions:

- To what extent are EPCs being implemented in the municipal and residential sectors in the U.S.?
 - o How are EPCs being implemented in these sectors?
 - o What effect do EPCs have on the barriers and opportunities to realizing energy savings?

- How are the energy performance contract markets serving these sectors organized, and in what manner are the incentives distributed in relation to the tasks and roles of participants?

- How might EPCs be designed to obtain the largest energy savings effects?

- What factors constrain the development of EPCs, and what conditions are most important for increasing the use of EPCs in these sectors?

- In what way are smart meters, or automated metering systems, and other “smart grid” technologies used in combination with EPCs?

II. Introduction

A. Terminology

Given that the questions at hand focus on energy savings as an outcome of EPCs, we must ask what is meant by energy savings and how do energy savings differ from energy efficiency or energy conservation? These different terms are bandied about in “energy efficiency” literature, yet are at times used interchangeably, and at other times used in reference to specific concepts. In general, for the purposes of this report, these terms are differentiated as follows:

Energy Conservation refers to absolute reductions in the quantity of energy consumption. For example, hanging laundry out on a line instead of drying it in a machine is a method of energy conservation.

Energy Efficiency is a measure of the quantity of energy consumed to produce some output; increasing energy efficiency means that the same output is produced using a lower quantity of energy input. Replacing a clothes dryer that consumed 2 kilowatt-hours (kWh) per pound of wet laundry with one that only consumed 1 kWh per pound would increase energy efficiency.

Energy Productivity is a measure of the economic efficiency of energy consumption, and incorporates the tradeoffs associated with how energy is used. Replacing a clothes dryer that consumed 2 kWh per pound of wet laundry during an hour-long operating cycle with one that consumed 2 kWh per pound during a half-hour-long drying cycle would increase energy productivity by reducing labor time and doubling the amount of laundry that could be done with the same equipment during the same period of time (ideally, of course, the replacement dryer would also be more energy efficient and use fewer kWh per pound of wet laundry).

Energy Savings is a measure of the cost of energy, and incorporates both the price and quantity of energy consumed. For example, using a clothes dryer during off-peak hours (i.e., when demand for electricity is lowest) consumes lower-cost electricity and results in energy savings.

B. Origin of the EPC

Energy use in the modern societies of developed nations is ubiquitous and often taken for granted – until it’s not available. Recognition of energy as a resource of finite supply and of potentially limited availability was first institutionalized in the U.S. as a result of the energy crises of the 1970s and resulted in the enactment of the Public Utilities Regulatory Policies Act of 1978 (PURPA) by the U.S. Congress. PURPA sparked a series of changes in the U.S. electric industry that continue to this day, primarily by acknowledging the importance of energy conservation and energy efficiency, but also by providing mechanisms for new entrants to access the theretofore exclusive monopoly of electricity generation.

Shortly following PURPA’s enactment, state regulators began requiring utilities to make investments in increased energy efficiency, and it is this recognition that the role of energy demand in the marketplace is of equal importance to that of energy supply that gave rise to the first generation of energy performance contracts (EPCs). The first generation of what would become the EPC as we know it today was rarely focused on energy conservation or energy efficiency and although they did tend to result in energy savings these outcomes came at a very high cost, commanding risk premiums as high as 2.5 cents per kilowatt-hour (Wolcott & Goldman, 1992).

1. Regulatory Context in Early EPC Markets

A primary constraint on early energy efficiency programs was the highly regulated structure of the electricity market. The first major changes to the highly regulated electricity industry in more than 40 years occurred with enactment of PURPA, a federal law that required electric utilities to allow certain

independent electricity generators, called qualifying facilities (QFs), non-discriminatory access to the electric grid – for the purposes of both buying and selling power – and also required the utilities to purchase QF-generated power at a standard rate, called the avoided cost. However, it was not until enactment of the Energy Policy Act of 1992 (EPAct92) that competitive markets for wholesale electricity began to emerge, and in regions of the country where wholesale competition was adopted, ownership and operational responsibility of the electricity transmission infrastructure was transferred from the vertically integrated monopoly utilities to non-profit organizations called independent system operators (ISOs) and regional transmission organizations (RTOs).

The first efforts to manage demand as a resource, called demand-side management (DSM), occurred in an industry structure where utilities earned profits based on their expenses. Without wholesale competition, the retail price of power was generally determined using the revenue requirement method under which state regulators set a rate of return the utility would earn on its capital equipment investment and operating expenses; so, to the extent that increased demand management would supplant the need for new capital investment higher prices were avoided, but when increased efficiency reduced the utilization of existing facilities the same costs were spread over a smaller quantity of electricity sales which resulted in higher prices in order to meet the revenue requirement.

Naturally, utilities had no interest in actual energy conservation, and early efforts to manage demand were incorporated into utility efforts to minimize the cost of adding new generating capacity necessary to meet peak demand loads. These initial forays into the DSM bidding market were deemed problematic for three reasons: 1) inclusion of DSM bidding in an integrated all-source procurement solicitation; 2) high transaction costs for bid preparations necessary to limit the bidder's performance risk; and, 3) vague and open-ended solicitations from utilities that failed to specify the utility's resource needs and constraints (Wolcott & Goldman, 1992).

From these early experiences, it became apparent that demand-side resources could not be evaluated on an apples-to-apples basis with supply-side resources as DSM activities embodied a variety of non-price factors not applicable in generation capacity bid responses. The effectiveness of these first-generation bidding programs was also constrained by the comparatively high costs energy service companies (ESCOs) incurred for preparation of DSM bids relative to the costs of bidding by power producers offering much larger generation resources. A large portion of these transaction costs are attributable to asymmetrical information – namely, that ESCOs' costs were driven higher as they invested substantial time and effort in identifying, marketing, and auditing the utilities' customers in order to mitigate performance risk.

2. Incorporating Performance Risk

The first generation of EPCs were not “true” EPCs in the sense known today, and took a form resembling energy service contracts (ESCs) rather than performance-based contracts. The critical difference between an EPC and ESC is that the EPC confers performance risk. Development of the International Performance Measurement and Verification Protocol (IPMVP) during 1996-1997 provided the first standardized framework for evaluating the performance of energy efficiency measures (IPMVP Committee, 2002).

Prior to the IPMVP, ESCOs were often compensated based on the outputs (e.g., number of energy audits performed) instead of the outcomes (e.g., peak load reduction or kWh savings). Incorporating pay-for-performance into DSM contracts greatly reduced the performance risk formerly borne by utilities, and made DSM contracts much more palatable to utilities that were concerned about making investments in DSM activities with no guaranteed benefits without which cost recovery would be subject to the whim of state regulatory bodies.

As the benefits of EPCs became more widely appreciated and the ESCO industry developed a track record of success, the 2000s saw commercial lenders displace utilities and electric ratepayers as the

Performance-based Potential for Residential Energy Efficiency

primary source of energy efficiency funding in EPCs. This new funding source coupled with new policies that expanded the potential market by establishing EPC standards and pre-qualified ESCOs to provide EPC services allowed state and federal government entities to make use of EPCs, and resulted in both rapid growth in the EPC market and the establishment of the EPC as a stand-alone business model that no longer was dependent on utility involvement.

III. Energy Service Companies & Performance Contracts

A common definition¹ of an energy service company is: “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.” (Larsen, Goldman, & Satchwell, 2012).

A. Types of ESCOs

The U.S. ESCO industry is estimated to have more than \$7 billion in revenue during 2011, up from about \$4.1 billion in 2008 (Satchwell, Goldman, Larsen, Gilligan, & Singer, 2010). According to the most recent survey of ESCOs in the U.S. (Satchwell, et al. 2010) the four largest ESCOs with 49% of total industry revenue are building equipment manufacturers, 43% of industry revenues are attributable to 35 companies classified as either engineering service companies – independent ESCOs – or other energy companies, and the remaining 8% of revenue is earned by 5 utility affiliates. Independent ESCOs have been the fastest growing segment of the ESCO industry, with this sector’s share of total industry revenue increasing from 10% of revenue in 2000 to 22% of industry revenue in 2008 (Hopper, Goldman, D., Singer, & Birr, 2007).

ESCOs can also be grouped based on their market focus. ESCOs can be affiliated with other companies (e.g., utility affiliates or divisions of equipment manufacturers) while others are independent companies. The geographic focus of ESCOs is also another defining characteristic, with some companies working in specific geographic areas and others offering services nationwide. ESCOs also target different market segments, some by specializing in specific types of facilities (e.g., commercial industrial, residential, universities, or hospitals) and others by concentrating on particular technical areas (e.g., lighting, HVAC, or certain industrial processes).

B. Types of EPCs

An EPC is the legal agreement between a facility owner/operator and the company providing the energy services. The EPC agreement is typically a multi-year arrangement that specifies the scope of services to be provided, responsibilities of the parties, and other terms. EPCs sometimes include capital equipment upgrades in addition to energy services, including: energy audits, project engineering, financing, equipment procurement, construction, commissioning, facility staff training, measurement and verification of energy savings, and sometimes include ownership or operation of new equipment, negotiating and managing fuel and/or power purchase agreements, and other energy management services.

Contracts for energy services do not always include a performance-related component, especially in the residential sector. About a quarter of ESCO revenues are earned from pay-for-service type contracts under which the ESCO is hired to provide services such as design/build (i.e., engineering, construction and commissioning) for a new facility, to conduct energy audits and recommend energy efficiency improvements, or to manage and evaluate the performance of a utility’s energy efficiency programs. In some cases in the U.S., where allowed by state regulations, ESCOs enter into chauffeage, or utility purchase agreement contracts, where the ESCO owns the equipment (e.g., HVAC, lighting, etc.) and sells the output to the customer.

¹ This definition is consistent with the standard definition of an ESCO in the European Commission Directive (2006/32/EC) on Energy End-use Efficiency and Energy Services, particularly in the delivery of energy services and assumption of some degree of performance risk by the ESCO.

Performance-based contracts generally take one of two forms: guaranteed savings or shared savings. As described by the Pacific Northwest National Laboratory (PNNL) in a guide to performance contracting with ESCOs (Baechler & Webster, 2011), these types of EPCs are characterized by:

- **Guaranteed Savings:** contracts have a fixed term and the ESCO ensures a minimum level of savings over a fixed term; financing is provided by the ESCO although the owner makes some capital investment in some cases; and, the ESCO receives no additional benefit if savings exceed the estimated amount.
- **Shared Savings:** contracts directly tie the compensation of the ESCO to the savings earned by the project, the specific arrangements may take a variety of forms (e.g., ESCO receives a fixed percentage of savings, a minimum fee plus a percentage of savings, or a fee that scales down over time as the ESCO recoups its investment); financing is mostly provided by the ESCO but may include some capital investment by the facility owner; and some provisions usually address the distribution of savings in excess of projections.

