On-Bill Financing Programs to Support Low-Carbon Energy Technologies

An Agent-Oriented Assessment

Mundaca, Luis; Kloke, Sarah

Published in:
Review of Policy Research

DOI:
10.1111/ropr.12302

2018

Document Version:
Publisher's PDF, also known as Version of record

RPR Review of Policy Research

On-Bill Financing Programs to Support Low-Carbon Energy Technologies: An Agent-Oriented Assessment

Luis Mundaca
International Institute for Industrial Environmental Economics, Lund University
Lund, Sweden

Sarah Kloke
German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
*Bonn, Germany**

Abstract

On-bill financing (OBF) schemes have been welcomed as innovative mechanisms for encouraging the adoption of low-carbon energy technologies. Yet while the potential effects of these schemes have received growing attention, less is known about their actual performance. Departing from New Institutional Economics and insights from Behavioral Economics, this theory-driven assessment examines the How$mart® program in Kansas (United States) and the Green Deal in the United Kingdom. The study identifies the mechanisms designed to trigger behavioral change and technology adoption. We focus on market agents, and related market failures and behavioral anomalies that often prevent energy efficiency improvements. The paper adds to our theoretical and empirical understanding of public and utility-driven OBF programs applied to the residential sector. Our findings suggest that simple, carefully designed on-bill programs, where the financing of efficient technologies takes the form of a service rather than a loan, are more effective for the diffusion of low-carbon energy technology and the reduction of transaction costs. At the same time, on bill-financing schemes challenge the core business of utilities, and given the complexities and dynamics of energy efficiency markets and energy use, other policy interventions are needed.

KEY WORDS: behavioral change, climate mitigation, comparative governance, energy use, on bill-financing schemes, policy innovation

支持低碳能源技术的账单融资计划：一项以agent为导向的评估

“账单上融资”（*On-bill financing*）计划一直以来因作为一种鼓励采用低碳能源技术的创新机制而受到欢迎。然而，当此计划的潜在效果受到越来越多关注时，计划的表现却越来越不受重视。本文从新制度经济学和交易成本分析出发，用理论评估方法检验了美国堪萨斯州的*How$mart®*计划和英国的“绿色协议”（*Green Deal*）。本文识别了能触发行为变化和技术采纳的机制。笔者聚焦于市场代理和，相关的市场失败及行为异常，后者通常阻碍了能源效率的提升。本文从理论和实证上增进了我们对由公共事业驱动的账单融资计划（应用于居民部门）的理解。研究结果表明，简易且用心设计的账单融资计划在进行高效技术融资时是以服务而非贷款的方式呈现，这样便更加有效地促进了低碳能源技术扩散和交易成本减少。与此同时，账单融资计划对公共事业的核心业务发起挑战；考虑到能源效率市场和能源使用的复杂性和动态，我们还需要其他政策干预措施。

关键词：行为变化，气候减缓，比较治理，能源使用，账单融资计划（on bill-financing schemes），政策创新

*The views expressed in this article are those of the author and do not necessarily reflect those of the Ministry.

Review of Policy Research, Volume 00, Number 00 (2018) 10.1111/ropr.12302

Programas de pago a través de factura para apoyar las tecnologías bajas en carbono: una evaluación orientada en agentes

Los esquemas de financiación a través de factura han sido bienvenidos como mecanismos innovadores para fomentar la adopción de tecnologías bajas en carbono. Sin embargo, mientras los efectos potenciales de estos esquemas han recibido más y más atención, se sabe menos acerca de su desempeño real. Basándose en la Nueva Economía Institucional y elementos de Economía del Comportamiento, esta evaluación basada en teorías examina el programa How$mart® en Kansas (Estados Unidos) y el Green Deal en el Reino Unido. El estudio identifica los mecanismos designados a desencadenar cambios de comportamiento y adopción de tecnología. Nos enfocamos en agentes del Mercado y fallas del Mercado relacionadas y anomalías de comportamiento que a menudo previenen las mejoras de eficiencia de energía. Este documento añade a nuestro entendimiento teórico y empírico de los programas públicos de financiación a través de la factura que se aplican al sector residencial. Nuestros hallazgos sugieren que los programas de pago a través de la factura simples y diseñados cuidadosamente, donde la financiación de tecnologías eficientes toma la forma de un servicio y no de un préstamo, son más efectivos para la difusión de tecnologías de energía con bajo uso de carbono y la reducción de costos de transacción. Al mismo tiempo, los esquemas de financiación a través de la factura compiten contra la actividad comercial principal de las utilidades y dadas las complejidades y dinámicas de los mercados de eficiencia energética y el uso de energía, otras intervenciones políticas se necesitan.