C. Measures Implemented and Savings from EPCs

Extrapolating from a database representing an estimated 20% of ESCO projects from 1990-2008, a Lawrence Berkeley National Laboratory (LBNL) report estimates that the ESCO industry has provided about \$23 billion in net direct economic benefits to customers, with the average public-sector project providing about \$0.89 per square foot in net direct benefits to customers (Larsen, Goldman, & Satchwell, 2012). Among projects in the database are 367 state and local government projects that received a total net direct benefit of more than \$442 million with a median benefit-cost ratio of 1.5, 186 projects at health/hospital facilities received a net direct benefit of more than \$330 million with an median project benefit-to-cost ratio of 2.6, and 68 public housing projects with nearly \$69 million in total net benefits at a median benefit-cost ratio of 1.4.

EPC projects in the public sector have a track record of meeting or exceeding the expected level of savings that has improved over time. Between 1990 and 1997, nearly 80% of projects in the database met or exceeded expected savings levels with nearly 65% exceeding expected savings levels. Between 1998 and 2004, about 85% of public-sector projects met or exceeded expected savings levels, but the ability of ESCOs to accurately predict energy savings improved with about a third meeting – without exceeding – projected savings. Again between 2005 and 2008 more than 80% of public-sector projects met or exceeded projected savings, but projections of savings by ESCOs improved dramatically so that less than a third of projects exceeded projected savings. This increasingly large portion of projects that meet but do not exceed projected savings levels is significant to the growth of EPCs because a project's savings determine the ESCOs profits and, in turn, confidence in the accuracy and level of projected savings constrains which projects ESCOs may be willing to take on.

1. ESCO Strategies

ESCO retrofit strategies included in EPCs include a wide array of measures and combinations of measures, ranging from lighting improvements or replacement of major HVAC equipment to installation of on-site generation facilities, replacing major equipment (i.e., laundry or kitchen appliances), or major facility construction (e.g., roof replacement or re-insulation of exterior walls). Retrofit strategies for EPCs, as classified by Lawrence Berkeley National Laboratory (LBNL), are shown in Table 1. These strategies are cumulative (with the exception of “Other”), so that the major HVAC would include lighting-only and minor HVAC retrofits in addition to major HVAC activities.

Table 1

Primary retrofit strategies utilized in ESCO projects

Primary retrofit strategy	Example of energy conservation measures (ECMs) included
Lighting-only	Technologies installed only include various lighting efficiency measures, controls and strategies.
Minor HVAC	Technologies installed only include less-capital intensive HVAC measures and controls (and exclude major HVAC equipment replacements) and may include lighting and other measures.
Major HVAC	Technologies installed include major HVAC equipment replacements (e.g., boilers, chillers, cooling towers, HVAC dist. improvements) and may include other HVAC control, high-efficiency lighting, and motors measures.
On-site generation	Technologies include installation of onsite generation equipment and may include other energy efficiency measures (e.g., lighting, HVAC equipment and controls, motor efficiency measures).
Non-energy ^a	Technologies installed include roof or ceiling replacement, asbestos abatement (i.e., measures that are not installed primarily for their energy savings), and may include other efficiency measures (e.g., lighting or HVAC upgrades).
Other	Technologies installed include all other measures including domestic hot water (DHW), water conservation, and installation of energy-efficient equipment such as vending machines, laundry or office equipment, high-efficiency refrigeration, industrial process improvements and strategies such as staff training or 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.

a (Hopper, Goldman, McWilliams, Birr, & McMordie-Stoughton, 2005) indicate that, in some cases, ESCO projects include some measures with significant costs that are not necessarily intended to produce energy savings (e.g., asbestos removal). Thus, we defined this retrofit strategy as "non-energy" to separate projects that may have relatively poor economic performance because they include some measures that provide non-energy benefits or are required for the project to move forward but whose value is difficult to monetize.

Table Source: (Larsen, Goldman, & Satchwell, 2012)

As each strategy incorporates a progressively more-involved level of retrofit activity, the rate of investment typically increases. Typical lighting-only retrofits have been historically undertaken at a real cost (in 2009 dollars) of less than \$2 per square foot, while minor HVAC retrofits have been undertaken at a real cost of about \$3/ft², and major HVAC improvements at an average real cost of about \$5/ft² although the 75th percentile of projects have required investment of about \$8/ft² (Larsen, Goldman, & Satchwell, 2012).

Non-energy project strategies, in particular, have the highest rate of investment and one of the lowest rates of return with an average investment of between \$8 and \$10 per square foot for projects offering a payback in excess of 12 years. However, more than 85% of projects installing non-energy measures between 2005 and 2008 in the U.S. were K-12 schools which utilize the EPC method as a means of securing needed capital without taking on additional public debt in order to fund long-overdue infrastructure and facility repairs and upgrades.

Project activities examined in the LBNL study were grouped into two general classifications based on the comprehensiveness of the EPC activities, with those implementing major HVAC, onsite generation and non-energy measures considered comprehensive, while those projects with lighting-only or minor HVAC activities were considered non-comprehensive. Overall, there were about 2.5 comprehensive projects for every non-comprehensive project, and the typical investment for comprehensive projects was about twice

that for non-comprehensive projects. The comparatively higher frequency of comprehensive projects suggests a preference by ESCOs, perhaps due to economies of scale, for large-scale projects with a broad scope of activity.

2. ESCO Activities

The single most common ESCO activity, as shown in Figure 1, is the installation of high-efficiency lighting, which is done by an estimated 93% of all projects. The second-most common source of energy savings is the installation of controls, both for lighting and HVAC systems, which are installed by more than 65% of projects in municipal, university, schools, and health facilities. Other common measures implemented in EPCs include upgrades to indoor climate control equipment (e.g., boilers, chillers, and ventilation ducts), water conservation devices, and building envelope improvements. Some customer classes, schools and public facilities in particular, also show a high incidence of implementing non-energy measures – typically including replacement of capital equipment, major building repairs (e.g., roof), or deferred maintenance activities. Some projects also feature on-site power generation, such as the installation of solar electricity generating equipment or solar water heating technology.

Most EPC projects included multiple energy conservation measures. A 2002 study (Goldman, Osborn, Hopper, & Singer, 2002) from LBNL examined projects entered in the National Association of Energy Service Companies (NAESCO) database between 1990 and 2000, and based on 11 categories of end-use retrofit measures² determined that the average institutional sector project (government, schools, universities, hospitals, etc.) featured activities from 2.2 measure categories. Within the institutional sector, the 181 state and local government projects averaged activities in 1.9 measure categories, and the 39 projects in public housing averaged activities from 2.4 measure categories.

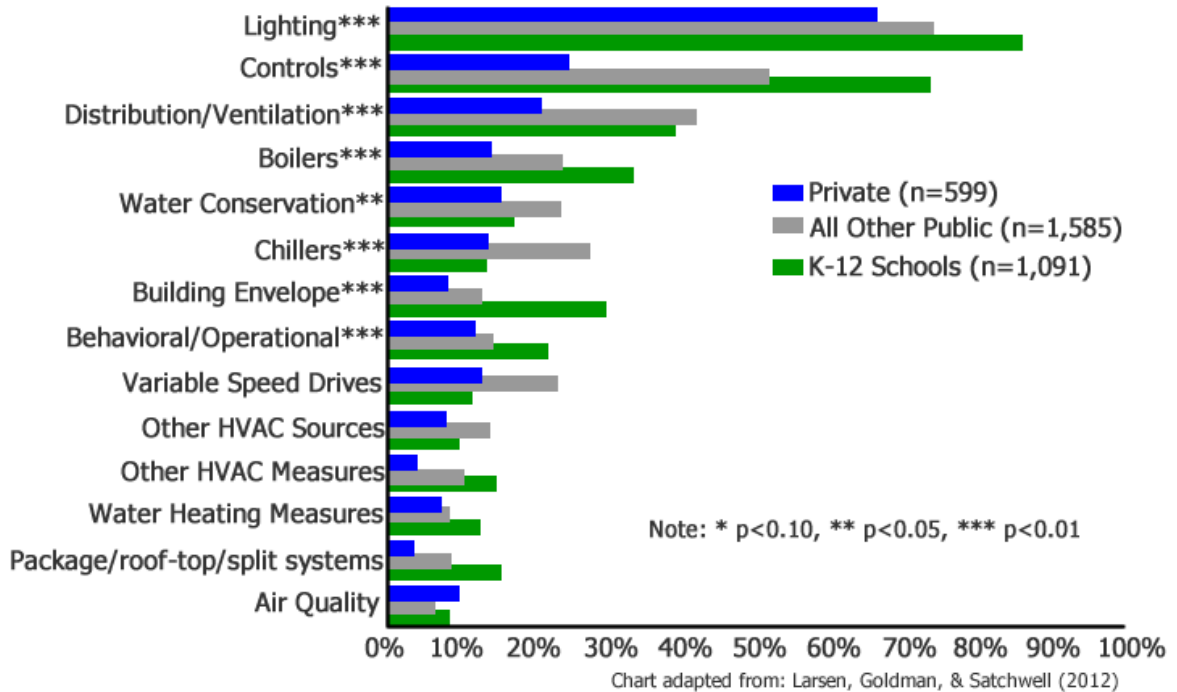


Figure 1 – Percentage of Projects Implementing Measures (Larsen, Goldman, & Satchwell, 2012)

² End-use retrofit measure categories are: lighting, comfort conditioning, motors/drives, water heaters, non-energy improvements, power supply, refrigeration, miscellaneous equipment and systems, industrial process improvements, other measures/strategies, and plumbing products and fittings.

D. Contracting for Energy Savings

1. EPC Process

The basic process for entering into an EPC includes the five phases, adapted from the PNNL guide (Baechler & Webster, 2011), shown in Figure 2. The first phase starts with the customer, or facility owner, who must define the general scope of the project – often using the results of an energy audit or feasibility study – and then select an ESCO or other company to carry out the work. Once financing for the project is secured, whether self-financed, through the ESCO, or from a third-party, the project is implemented and the equipment is commissioned and brought into service. During the course of the project, regular measurement and verification of energy savings is performed along with general operations and maintenance activities, until the end of the contract term when all financial and other obligations are fulfilled.

There are standard contract terms and pre-approved ESCOs for the use EPCs at federal government facilities in the U.S., and many states have adopted a similar approach with pre-approved contract templates and lists of ESCOs that are pre-qualified for EPC activities in state and municipal facilities. In addition there are several resources³ from the energy management industry associations which also provide templates and resources to support facility owners' pursuit of an EPC.

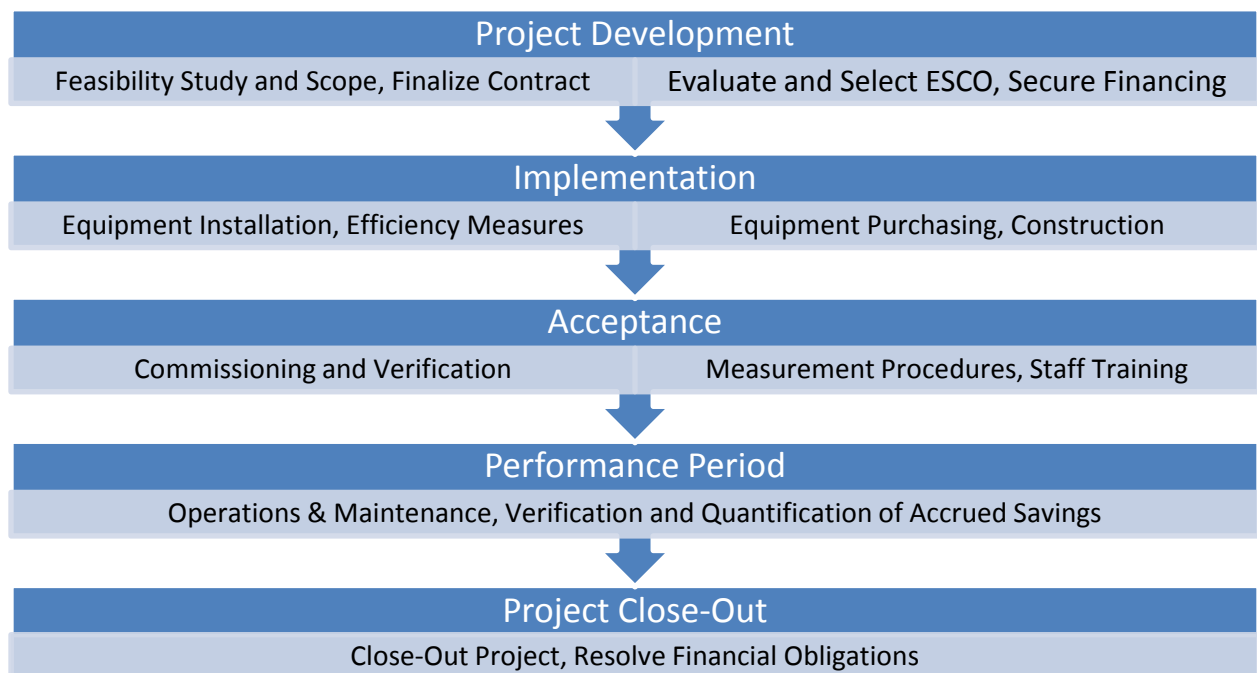


Figure 2 - Energy Performance Contract Phases

³ These include the National Association of Energy Service Companies (NAESCO) at <http://www.naesco.org>; the Energy Services Coalition at <http://www.energyservicescoalition.org/resources/model/index.html#Pre-Qualify>; the U.S. Department of Housing and Urban Development's Public Housing Energy Conservation Clearinghouse at http://portal.hud.gov/hudportal/HUD?src=/program_offices/public_indian_housing/programs/ph/phecc/eperformance; and the Building Owners and Managers Association's International Energy Performance Contracting Model at <http://www.boma.org/resources/bepc/Pages/default.aspx>

2. EPC Terms & Approaches

While most EPC projects are completed in a single phase, about 13% of projects studied from the NAESCO database were implemented in multiple phases. A high percentage (41%) of multi-phase projects reported multiple phases of lighting-only retrofits – only 24% of all projects reported lighting-only retrofits. Overall, multi-phase projects tended to be more comprehensive (i.e., utilize more activity measures or strategies) than their single-phase counterparts. Some reasons cited for the use of a phased approach include: minimize construction-related disruption, constraints on contracting and procurement, and a desire to assess ESCO performance on an individual project prior to making larger/longer commitment (Goldman, Hopper, & Osborn, 2005).

The length of EPC contract terms also varies, in some cases based on the types of retrofit measures selected and in others due to restrictions imposed by third-party funding programs (e.g., ratepayer funded efficiency programs, state contract rules, etc.). The NAESCO database – less ratepayer or other publicly funded projects – indicates that slightly more than 20% of projects completed between 1996 and 2000 had contract terms of less than five years, about half of projects during the same time period had contract lengths of between 10 and 14 years, and that about 10% of EPCs had contract terms of 15 years or longer (Goldman, Osborn, Hopper, & Singer, 2002).

3. Performance Requirements, Guarantees, and Insurance

Much like the ESCO offering the EPC assumes some or all of the performance risk associated with the guaranteed level of savings and may be exposed to the credit risk of the EPC counterparty, the facility owner or operator who will receive EPC services from the ESCO also incurs a performance risk – the risk that the new equipment or repairs installed by the ESCO may not be as durable, functional, or reliable as what is being replaced. After all, the energy savings from a new high-efficiency device are of little-to-no benefit if the device is unreliable and in frequent need of repair. EPC contracts with federal housing agencies in the U.S. address this risk by incorporating performance specifications into the EPC.

EPC's with federal agencies (or public housing agencies using federal funds from Housing and Urban Development (HUD)) have a maximum statutory contract length of 25 years⁴, and energy savings performance contracts (ESPCs) require annual energy audits and terms specifying government payments and performance guarantees – effectively placing the burden of ensuring the efficacy of equipment operation on the contractor for a specified length of time.

Federal law⁵ requires that, “Any such performance guarantee shall provide that the contractor is responsible for maintenance and repair services for any energy related equipment, including computer software systems.” So, EPC contracts with the federal government in the U.S. require guarantees of not only energy savings but also of equipment operation; state agencies likely have similar clauses, the specifics of which vary from state to state, and private organizations are generally left to fend for themselves in negotiating contract clauses.

The generic indefinite delivery, indefinite quantity (IDIQ) contract for ESPCs from the Federal Energy Management Program⁶ includes standards of service specifications as part of the performance requirements for energy conservation measures (ECMs) in each ECM's task order (TO). These standards of service could include specifications such as acceptable temperature, lighting level, noise criteria, or other factors (e.g., even a minimum amount of operational time required) (IDIQ Contract, C.3). The IDIQ

⁴ 42 USC §8287 (a)(1)

⁵ 42 USC §8287 (a)(2)(A)

⁶ IDIQ contract template available at http://www1.eere.energy.gov/femp/financing/espcs_resources.html

contract also requires post-installation reports and annual measurement and verification reports (IDIQ Contract, C.4.6) that include not only energy savings but standards of service evaluations as well.

Operational requirements are also specified in the IDIQ Contract (C.6), which states “Regardless of who performs the operations, the contractor shall be responsible for the operations of all installed ECMs” (C.6.1). Contractors are also responsible for all preventive maintenance, including even maintenance activities performed by the government agency (IDIQ Contract, C.7), and responsibility for repair of all energy conservation measures also falls on the contractor (IDIQ Contract, C.8):

IDIQ Contract, C.8.2 Repair of ECMs includes all material and equipment associated with the replacement or repair of facilities, systems, or equipment that have failed or are in a condition of diminished ECM performance as determined by the contractor, and concurred to by the agency.

IDIQ Contract, C.8.3 Equipment Failure - If equipment failure or damage is a result of the contractor’s failure to perform or negligence in performing repairs, the contractor shall provide repair or replacement at its expense or, if repaired or replaced at agency expense, the contractor shall reimburse the agency for losses attributable to the contractor’s failure or negligence.

Generally, title to the ECM-related equipment vests with the government after the government’s acceptance, but acknowledgement is given to the possibility of equipment title vesting with the contractor or a third party (i.e., financier) (IDIQ Contract, H.2). Specific responsibilities of the parties are designated in the Risk, Responsibility and Performance Matrix⁷ with subparts for a) equipment performance, b) operations, c) preventive maintenance, and d) equipment repair and replacement.

Aside from the above provisions, there are additional alternatives, both established and emerging. The first obvious alternative is requiring [or considering] equipment warranties in any EPC solicitation. There are also a variety of insurance products increasingly being used in the renewable energy industry in the U.S. that would be applicable to mitigate the risk of nonperformance (Janison & Schlosberg, 2011), including:

- Boiler and machinery insurance, or equipment breakdown insurance (a specialized but common supplement to property insurance);
- Equipment warranty insurance, for some level of performance over a period of time;
- Warranty surety assurance that warranty will be honored even if company offering warranty is insolvent;
- System performance/installation warranty insurance mitigated performance risk, typically by backing the performance guarantee of the contractor; and,
- System performance insurance which is more idea or concept than available insurance policy at the moment, but would insure the total system’s performance and not just individual components.

⁷ See IDIQ Contract, Attachment J-7, Section 3. Performance

IV. Development, Design, and Operation of EPCs

A. Lessons Learned from the Growth of EPCs

The history of the ESCO industry provides some clues as to what factors drive success in the energy services business and performance contracting in particular. As summarized by a report (ICF International, NAESCO, 2007) prepared for the U.S. Environmental Protection Agency (EPA), ESCOs originated in response to state regulations mandating that utilities increase energy efficiency efforts following the energy crises of the 1970s, and while ESCO activity during the late 1970s and early 1980s is often described as the first generation of EPCs, projects during this period rarely involved the ESCO assuming any performance risk and were typically executed on a fee-for-services basis.

The period from the late 1980s through the early 1990s saw the first true performance contracts emerge as utilities were required to incorporate procurement of energy efficiency as a resource in a planning process called integrated resource planning (IRP). With the U.S. electricity market still composed of regulated monopolies operating without wholesale or retail competition, this period was dominated by a focus on reducing peak load in an attempt to avoid construction of new generation facilities that would otherwise be needed to serve rising peak demand load. Inclusion of energy efficiency as a resource on par with generation resources brought the need for reliable standardized protocols or measurement and verification (M&V) of energy efficiency.