PALABRAS CLAVE: cambio de comportamiento, mitigación del clima, gobernanza comparativa, uso de energía, esquemas de financiación a través de la factura, innovación política

Introduction

Innovative financing schemes that address behavioral change, support sustainable development, and encourage a low-carbon economy transition are receiving increasing attention (Bobinaite & Tarvydas, 2014; Borgeson, Zimring, & Goldman, 2012; Carley, 2011; Hudson, 2015; Lam & Law, 2016; Pathania & Bose, 2014; UNEP, 2010, 2011a, 2011b, 2015). The past decade has seen the introduction of *on-bill* programs that are designed to finance low-carbon energy technologies; first in the United States' residential sector and later in Europe. Supporters claim that they can address both the market failures (e.g., information asymmetries, principal–agent problems) and behavioral anomalies (e.g., *status quo* bias, heuristics, limited attention) that undermine the adoption of efficient technologies (Bell & Nadel, 2012; Hayes, Nadel, Granda, & Hottel, 2011; Lachman, 2013). Behavioral anomalies can lead to systematic differences between decision utility (i.e., expected or intended utility at the time of choice) and experienced utility (i.e., hedonic utility experienced after the choice) (Kahneman & Thaler, 2006).

In theory, on-bill programs eliminate high upfront costs for energy users and thus support low-carbon energy technology policies. Installation costs for new, efficient technologies are added to the consumer's energy bill rather than charged separately (by the contractor or a bank). Customers can see an immediate benefit as costs cannot exceed the estimated savings created by the efficiency improvement, often defined as the "Golden Rule" (or "Bill Neutrality"). A key feature of such programs is that repayment obligations are not linked to an individual, but to the electricity or gas meter. If a consumer moves out, liability is transferred to the new resident (Bell & Nadel, 2012; Bell, Nadel, & Hayes, 2011; Borgeson et al., 2012;

Cillo & Lachman, 2013; Lachman, 2013; UK-GBC, 2009). In practice, schemes can be divided into two main categories: on-bill financing (OBF) and on-bill repayment (OBR). In both cases, a third party (the utility company or an energy service company) pays upfront costs related to the energy efficiency measures. The provider might finance the renovation from its own budget or seek external funding. The payback for the beneficiary of the energy efficiency improvement is not set up in a separate payment stream, but added to the energy bill. The key feature of OBF is that the on-bill product takes the form of a service that is provided by the utility company. From a consumer perspective, the OBF design has the advantage that outstanding service charges are not considered as debt.[1] Therefore, and in principle, participating in an OBF program has no impact on the ability to access credit for other purposes or mortgage financing. This is also relevant for businesses that are often reluctant to take on debt on their balance sheets.[2] Conversely, under the OBR model, repayment takes the form of a loan (Burr, 2013).

Despite the fact that more than 15 on-bill programs have been introduced in six American states over the past decade, there have been few systematic empirical evaluations of their performance, notably their role and effectiveness in climate mitigation (cf. Gupta et al., 2014; Lucon et al., 2014). In 2013, the United Kingdom became the first European country to introduce a policy framework to encourage the uptake of on-bill programs, through the introduction of the so-called "Green Deal"[3] (Rosenow & Eyre, 2013).[4] However, here again, there are few systematic assessments of its impacts and outcomes. More importantly, there appear to be no comparative assessments of whether OBR or OBF models are more effective in overcoming market failures and behavioral anomalies, thereby supporting low-carbon policies. This article addresses these questions.