Following the development of reliable M&V protocols with the introduction of the IPMVP and a track record of success with early projects, the EPC business entered a period of rapid growth. Industry growth during the mid-to-late 1990s was driven by several factors: 1) increased access to finance provided by commercial lenders, 2) reduced ESCO transaction cost and risk, allowing customers to realize a greater portion of a project's energy savings without lowering ESCO return, 3) the incorporation of non-energy benefits (e.g., use of capital leases, deferred maintenance, water savings, etc.) into the EPC model, and 4) the adoption of standard EPC programs by local, state and federal government.

Following a brief lull in the EPC market after the efforts to restructure U.S. electricity markets faltered in the wake of the collapse of Enron⁸ in the early 2000s, increased energy market volatility, rising energy prices, major energy infrastructure disruptions⁹, and a renewed focus on energy efficiency brought about new market opportunities for the ESCO industry in the mid-to-late 2000s. This recent period of industry growth saw the introduction of new technologies, particularly on-site generation and renewable energy, provide an additional source of value in the product and service offering of ESCOs.

These periods of change in the history of the ESCO industry provide some insight into the factors driving the success of EPCs in the U.S. market, and provide a framework for examining the potential for future increases in EPC activity within the municipal and residential market segments. The remainder of this section discusses specific barriers to the EPC business model and how their mitigation has contributed to the growth of the ESCO industry in the U.S.

1. Transaction Costs

Transaction costs constrain the size of the potential EPC market as high transaction costs increase the minimum, or break-even, quantity of energy savings necessary for a project to be successful. The first

⁸ Enron Corp. was a leading innovator in wholesale electricity trading and a primary driver of electricity-market restructuring across the U.S. until the company's collapse amid scandal in late 2001.

⁹ The disruptions include repeated summertime rolling blackouts in California, shutdown of pipelines delivering natural gas and petroleum products from the Gulf of Mexico to the Eastern Seaboard in the wake of Hurricanes Katrina and Rita, and large-scale blackouts in the Northeastern U.S.

generation of demand-side bidding provided results that were generally considered suboptimal, largely due to unnecessarily high transaction costs (Wolcott & Goldman, 1992). These high transaction costs are largely attributable to the manner in which utilities sought to procure energy efficiency resources. ESCOs, in preparing responses to requests for proposals (RFPs), were provided little, if any, information about: 1) the energy consumption or peak load of utility customers, 2) the amount or type (i.e., reduced peak load, reduced consumption, etc.) of energy efficiency resources being sought, or 3) the nature of the services or type of compensation the utility was willing – or able – to provide.

These early inefficiencies in the process to procure energy efficiency resources were remedied to some extent by RFPs for energy efficiency that were issued separately from those for generation resources, RFPs seeking resource quantities of a specific type, and RFPs targeting specific market segments (i.e., industrial, commercial, residential). These process improvements allowed ESCOs to reduce the time and effort necessary to prepare a response to bid solicitations, and allowed the development of proposals that were more consistent with the utility's needs.

2. Information

Information is fundamental to the EPC model – information about both the potential energy savings and the actual energy savings that result from project activities. Information about energy savings potential requires not only knowledge of how much energy is used by the customer's equipment and devices, but also the operating cycle (i.e., frequency, duration) of the energy-using equipment. While government, commercial, and industrial facilities are typically operated on a reliable consistent cycle with many similarities from one customer to another, residential customers in comparison are much more varied in how they use energy.

Potential energy savings are also determined based on the extent to which upgrades or retrofits can reliably alter energy consumption. The importance of reliable energy efficiency improvements is demonstrated by the ESCO industry's emphasis on lighting upgrades and HVAC improvements. Both of these areas feature regular energy use on a consistent schedule by non-residential customers, both are often installed when a building is constructed and without a targeted intervention are likely to be repaired rather than replaced and therefore the outdated less-efficient legacy models are likely to remain in service. Additionally, equipment of this type can often be upgraded with limited disruption to other aspects of the facility, at a known cost, and without the risk of unexpected costs or delays as may occur in more invasive upgrades such as improving a building envelope.

In order to properly evaluate the energy savings from an EPC project, the energy savings must be measured and verified. Depending on the nature of energy use and the activity level in a facility, M&V of energy savings is not always possible from a basic measure of the facility's total energy consumption. Energy consumption may rise following EPC improvements, yet energy savings may be substantial – some potential causes of this circumstance include: increased activity levels, changes in weather (i.e., cooler summer or warmer winter than normal), new devices or equipment are installed, or EPC changes may result in the facility's occupants changing behaviors (e.g., a new HVAC system and controls may result in occupants using fans for summer cooling or inefficient personal space heaters in winter).

3. Financing

Access to financing for EPC improvements greatly expanded the ESCO industry. The entry of commercial lenders brought increasingly sophisticated financing arrangements and increased the appeal of and feasibility for customers considering entering into an EPC. The financing barrier is closely tied to the allocation of both performance and credit risk. The expertise of ESCOs in producing energy savings and the assumption of project performance risk by ESCOs provides lenders with greater assurance of a project's financial viability. Furthermore, modern EPC models are structured so that the ESCO finances the project at the customer's facility, and commercial lenders provide financing to the ESCO – thereby

attaching the credit risk of the commercial lender to the ESCO, and allowing the ESCO to divide its risk among a portfolio of several projects.

An examination (Goldman, Osborn, Hopper, & Singer, 2002) of “turnkey” project costs – not including financing costs – for 1,426 projects reporting cost information to the NAESCO database between 1982 and 2000 indicated median and average project costs of \$700,000 and \$1,800,000, respectively. About 280 projects (20%) had a cost of less than \$200,000, about 35% of projects had a cost of less than \$400,000, and only 10 to 15 projects had a cost in excess of \$20 million. The “turnkey” project costs described above represent “The cost to develop and construct the project including all development, engineering, installation, and construction financing costs as of the date of acceptance by customer,” and exclude both financing costs and ongoing service costs such as those for monitoring and maintenance. Based on this set of projects in the NAESCO database, Goldman, et al. (2002) estimate future financing costs increase the “turnkey” project costs by about 21%.

Greater access to financing has allowed the ESCO industry to expand, but has also added another dimension to the required scale economies for EPCs – larger amounts of capital require both larger-scale projects and a larger number of projects to be undertaken without significant increases in the transaction cost of each project. The 39 public housing EPC projects reported in the NAESCO database had a median cost of about \$1.9 million, with the lowest quartile of projects costing about \$1 million and the highest quartile about \$6 million. Of all sectors in the database, public housing had the highest median and 25th percentile cost as well as the highest interquartile spread by far; although when normalized by floor area, the median and 25th percentile of public housing sector costs were about \$1.75/ft² and were well within the range of other sector costs (Goldman, Osborn, Hopper, & Singer, 2002).

4. Streamlined Process

The development and growth of EPCs was also facilitated by state and federal government efforts to streamline the EPC process. On one side, utilities and other parties seeking to employ EPCs as a source of energy efficiency made clear in their solicitations for competitive proposals their goals for energy savings, their targeted market segments, and provided indications about what they were willing to pay for energy (kWh) and load (kW) reductions. Another approach used by utilities and governments alike was to pre-qualify ESCOs, so that any pre-qualified ESCO could provide services to a facility owner following certain guidelines. A final approach to streamlining the process was the use of template-based EPC agreements with standard terms and conditions.

B. Evolution of Energy Efficiency Efforts

1. Regulatory Impetus

The Public Utilities Regulatory Policy Act of 1978¹⁰ (PURPA) was the first federal legislation enacted to provide for the increased conservation of electric energy and increased energy efficiency¹¹ as a means to provide equitable rates to consumers. PURPA provided for the market entry of new generators by ensuring access to transmission infrastructure and requiring that these new generators, called qualifying facilities (QFs), be compensated for providing energy or capacity to the utility at a rate called the avoided cost¹².

¹⁰ 16 U.S.C. Chapter 46

¹¹ 16 U.S.C. §2601

¹² Avoided cost means the incremental costs to an electric utility of electric energy or capacity or both which, but for the purchase from the qualifying facility or qualifying facilities, such utility would generate itself or purchase from another source. See 18 CFR §292.101(b)(6)

Through the 1980s vertically integrated electric utility monopolies entered into long-term avoided cost contracts with independent power producers requiring the utility to pay these QFs their incremental cost, which in many cases was set based on the cost of the large-scale nuclear generating facilities that had been constructed during the preceding decade and were just beginning to enter service. As the real price of natural gas fell precipitously during the 1980s and 1990s, independent power producers saw significant profit margins as the spread between their generation cost and the avoided cost rate grew larger (Borenstein & Bushnell, 2000). The result of these high-cost contracts in many cases was high electric rates due to stranded costs that were recovered by utilities at the expense of their customers.

While utilities and their customers were locked in to paying high electricity prices for excess baseload capacity, they still faced the need to add capacity to meet peak demand which further increased electricity generating costs and, in turn, retail prices. In response to rising electricity prices, many states began to require more comprehensive planning methods that included consideration of energy efficiency and peak load-reduction measures in determining the future resource mix. The result was the emergence of the first substantial activity in the energy efficiency market area by U.S. electric utilities.

2. Competitive DSM Bidding

This push into the energy efficiency arena by electric utilities drove considerable interest in demand-side management activities, particularly those that reduced peak load. Many utilities established their own DSM programs in an attempt to avoid making additional investments in new generation capacity, and typically offered customers discounted rates or some other form of compensation in exchange for allowing the utility to turn off equipment with high electric capacity requirements during peak hours; the corresponding program in the residential sector typically focused on remote utility control over air conditioners and electric water heaters during normal workday hours.

These programs did little to actually conserve energy, but rather created energy savings by allowing the utility to avoid increasing electric rates to pay for the cost of new peak generation capacity. Often peak load-focused DSM programs merely shifted consumption from peak hours to off-peak hours. Incentives in these early programs were typically paid to the participating electric consumers, but by reducing utility investment and lowering demand for the highest-cost electricity generation, all ratepayers benefitted from electric rates that were either reduced or lower than they otherwise would have been.

By the mid-1980s the utility practice of demand-side management (DSM) had become widespread, signifying a fundamental shift in industry planning and operation as the concept of a utility influencing and managing its customers' demand as a supply resource similar to the way supply from generation facilities is managed began to take hold. By 1993, DSM programs were well established and utility spending reached \$1.8 billion (York, Witte, Nowak, & Kushler, 2012). However, despite an increased focus on managing demand, the high avoided cost rates and past investment decisions by utilities in some states continued to yield comparatively high retail electricity prices, and as a result these states sought to form broader regional markets for wholesale electricity which would allow for more efficient use of existing generation capacity.

3. Consumer Awareness

Concurrent with development of utility programs to stimulate energy efficiency were other efforts such as the ENERGY STAR program of the U.S. Environmental Protection Agency and U.S. Department of Energy. The ENERGY STAR is a product certification label first introduced in 1992 to assist consumers with identifying energy efficient personal computers that has expanded to include more than 60 product categories which had over 15,000 certified products and another 10,000 products registered for certification in 2011 (U.S. EPA, 2011). The ENERGY STAR label, which assures consumers that a product is up to 65% more energy efficient than the standard model, reached a milestone in 2011 with

more than 80% of the American public recognizing the label, 75% of whom credit the label as an important factor in their purchase decision (U.S. EPA, 2012).

The ENERGY STAR Homes label was first adopted in 1995, and since then more than 1.3 million homes have received the ENERGY STAR label across the U.S. Energy efficiency and other green building practices have also become widespread, such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standard for homes and buildings. The LEED program provides training and certification in cost-efficient and energy-saving building techniques for its 162,000 professional members and 14,000 member companies.

4. Competition into the Marketplace

The introduction of competition into some electricity markets in the U.S. heralded a shift in focus for utilities away from managing demand and back towards a supply-dominated mindset as the opportunity to procure lower-cost generation resources in competitive wholesale markets was made available in many regions of the country. The result of this reoriented focus was a decline in utility spending on energy efficiency programs, and in response many states established new policies and sources of funding for energy efficiency. The two primary mechanisms that have since been increasingly adopted to fund utility energy efficiency efforts are the public benefits fund (PBF) and the energy efficiency resource standard (EERS), and, in a group of northeastern states, funds generated through the Regional Greenhouse Gas Initiative (RGGI) have become a source of energy efficiency funding.

Public benefits funds (PBFs) are state-level programs generally adopted to provide support for renewable energy and energy efficiency following electricity market restructuring (i.e., wholesale competition). PBFs are often capitalized by fees charged to electric ratepayers, which may either be a flat fee or a charge based on electricity consumption. The consumption-based charge is typically assessed in increments of mills per kWh, or in units of 1/10th of one cent per kWh, and range from a high of 4.82 mills in California to a low of 0.03 mills in North Carolina (U.S. Department of Energy, 2010). The 18 states with PBFs in mid-2012 all have unique PBF programs, some like Delaware have established a Sustainable Energy Utility to manage the fund and determine the share of investment in renewable energy versus energy efficiency, while others like Hawaii have state legislation specifying central fund administration and uses the fund to only provide incentives for energy efficiency and solar water heating. Michigan uses the majority of the \$89 million annual PBF receipts to support the state's low-income energy efficiency fund (DSIRE, 2012).

Another source of funding for energy efficiency in 10 northeast states is the U.S.'s only multi-state mandatory greenhouse gas emission reductions program, called the *Regional Greenhouse Gas Initiative* (RGGI). Under the RGGI program, electric utility emissions are capped and required to decline slightly year by year. Compliance is demonstrated by a utility through the submission of allowances equal to its greenhouse gas (GHG) emissions for the year. Quarterly auctions are held through which utilities purchase allowances, and auction proceeds are provided to the individual states to use as they see fit. Through the RGGI's first phase (ended Dec. 31, 2010), nearly \$790 million was generated from auction proceeds, and 51.6% of that amount was invested in energy efficiency programs. Excluding program administrative costs, four states – Vermont, Rhode Island, New Hampshire¹³, and Maine¹⁴ – used auction proceeds exclusively for energy efficiency. Energy efficiency activities supported by RGGI auction funds include: home weatherization and retrofitting, incentives for energy-efficient appliances, educational programs, and energy-sector occupational training programs (RGGI, 2011).

¹³ 11% of auction proceeds received by New Hampshire went to reducing the state budget deficit and resolving a fiscal crisis in 2010, while the remainder less program administration costs was invested in energy efficiency.

¹⁴ 1% of auction proceeds received by Maine were allocated to the "Other GHG Reduction Programs" category.

An *Energy efficiency resource standard* (EERS) is a state-level policy requiring a minimum level of increased energy efficiency. As of July 2012, EERS had been implemented by 20 states and another 7 states had a voluntary goal, 12 of which included both natural gas and electricity while the remainder included only electricity (DSIRE, 2012). EERS are a relatively new phenomenon in the U.S. with about two-thirds of state policies having been enacted in the past five years and many programs still approaching their first benchmark savings year. The EERS take a variety of forms; Vermont and New York requiring consumption to be reduced by a cumulative percent below a baseline by a target year, Hawaii has established a long-term goal to achieve reductions of 4,300 GWh by 2030, Texas requires savings equivalent to 20% of incremental load growth in 2011 and increases the share of incremental load growth that must be avoided to 25% in 2012 and 30% in 2013 and thereafter, but the majority of EERS in place require a small amount of annual savings – about 1% to 1.5% – at the outset and increase the annual savings target in future years (Sciortino, Nowak, Witte, York, & Kushler, 2011).

C. Interaction between Energy Efficiency Barriers & EPCs

A large gap exists between the potential cost savings and economic benefits of energy efficiency and the actual implementation of energy efficiency measures (Granade, Creyts, Derkach, Farese, Nyquist, & Ostrowski, 2009). According to data from a survey conducted by the Consortium for Energy Efficiency and Institute for Energy Efficiency, total ratepayer-funded electric efficiency budgets¹⁵ reached more than \$6.8 billion in 2011 – 84% of which was attributable to utilities (Cooper & Wood, 2012). According to this same study, energy efficiency expenditures in 2010 saved more than 112 TWh¹⁶ nationwide at an average cost of 4.3 cents per kWh, or about 66% less than the 2010 U.S. average electricity price of 9.83 cents per kWh (EIA, 2011). The residential sector – including low-income energy efficiency programs – represented about 31% of these savings.

Data from the Energy Information Administration (EIA, 2011) show a similar share of savings from energy efficiency in the residential sector, with total 2010 energy efficiency savings from utility programs of more than 32 million MWh, representing about 37% of energy savings from utility programs. The direct cost – not including customer incentives or utility administration – of these savings was \$573 million, or 1.785 cents per kWh saved. The term “energy-efficiency gap” (Jaffe & Stavins, 1994) is demonstrated by the vast difference between the costs of energy efficiency measures and the cost of electricity. Described as a market failure, this gap between the direct cost of electricity and the cost of saving electricity understates the efficiency gap since this direct cost-benefit comparison is not inclusive of the many indirect social and environmental costs (e.g., climate change, resource consumption, air and water pollution, health effects, etc.) associated with the most common electricity generation technologies (Golove & Eto, 1996).

1. Barriers to Energy Efficiency

The first systematic presentation of the causes of this gap between opportunity and exploitation were presented in a 1980 paper (Blumstein, Krieg, Schipper, & York, 1980) that categorized the social and institutional barriers to economically rational decisions of consumers. Blumstein, et al. (1980) identified six classes of barriers: 1) misplaced incentives, 2) lack of information or misinformation, 3) regulation, 4) market structure, 5) financing, and 6) custom. As these barriers relate specifically to the residential market, an additional barrier called the inseparability of features, or gold plating has been identified

¹⁵ Budgets include not only expenditures on energy efficiency and demand response, but also spending on evaluation, measurement and verification activities.

¹⁶ TWh = TeraWatt hour = 1,000 GigaWatt hours (GWh) = 1,000,000 MegaWatt hours (MWh) = 1,000,000,000 Kilowatt hours (kWh)

(Ruderman, Levine, & McMahon, 1987), and for residential markets I propose a new class of obstacle called consumer heterogeneity.

2. Addressing Barriers with EPCs

EPCs address many of these obstacles to increase energy efficiency. Early EPCs aligned some misplaced incentives by focusing on efforts to reduce in peak demand load in utility customers' facilities, thereby supporting lower electricity rates for all utility customers while providing additional savings for participating customers. The ESCOs that generally enter into EPCs are, by definition, specialists in energy efficiency and as previously discussed have a strong track record of applying their technical knowledge via EPCs where the ESCO assumes performance risk, a structure that reduces mis- or lack-of-information as a market barrier. To some extent, the market structure barrier and inseparability of features/gold plating barriers have been reduced, largely because many manufacturers of energy efficiency equipment have expanded their business and now include their own ESCO division. The adoption of mandates for energy efficiency and capitalization of funds have reduced regulatory barriers, as have standardization of EPC contracts and ESCO pre-qualification for state and local government facilities.

3. Key Obstacles Remaining for Small-Scale Projects

Financing is one key remaining barrier to developing EPCs for smaller-scale residential and municipal EPCs. Funding sources such as those previously identified along with commercial lenders and other sources of capital have the potential to support EPCs in these market segments, but economies of scale still prohibit most EPC-like structures from being implemented since individual projects are simply too small in terms of their potential energy savings to justify the overhead and transaction costs. For residential projects in particular, the transaction cost is very high as a portion of potential project savings. Even estimating the actual ratio of transaction cost to potential savings is remarkably difficult due to the obstacle proposed in this paper – consumer heterogeneity.

Commercial, industrial, education, and municipal buildings tend to operate on set schedules with reasonably consistent consumption patterns that are somewhat transferable from one facility to another. These characteristics simplify modeling and estimating potential energy savings for facilities within these segments even if potential savings at an individual facility are of insufficient size to be of interest to an ESCO under an EPC model. Residences however, may contain a wide variety of energy-consuming appliances and devices, numerous types of lighting fixtures, have unknown building characteristics that may negatively impact the effectiveness of energy efficiency upgrades (e.g., leaky windows, moisture problems, improperly installed building envelopes, improperly installed equipment, etc.), consume energy based on the behavior of occupants, and – most importantly – energy consumption patterns may vary widely from one household to another and among individual members of the same household.

To even begin developing strategic approaches to implementing energy efficiency, energy conservation, or energy savings measures at the residential level on any meaningful scale, the limitless potential variations in household consumption – regardless of whether attributable to differences in household equipment, or the number and behavior of consumers in the household – require that information about individual consumption be accessible and quantifiable. Advanced metering and controls are foundational requirements for residential-sector energy efficiency on a large scale.

As of mid-2011, between 13.4% and 18.4% of electric meters in the U.S. were considered advanced meters – meaning that they can communicate in at least one direction (Federal Energy Regulatory Commission, 2011). These so-called “smart meters” are essential to improving the transparency of residential sector energy consumption habits as they allow consumers [or ESCO, utilities, etc.] to identify how much energy is consumed at what times, for what purpose [or by what device], and, in some cases, allow automated consumer responses to price and other market signals.