The study provides theoretical and empirical insights into on-bill policy programs that have been used to finance efficiency improvements in the residential sector. We take new institutional economics (NIE) as a main theoretical point to frame the policy assessment. NIE focuses on how decisions and transactions made by market agents are frequently based on imperfect information (Menard & Shirley, 2008). NIE addresses how institutional frameworks influence the behavior of market agents (Menard, 2005). The NIE approach stresses the notion that transactions, or contracting decisions, made by market agents are rationally bounded (Williamson, 2000). We use Commons's (1934) approach to frame the study, which establishes "contracting" or "transaction" as a relevant unit of analysis. The concept of transaction costs (TCs) has been largely developed by the NIE (Williamson, 2010). We support the approach with insights from behavioral economics, paying particular attention to (potential) behavioral anomalies and deviations from rational choice theory (Shogren & Taylor, 2008). Based on this, our theory-driven evaluation seeks to identify the mechanisms that prevent (or trigger) behavioral and technology change (details in the Methodology section).

We take the How$mart® program in Kansas (United States) and the Green Deal (United Kingdom) as case studies. The How$mart® program was established in 2007, and is one of the most mature on-bill schemes. The utility company that implemented it was the first to voluntarily adopt the Pay as You Save® (PAYS®) system, a template for OBF schemes, developed by the Energy Efficiency Institute (EEI) in Vermont (Johnson, Willoughby, Shimoda, & Volker, 2012). In the United Kingdom,

the Green Deal was the first European financing mechanism based on an on-bill model. However, as our study will show, the program did not perform as expected and public funding ended in July 2015, just two years after its implementation. Furthermore, there are concerns about utility company commitment to on-bill schemes because revenues are tied directly to energy sales. Thus, increased energy efficiency reduces energy use and thus utilities' revenue, which creates a perverse incentive for utilities to effectively engage in OBF schemes (Bird & Hernández, 2012).

Our analysis provides critical insights into the policy, market, and behavioral conditions that influenced their performance. We argue that OBF is not a silver bullet for leveraging finance into energy efficiency markets and encouraging behavioral change. Whereas economic and operational aspects do play a role, policy makers, utilities, and contractors must give equal attention to behavioral and contextual aspects that prevent efficiency improvements. Carefully designed OBF schemes have the potential to effectively enable investments in highly cost-effective technology segments and increase the attractiveness of these investments for energy users. At the same time, on-bill financing schemes challenge the core business of utilities, and given the complexities of energy efficiency markets, other policy interventions are needed.

The article is structured as follows: the next section outlines the methodology, including the approach, the theory of on-bill programs, description of case studies, and main data sources. The results of our assessment are presented in the third section, which discusses the effectiveness of consumer and provider mechanisms. Finally, key conclusions are drawn in the last section.

Methodology

A Theory-Driven Evaluation Approach

In general terms, a theory-driven evaluation *describes* and *prescribes* what evaluators (or practitioners) do, or should do, when carrying out policy assessments (Briedenhann & Butts, 2005; Coryn, Noakes, Westine, & Schröter, 2011).[5] The descriptive component focuses on causation and explanations of the phenomenon (i.e., what *is*), while the prescriptive component addresses normative aspects (i.e., what *ought* to be) and the criteria used in value judgments (Bemelmans-Videc, 1998; Chen, 1990; Mickwitz, 2003). According to Rogers (2000), a theory-driven evaluation takes as its point of departure how a given program/policy meets the intended outcomes and/or has the desired effects. The underlying premise is that well-targeted policies and programs need to be grounded in plausible theory that establishes how they will achieve the desired effect (Blumstein, Goldstone, & Lutzenhiser, 2000). The focus is on the identification of (nonquantifiable) causal mechanism(s), rather than a simple assessment of whether a predefined goal has been attained (Blumstein et al., 2000; Vedung, 2009).[6] For applications in the fields of policy, finance, and/or sustainable development, see for example, Ekins and Medhurst (2006), Jackson (2013), Khandker (1998), and Lewis, Provencher, and Beardmore (2015).