V. Prospects for the Future of Performance-based Energy Savings Contracts in Housing

The residential sector comprises only a small portion of ESCO revenue, with utility residential programs and public housing representing a combined 5% of ESCO revenue in 2006 and increasing to represent a combined share of 9% of ESCO revenue in 2008 at 6% and 3%, respectively (Satchwell, Goldman, Larsen, Gilligan, & Singer, 2010). Residential-sector revenue earned by ESCOs is mostly from ESCOs providing energy services to utility energy efficiency programs rather than performance contracting.

A. Energy Savings in Housing: Barriers & Opportunities

More than three decades into U.S. efforts to increase energy efficiency, it is clear that there is no simple, easy solution, especially in the housing market. EPCs have proven to be an effective mechanism for driving energy efficiency in some market segments – mostly large-scale institutional users, but of limited effectiveness in reaching small-scale energy users on a disaggregated basis. To address this challenge, not only is a basic understanding of energy efficiency and its barriers required, but this understanding must also be overlaid onto the specific circumstances found in the housing sector.

Towards a more thorough understanding of the barriers to energy savings and the viability of EPCs in the residential housing sector, this section will examine the facets of these barriers from two perspectives – that of the ESCO and that of the residential consumer. A number of barriers to energy efficiency have been previously identified, and as evidenced by the burgeoning growth of the EPC market have been either overcome or worked around in many consuming sectors. The fact that housing – both residential and public housing – remains such a small portion of the EPC marketplace is indicative of this sector's unique attributes.

As an initial foray into better understanding the uniqueness of the housing sector, we first examine the ways in which EPCs have worked and identify characteristics of housing that constrain the effectiveness of EPCs. Following that comparison is an examination of experiments showing successful approaches to increasing energy efficiency in the housing sector.

1. Successful EPCs & U.S. Housing Stock

a) EPC Investment Trends

There are some basic fundamental requirements to make EPCs feasible, starting with a large volume of energy consumption and correspondingly large energy expenditures. Typical public and private sector energy intensity reported by Larsen et al. (2012) was about 100,000 Btu per square foot per year prior to the retrofit, with retrofits resulting in reductions of about 25% and 35% in the public and private sectors, respectively. EPCs have typically been implemented starting with simple, low-risk investments (e.g., lighting and controls) and incrementally increasing to more investment-intensive and involved efficiency improvements (e.g., minor and major HVAC retrofits), and finally expand to include new power generation sources and other non-energy infrastructure activities.

Larsen, et al. (2012) reports investment rates per square foot of about \$2 for lighting-only, \$3 for minor HVAC, and \$4 for major HVAC retrofits. On-site generation investment rates vary widely among the breakout sectors with the private sector yielding the lowest rate, quite possibly due to numerous tax incentives available to private entities for on-site generation investments in the U.S., but the public investment rate in on-site generation showed a normalized value of about \$6/ft² while non-energy retrofits were typically in the range of \$8 to \$10 per square foot.

Typical savings reported by Larsen et al. (2012) were between \$0.50 and \$0.60 per square foot in the public and private sectors, respectively – about 20% of which were attributable to non-energy savings in

both sectors. On average, across all sectors, the number of measures installed as part of an EPC has increased over the past two decades, while “comprehensive” retrofits have become more common, and between 1990 and 2008 the median project investment rate in the public sector has more than doubled from about \$3/ft² to more than \$6/ft² and increased by 50% in the private sector to about \$3/ft².

In the private sector, a large majority (61%) of EPC projects have targeted a specific piece of equipment, while in the public and institutional sector only 1/3 of projects have targeted a specific piece of equipment for quantifying savings, 54% have savings based on the total utility bill, and the remaining projects have focused on savings attributable to a specific end-use.

b) U.S. Residential Energy & Housing Characteristics

According to the Energy Information Administration’s 2009 Residential Energy Consumption Survey, the average U.S. home consumes 940 kWh per month at a price of 11.72 cents per kWh, and spends \$110.14 per month on energy. U.S. homes average 1,971 square feet and spend an average of \$2,024 per year on all energy sources combined. Average annual energy expenditures per square foot in 2009 were just under \$1.03.

Average energy expenditures per square foot in detached single family homes were \$0.948 in 2009, \$1.46/ft² in apartment buildings with 2-4 units, and \$1.347/ft² in apartments with 5 or more units. Homes built in 1990 or later have an average size of 2,329 ft² and spend an average of \$2,139/year on energy - \$0.918/ft² on energy. Even the most energy-inefficient houses – the 57% of U.S. houses built prior to 1980 – have annual average energy expenditures of only \$1.085/ft².

c) Barrier of Scale & Opportunity

There is perhaps no more clear a demonstration of why the residential sector accounts for such a small share of the EPC market in the U.S. – the scale of energy intensity in U.S. housing is simply insufficient to support even minimal EPC investment based on typical investment rates per square foot for the EPC industry.

Consider the typical EPC investment rate of about \$2/ft² for the most entry-level lighting-only retrofits. Lighting represents an estimated 6% of residential energy demand (U.S. Department of Energy, 2011), or about \$0.06/ft² worth of annual energy expense in 2009. Even if the lighting retrofit eliminated all lighting energy consumption it would take more than 30 years before the retrofit achieved a simple payback – many times longer than any lights could reasonably be expected to last. The approach to residential energy efficiency has been modeled after the successes in other sectors, but with much less success.

Electric utility-operated energy efficiency, or demand-side management, programs have found compact fluorescent lamps (CFLs) to be a major source of savings, with recent reports from the U.S. Department of Energy (Swope, 2010) indicating that 84% of total DSM savings in programs of the New York State Energy Research and Development Authority (NYSERDA) are attributable to CFL programs, and similar results have been experienced by programs in Wisconsin and in the territory of California’s Pacific Gas & Electric (PG&E) with CFLs representing 64% and 62% of total DSM program savings, respectively.

The numerous benefits of using CFLs have been well documented and a number of reasons for the remarkably low adoption rates have been postulated (Haddad, 1994). Yet, even in utility efficiency programs focused on CFLs, the market penetration level seems stuck well below the projected maximum socket saturation level projected by Swope (2010) of around 80%. A study of the Xcel Energy Home Energy Lighting Program performed at the end of 2009 indicated CFLs had been installed in an estimated 16% of sockets in the utilities’ territory with survey respondents indicating a median of 6.7 CFLs installed per household, and 65% of respondents indicating they had at least one CFL installed (Dimetrosky, Winch, Albee, Parkinson, Oman, & Wilson-Wright, 2010). Customers are apparently satisfied with CFLs, with the results of a recent survey of CFL users indicating that 86% of those surveyed were either

“somewhat satisfied” or “very satisfied” with the standard CFLs they currently used (Nexus Market Research, 2009); yet, in the same year the lighting market share of CFLs was only 16%, down from a peak of 22% in 2007 (Bickel, Swope, & Lauf, 2010). Ultimately, seeing few other options, the U.S. Congress finally enacted legislation¹⁷ in 2007 that amounts to little more than a technological mandate to prohibit the sale of incandescent lamps.

2. The Role of Information in Residential Energy Efficiency

Simply put, residential EPCs have not worked because the residential energy market is different than other market segments – different in the way energy is used, the rationale through which efficiency is evaluated, the per-unit scale of energy use, and in the capacity for energy consumers to modify their energy use. Although energy consumption in the residential segment differs in many respects from consumption in other sectors, housing is not without opportunity to realize energy savings.

Research at LBNL has estimated that U.S. residences could reduce their standby energy load by as much as 10% without changing regular activities simply by eliminating the phantom, or standby, electric load¹⁸ attributable to devices that are not being used. Another recent study (Allcott, 2011a) has identified potential savings in the residential sector attributable to individuals’ desire to conform to social norms. This study examined the impact of informing people about how their energy consumption compares to that of their peers in similar circumstances, and determined that the highest energy users responded to information about their relative consumption with reductions in excess of 6%, and the program reduced consumption on average by about 2%.

Allcott’s (2011) study and a related effort (Jessoe & Rapson, 2012) provide strong indications that residential energy consumers have a substantial capacity to reduce energy consumption but lack the necessary information – both consumption quantity and price data – to stimulate a conservation response. In an experiment conducted using randomized controlled trials, Jessoe and Rapson (2012) demonstrated that electricity consumers who were given short-term advance notice of electricity price increases responded by reducing demand by as much as 7% compared to a control group, but, more importantly, another group of consumers in the same experiment reduced their consumption by between 8% and 22% when given both advance notice of price increases and information about their electricity consumption quantity via in-home displays¹⁹.

The in-home displays enabled consumers to receive feedback on electricity consumption-related behaviors, which was estimated to increase consumers’ price elasticity of demand by a factor of three over consumers receiving price information alone when presented with a price increase consistent with dynamic pricing during critical peak periods. Consumers with access to information about consumption quantities in addition to price information demonstrated both a learning effect and habit formation that extended beyond the specific pricing events.

3. Electricity Pricing – A Market Inefficiency

Retail electricity prices in virtually all U.S. states, especially those for the residential sector, are typically a flat charge per kWh consumed – the same price every day of the week and every hour of the day. However, the cost of providing that electricity varies by day, time of day, and by month. The result is two-fold: some consumers’ consumption habits have an upward influence on overall electricity prices

¹⁷ Energy Independence and Security Act of 2007, 42 USC §6295

¹⁸ Phantom load is the power that devices draw simply by being plugged into the wall, even when not turned on and in use. More information on standby power is available at <http://standby.lbl.gov>

¹⁹ In-home displays used in this experiment provided both the utility and consumers with real-time information about prices and usage.

while other consumers have a downward impact on overall prices – although it is unlikely that consumers would even know into which group they fit.

a) Peak Pricing

There are a number of viable alternative to traditional flat-rate pricing that more closely correlate the electricity price with the costs of supply, including: critical peak pricing (CPP), time-of-use pricing (TOU), and real-time pricing (RTP). All of these pricing approaches lower the price of electricity during most hours of the day and increase the price only during times when the cost of supply is highest – the closer the peak time price is to the cost of supply, the lower the price during other hours of the day (Farqui, 2010).