The typology of theory-driven evaluations (for details, see Chen, 1990) shows that they are a mix of *normative* and *causative* frameworks. In the case of on-bill programs, the normative aspect seeks to elicit knowledge about the extent to which they can change behavior of market agents in order to increase energy efficiency and energy conservation efforts. From a causative point of view, the evaluation aims to establish their effectiveness by identifying the critical conditions for, and consequences of, key activities (e.g., customer persuasion, financing plans, and technology implementation).

Within this general framework, we draw upon the work of Pawson and Tilley (1997), whose underlying rationale is that outcomes can only be understood by analyzing the causal mechanisms that underlie them. We investigate how on-bill programs that aim to improve energy efficiency *should* work, and analyze the mechanisms underlying how they *do* work. Pawson and Tilley (1997, p. 154) provide the following methodological guidance: a "realistic explanation of programs [which] involves an understanding of their mechanisms, contexts, and outcomes, and so requires asking questions about the reasoning and resources of those involved in the initiative, the social and cultural conditions necessary to sustain change, and the extent to which one behavioural regularity is exchanged for another." Therefore, instead of asking "does a program work?" the question becomes "what is it about the program that works for whom?" (Pawson & Tilley, 1997, p. 66). A key element is change theory, which aims to understand the "underlying logic, assumptions, influences, causal linkages and expected outcomes of a given programme" (Jackson, 2013, p. 100). The identification of causal factors is often nonquantitative in nature.

Pawson and Tilley (1997) argue that in a given context (C_1), social programs emerge from behavioral patterns (T_1) that create or are perceived as problematic regularities (R_1), and which are based on underlying explanatory mechanisms (M_1). Effective social or behavioral change programs lead to the introduction of new mechanisms (M_2) that are expected to disrupt the *status quo* (M_1). The result is that the desired behavioral pattern (T_2) replaces the existing, undesirable one (T_1), triggering a shift from an old (R_1) to a new pattern (R_2), which is the outcome (O) of the intervention (see Figure 1). Applied to on-bill energy efficiency programs, this translates into a departure from the existing pattern of consumers saying *no* to energy efficiency improvements and a move toward them saying *yes*. This focus highlights the following question: "What are the mechanisms for change triggered by a program and how do they counteract the existing social processes?" (Pawson & Tilley, 1997, p. 75).

The PAYS® system provided an assessment template to address the market failures and behavioral anomalies that were thought to prevent both consumer-side

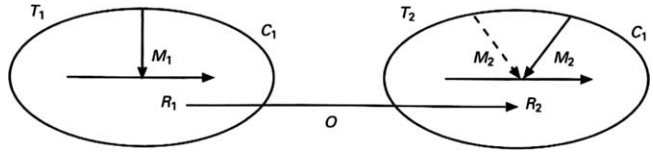

Figure 1. Central Elements of Effective Programed Social Change
Source: Pawson and Tilley (1997).

efficiency improvements (e.g., lack of available capital, inertia, long repayment periods) (Burr, 2013) and provider-side (high administrative, transaction, and financing costs) (Lachman, 2013). The PAYS® system was developed by the EEI in 1998 and laid down the framework for OBF schemes, allowing building owners or tenants to buy and install efficient technologies with no debt obligation and upfront payments.[7] Taking into account that OBF schemes drive the core business of utilities into uncharted territory (e.g., increased energy efficiency reduces energy use and thus utility profits), it is argued that OBF requires legislation in which profits are "decoupled" from retail sales (Bird & Hernández, 2012).[8] Within this context, performance-based ratemaking (PBR) regulation has been introduced (e.g., across several states in the United States) to overcome the disincentives that utilities may confront when implementing energy efficiency programs (Bachrach, Carter, & Jaffe, 2004). PBR regulation often encompasses award-penalty mechanisms (e.g., for safety, reliability, or efficiency) and a multiyear rate plan that addresses the rates that utilities can charge to their customers (Navarro, 1996). If properly designed, PBR provides incentives to operate utilities in a more efficient way, enhance overall performance and lower electricity costs (Woolf & Michals, 1995). However, it has been argued that PBR may still be insufficient to promote energy efficiency technology investments from a utility point of view, and that other instruments may be needed (e.g., procurement benchmarking) (Bachrach et al., 2004). Furthermore, it is also argued that policy makers confront critical challenges to design an effective PBR, including asymmetric information regarding utility's real cost structure and high TCs related to effective oversight control mechanisms (Navarro, 1996).