Traditional flat-rate pricing is, in several ways, a barrier to increased residential energy efficiency in the U.S. Residential consumers have shown some price elasticity of demand in respond to price signals – Jessoe and Rapson (2012) found a demand response of 7% to simulated CPP price signals delivered one day ahead, and another study identified a demand reduction of 1% to 2% in response to hourly real-time pricing (Allcott, 2011b). Interestingly, both of these studies reported that energy conservation in response to price signals did not result in increased consumption during other times – residential consumers actually reduced consumption as opposed to merely shifting load from peak hours to off-peak hours.

Another way in which flat-rate pricing inhibits residential energy savings is the misallocation of benefits from reduced energy consumption. Consumers who reduce consumption during peak demand times do not receive the market value of these energy savings. Consider the chart shown in Figure 3 (Newell & Faruqui, 2009) from a report on dynamic pricing in the New York Independent System Operator (NYISO) region which shows several periods during which the electricity price would have briefly risen well above \$1.00/kWh. Residential consumers on a flat-rate pricing schedule who reduced their consumption during these times would provide system-wide savings of about \$1.10/kWh, but would themselves only accrue savings at the flat rate of about \$0.18/kWh.

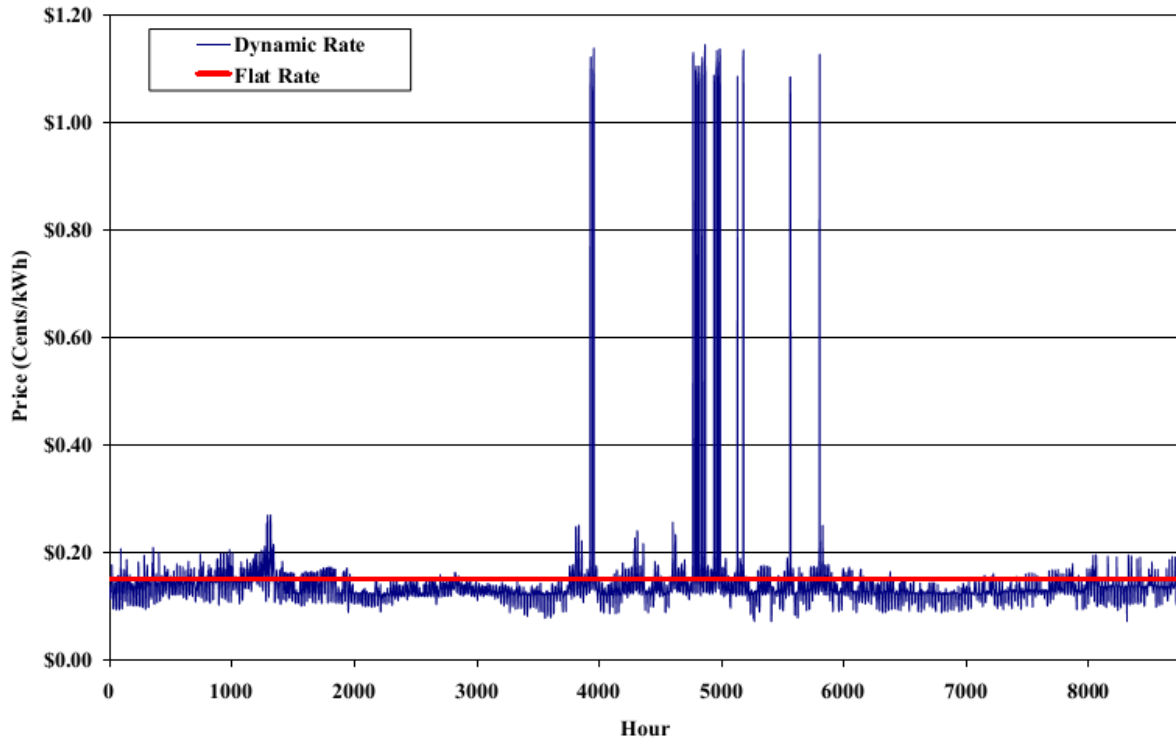


Figure 3 - Comparison of Flat and Dynamic Rates for Residential Customers in New York City (Newell & Faruqi, 2009)

Actual savings could be substantial, not just to the consumer who reduces electricity consumption during peak hours under an electricity pricing schedule that more closely mirrored the marginal cost of electricity generation, but also to all consumers as reducing peak demand would drive overall costs downward. In states where the electricity market remains fully regulated (i.e., no competition), new approaches are being adopted to stimulate utilities to encourage energy efficiency that entail the utility being compensated for both efficiency program costs and some portion of the electricity they would otherwise have sold, via a method called decoupling (York, Witte, Nowak, & Kushler, 2012).

b) Role of Technology in Price Response

The structure of electricity pricing is a barrier 1) to consumers having a price signal to which they can respond, and 2) to consumers directly receiving the benefits they produce by conserving energy. However, dynamic pricing structures require the installation of advanced metering infrastructure as a basic precursor to adoption. Currently, the FERC estimates that less than 20% of electric meters in the U.S. are advanced meters and capable of communication (Federal Energy Regulatory Commission, 2011). Without consumer access to real-time price information and utility access to real-time electricity consumption, dynamic pricing mechanisms are not possible.

Furthermore, consumers also need technology that enables them to actually respond to price signals. Possibly some form of automated home control device that could be pre-programmed to turn off or restrict operation of certain equipment given a price signal pre-determined by the consumer. Technology such as home area networks (HANs) are early-stage rudimentary examples of this concept, and even at the start of the technology's lifecycle are producing savings on residential electricity bills of 15% to 20% in utility territories across the nation (Sulavik, 2010).

4. Financing Mechanisms

Financing is a key aspect of EPCs, and the entry of commercial lenders into the efficiency market supported rapid expansion of ESCOs. However, the entry of commercial lenders added another facet to the EPC business model – credit risk. The ESCO has the expertise to guarantee savings and accept the performance risk, but when third-party financing enters the equation a “hell-or-high-water” payment provision often enters the picture under which commercial lenders expect repayment of the outstanding debt obligation whether or not the project performs as expected (Freehling, 2011).

Freehling (2011) provides many examples of government-backed loans and grants, community development corporations, credit unions, non-profit organizations, and state and local government funded programs which are acting to reduce the credit risk that attaches to major upgrades undertaken by residential and other small-scale energy efficiency projects. These programs typically do one of several things: 1) capitalize loan funds which are administered by government agencies, non-profits or utilities, 2) provide loan guarantees to loan funds capitalized by other parties (e.g., ratepayer-funded programs like PBFs, grants, etc.), or 3) provide seed funding to support start-up revolving loan funds.

However, even with these innovations in financing structures, economies of scale impose transaction costs that remain prohibitive. Consider that the most common sources of efficiency upgrades – lighting and HVAC systems – may represent several thousand dollars at their maximum level. As Freehling (2011) describes, even a multi-family housing building with 100 units would be unlikely to require investment of more than \$500,000 – about 10% of what is considered a small project on the scale of commercial lenders, and paltry compared to the \$25-\$30 million in annual loan originations the largest of these financiers target. To provide for increased scale some communities and states have sought bond issues to establish efficiency funds.

Other efforts to address this scale obstacle are focused on diversifying the origin of loan funds – allowing utilities to provide on-bill financing for customers or allowing customers to finance energy efficiency improvements on their property tax bill through a method called property assessed clean energy financing (PACE). These efforts are also being streamlined by engaging credit union, community banks, and non-profit finance organizations that are stakeholders in their local communities and who are not beholden to large shareholder interests to manage and underwrite these loans. However, these approaches are not without their challenges as well; for instance, there has been resistance from mortgage owners (particularly federally backed mortgages through the Federal Housing Authority) regarding PACE financing as the primary mortgage becomes subordinate to the energy efficiency loan, and efforts to allow financing of energy efficiency improvements through charges levied on electric bills, called on-bill financing, also face numerous issues such as whether the utility and customer are jointly and severally liable for the loan or whether the loan attaches to the meter and would change hands with the deed to the property.

B. Two Keys to Approaching Residential Energy Efficiency

Residential energy savings is possible, as recent studies have demonstrated. The main barriers are access to information and incentivizing consumer response to both knowledge and price. Residential energy savings require an approach oriented towards the residential market which involves: advanced metering and controls technology as well as value to the customers more representative of the actual benefits engendered by residential activity.

1. Automated Metering and Smart Grid Technology

A key aspect of enabling performance-based energy efficiency contracts to succeed is not only the ability to accurately and reliably project energy savings, but also to measure the actual savings. Until the advent of smart grid technology such as automated metering systems this was relatively expensive and not

feasible for individual residences. Automated meter data in digital format allows a variety of systems to be integrated into the home electrical system, some of which can attach at the appliance level, some can be connected through the main electric circuit box, and others can use software algorithms to estimate which devices and appliances in a home use how much energy at what time. This level of detailed information about energy use allows heretofore unavailable insight into the characteristics of an individual home's energy use, and, similarly to the way better information reduced the transaction costs and improved the service of ESCOs in the early generations of performance contracting, this granular level of detailed consumption data can be invaluable in minimizing the transaction cost associated with estimating a home's potential energy savings.

This opportunity is not without its challenges as well, however. A major challenge in some states is privacy – many utilities are prohibited from allowing third-party access to consumption data about individual accounts, even with permission from the account holder. Also, many smart-grid and automated meter systems being deployed are not focused on providing functionality for increasing energy efficiency or managing demand as a resource, but instead are being adopted partly as a method of upgrading decades old equipment, reducing utility meter-reading costs and improving response time in the event of grid outages or other disruptions, and also to proactively prevent outages by measuring infrastructure performance and identifying problems before they reach a critical point of failure.

2. Efficiency as a Supply-Side Resource

Finally, the goal of managing demand as a resource equivalent to generation which was first articulated in 1978 with the enactment of PURPA is slowly creeping towards realization more than three decades later. The Federal Energy Regulatory Commission, in a final rule²⁰ promulgated in March of 2011, articulated the “net benefits test” for determining when demand-side resources must be compensated for the service provided to the energy market at the market price for energy in competitive wholesale markets. This rule provides a revised framework that requires demand-side management resources to be accepted into competitive wholesale markets for electricity and compensated on par with supply-side generation, remedying longstanding inequities for efficiency in the marketplace.

Although the required filings by transmission operators have a deadline of Fall 2012 and the details or acceptability of each RTO or ISO plan is far from settled, the groundwork has been laid for energy efficiency to not merely be a source of reduced cost but for energy efficiency to become a source of revenue. For the residential segment, this change in the market's regulatory structure could increase the rate of return, provide compensation for energy conservation at the marginal cost of electricity, and reduce credit risks associated with efficiency financing.

This single change, when coupled with greater information about energy consumption patterns by small-scale consumers and the two-way interface made possible through automated metering and smart-grid technology could vastly change the landscape of energy efficiency and fundamentally alter the prospects for performance-based contracting in the residential sector. Combined, these new trends may offer increased access to finance for small-scale energy consumers, the technological capability for electricity consumption that is responsive to both real-time price and overall power system load, and together may represent the final piece of the puzzle for new EPC-like business models created to aggregate residential DSM technologies so that a neighborhood becomes the market equal to the power plant, and so that conserving energy isn't only a source of savings but is also a source of revenue.

²⁰ 18 CFR Part 35; Order No. 745, FERC Docket No. RM 10-17-000, Issued March 15, 2011

VI. Conclusion

The traditional EPC approach is ineffective in the residential market due to several aspects of the residential energy consumer, specifically:

- Residential consumers lack scale, both in per-unit consumption and in the number of readily identifiable homogenous units;
- Residential consumers lack the necessary energy intensity [on a square-foot basis] to justify investment within the structure of present-day EPC business models; and,
- Consumption in the residential sector is driven by different factors than in other sectors.

However, despite some long-held beliefs, residential consumers can exhibit price-elastic demand for energy, and can successfully modify behavior and habits to increase energy conservation. A number of recent studies – made possible by advanced meters, in-home displays, and home area networks – have demonstrated that residential consumers exhibit a small response to both price signals and information related to their social standing, but when provided with feedback on consumption quantity and how their actions affect energy consumption in real time residential consumers can substantially reduce consumption. Furthermore, price and quantity data coupled with real-time feedback has produced a learning effect resulting in savings additional to those directly stimulated by a price signal and indicate the potential for the formation of energy conservation habits.

Performance contracting in the residential sector requires a different business model than the ESCO industry has traditionally employed. The main advantage of residential consumers is their flexibility of energy usage and the large number of users who could potentially enact a conservation response. Unlike traditional EPC models, residences typically lack the necessary scale to justify investments on the basis of energy savings, but rather with limited capital investment and retrofit activities, the residential segment can be called upon as a supply resource.

Ultimately, the same characteristics that make the residential segment difficult to target and set it apart from other segments in energy conservation efforts are the attributes that must be leveraged for energy savings value – disaggregated demand, unique economic valuation and utility perspectives, and individual capacity to learn and respond to stimuli. The three fundamental requirements to tap into this potential for increased energy savings are:

1. **Access to information** on price, quantity, effects of behavioral changes, and social norms;
2. **Technology** to enable price responses, demand and consumption control, and greater consumer autonomy and independence in managing energy consumption; and,
3. **Motivation** to change behaviors and invest time and effort in the form of individual feedback, economic incentives, and comparative social feedback.

VII. Works Cited

- Allcott, H. (2011a). Social norms and energy conservation. *Journal of Public Economics*, 1082-1095.
- Allcott, H. (2011b). Rethinking real-time electricity pricing. *Resource and Energy Economics*, 820-842.
- Baechler, M., & Webster, L. (2011). *A Guide to Performance Contracting with ESCOs*. Building Technologies Program. Richland: Pacific Northwest National Laboratory.
- Bickel, S., Swope, T., & Lauf, D. (2010). *ENERGY STAR CFL Market Profile: Sales Trends and Market Insights*. Washington, DC: U.S. Department of Energy.
- Blumstein, C., Krieg, B., Schipper, L., & York, C. (1980). Overcoming Social and Institutional Barriers to Energy Conservation. *Energy*, 5, 355-371.
- Borenstein, S., & Bushnell, J. (2000). Electricity Restructuring: Deregulation or Reregulation? *Regulation*, 23(2), 46-52.
- Cooper, A., & Wood, L. (2012). *Summary of Ratepayer-Funded Electric Efficiency Impacts, Budgets and Expenditures*. Institute for Electric Efficiency, The Edison Foundation.
- Dimetrosky, S., Winch, C., Albee, K., Parkinson, K., Oman, S., & Wilson-Wright, L. (2010). *Colorado Home Lighting Program Process and Impact Evaluation Report*. Prepared for Xcel Energy by The Cadmus Group/Energy Services and Nexus Market Research.
- DSIRE. (2012, May). *Summary Maps*. Retrieved August 2012, from Database of State Incentives for Renewables & Efficiency: http://dsireusa.org/documents/summarymaps/PBF_Map.pdf
- EIA. (2011, November). *Electric Power Annual 2010*. Washington, DC, USA: Energy Information Administration, U.S. Department of Energy.
- EIA. (2011, November). *Form EIA-861 data files, 2010*. Washington, DC: Energy Information Administration, U.S. Department of Energy.
- Farqui, A. (2010). *The Ethics of Dynamic Pricing*. The Brattle Group.
- Federal Energy Regulatory Commission. (2011). *2011 Assessment of Demand Response and Advanced Metering*. Washington, DC: U.S. Department of Energy.
- Freehling, J. (2011). *Energy Efficiency Finance 101: Understanding the Marketplace*. Washington, DC: American Council for an Energy-Efficient Economy.
- Goldman, C. A., Hopper, N. C., & Osborn, J. G. (2005). Review of US ESCO industry market trends: an empirical analysis of project data. *Energy Policy*, 33, 387-405.
- Goldman, C. A., Osborn, J. G., Hopper, N. C., & Singer, T. E. (2002). *Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project*. Berkeley, CA: Lawrence Berkeley National Laboratory.

- Golove, W. H., & Eto, J. H. (1996). *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency*. Berkeley: Lawrence Berkeley National Laboratory.
- Granade, H. C., Creyts, J., Derkach, A., Farese, P., Nyquist, S., & Ostrowski, K. (2009). *Unlocking Energy Efficiency in the U.S. Economy*. McKinsey & Company.
- Haddad, B. M. (1994). Why Compact Fluorescent Lamps are Not Ubiquitous: Industrial Organization, Incentives, and Social Convention. *The Proceedings of the ACEEE 1994 Summer Study on Energy Efficiency in Buildings* (pp. 10.77-10.83). Washington, DC: American Council for an Energy-Efficient Economy.
- Hopper, N., Goldman, C., D., G., Singer, T., & Birr, D. (2007). *A Survey of the U.S. ESCO Industry: Market Growth and Development from 2000 to 2006*. Berkeley, CA: Lawrence Berkeley National Laboratory.
- Hopper, N., Goldman, C., McWilliams, J., Birr, D., & McMordie-Stoughton, K. (2005). *Public and Institutional Markets for ESCO Services: Comparing Programs, Practices and Performance*. Berkeley, CA: Lawrence Berkeley National Laboratory.
- ICF International, NAESCO. (2007). *Introduction to Energy Performance Contracting*. Washington, DC: ENERGY STAR, U.S. Environmental Protection Agency.
- IPMVP Committee. (2002). *International Performance Measurement & Verification Protocol: Concepts and Options for Determining Energy and Water Savings*. Oak Ridge: U.S. Department of Energy.
- Jaffe, A. B., & Stavins, R. N. (1994). The Energy-Efficiency Gap. *Energy Policy*, 22(10), 804-810.
- Janison, E., & Schlosberg, D. (2011). *Insuring Innovation: Reducing the Cost of Performance Risk for Projects Employing Emerging Technology*. San Francisco: CalCEF.
- Jessoe, K., & Rapson, D. (2012). *Knowledge is [less] Power: Experimental Evidence from Residential Energy Use*. Berkeley, CA: University of California Center for Energy and Environmental Economics.
- Larsen, P. H., Goldman, C. A., & Satchwell, A. (2012). *Evolution of the U.S. Energy Service Company Industry: Market Size and Project Performance from 1990-2008*. Berkeley: Ernest Orlando Lawrence Berkeley National Laboratory.
- Newell, S., & Faruqui, A. (2009). *Dynamic Pricing: Potential Wholesale Market Benefits in New York State*. Rensselaer, NY: New York Independent System Operator.
- Nexus Market Research. (2009). *The Market for CFLs in Connecticut (DRAFT)*. Connecticut Energy Conservation Management Board, Connecticut Light & Power, The United Illuminating Company.

- RGGI. (2011). *Investment of Proceeds from RGGI CO2 Allowances*. Regional Greenhouse Gas Initiative, Inc.
- Ruderman, H., Levine, M., & McMahon, J. (1987). The Behavior of the Market for Energy Efficiency in Residential Appliances including Heating and Cooling Equipment. *The Energy Journal*, 8(1), 101-124.
- Satchwell, A., Goldman, C., Larsen, P., Gilligan, D., & Singer, T. (2010). *A Survey of the U.S. ESCO Industry: Market Growth and Development from 2008-2011*. Berkeley: Lawrence Berkeley National Laboratory.
- Sciortino, M., Nowak, S., Witte, P., York, D., & Kushler, D. (2011). *Energy Efficiency Resource Standards: A Progress Report on State Experience*. Washington, DC: American Council for an Energy-Efficient Economy.
- Sulavik, C. (2010). *Smart Grid Growing Pains*. PriceWaterhouse Coopers.
- Swope, T. (2010). The Present and Possible Future CFL Market. *Notes & Presentations from Northeast Residential Lighting Stakeholders Meeting*. Boston: Northeast Residential Lighting Stakeholders Meeting.
- U.S. Department of Energy. (2010). *Public Benefit Funds: Increasing Renewable Energy & Industrial Energy Efficiency Opportunities*. Washington, DC: Energy Efficiency & Renewable Energy Division, U.S. Department of Energy.
- U.S. Department of Energy. (2011). *Buildings Energy Data Book*. Retrieved October 9, 2012, from EERE, US DOE: <http://buildingsdatabook.eren.doe.gov>
- U.S. EPA. (2011). *ENERGY STAR Overview of 2011 Achievements*. Washington, DC: U.S. Environmental Protection Agency.
- U.S. EPA. (2012). *National Awareness of ENERGY STAR for 2011: Analysis of 2011 CEE Household Survey*. Washington, DC: EPA Office of Air and Radiation, Climate Protection Partnerships Division.
- Wolcott, D., & Goldman, C. (1992). *Moving Beyond Demand-Side Bidding: A More Constructive Role for Energy Service Companies*. Berkeley: Lawrence Berkeley National Laboratory.
- York, D., Witte, P., Nowak, S., & Kushler, M. (2012). *Three Decades and Counting: A Historical Review and Current Assessment of Electric Utility Energy Efficiency Activity in the States*. Washington, DC: American Council for an Energy-Efficient Economy.