The following paragraphs describe how, from a theoretical perspective, the new mechanisms (M_2) implemented in PAYS® programs aimed to replace existing patterns by desired patterns and thus achieve the desired outcome (O), energy efficiency improvements. Consistent with the theory-driven evaluation approach, the elements presented below focus purely on the theoretical aspects of on-bill programs (e.g., expected benefits, areas of uncertainties). Critiques and concerns related to their actual performance are elaborated in the Results section.

Behavioral inertia: This is often defined as "a tendency to do nothing or to remain unchanged" (Oxford Dictionaries, 2016). It is a frequent barrier to the uptake of cost-effective energy efficiency technologies. Even when offered substantial incentives, *status quo bias* limits consumer uptake (CCC, 2009; Krarup & Russell, 2005; Venkatachalam, 2008). Contributing factors are a lack of information, the endowment effect, risk aversion (cf. Kahneman, Knetsch, & Thaler, 1991), and a limited ability to carry out cost–benefit comparisons (cf. Kahneman & Tversky, 1979; Lutzenhiser, 1994; Sanstad & Howarth, 1994; Thaler, 1999; Zundel & Stieß, 2011). The PAYS® mechanism aims to overcome behavioral inertia by taking a proactive approach. Typically, the utility company (or a contractor) contacts consumers with an offer to install efficiency measures and provides them with a cost–benefit calculation. The company incurs TCs related to search for technology information, installation, administration, marketing, and financing, among others (details about customer TCs are provided below). These costs are repaid by consumers on a monthly basis, but are typically less than 75–80% of expected energy savings. The

model is designed to ensure that consumers see an immediate, partial net benefit, while they can enjoy full savings once all repayments have been made.

Lack of available capital or liquidity: Households can find it difficult (particularly those under "energy poverty"[9]) to pay the upfront costs of efficiency measures (Berlo et al., 2011; Guertler & Royston, 2013; Sanstad & Howarth, 1994; Schleich, 2009). It is claimed to be a major problem that prevents low-income households from implementing energy efficiency measures in the United States and the UK (Bird & Hernández, 2012; Rosenow, 2012). PAYS® addresses this barrier, as investment costs are borne by the utility company or a third-party lender. The benefit for consumers is that they do not incur any upfront costs or debt and they do not have to undergo a credit check. Therefore, the program does not impact their ability to access credit for other purposes. This also applies to businesses, which are often reluctant to incur debt.[10]

Uncertainty over long repayment periods: The repayment period for many energy efficiency measures often exceeds, let us say, ten years, fostering uncertainty and apathy among end-users. In addition, households are likely to disproportionately discount future impacts (i.e., present bias) (Gates, 1983; Sanstad & Howarth, 1994). PAYS® is designed to address this problem. Under the system, a certain share of financial savings is shifted from future, long-term savings to the present. The 75–80% rule means that consumers see an immediate benefit in the form of a reduced energy bill even before investments are amortized. Furthermore, repayments are linked to the gas or electricity meter, rather than a legal person. If the first program participant moves out, the charge is transferred to the next user. This ensures that the actual beneficiary of the savings reimburses the costs.

Risk aversion: Investments in energy efficiency measures are by nature highly illiquid and tend to be irreversible (Anderson & Newell, 2004; Sutherland, 1991). Furthermore, as many measures are characterized by high upfront costs and long amortization periods, consumers face significant losses if it breaks down, or does not yield the expected savings (Anderson & Newell, 2004; Gates, 1983). Combined with other factors (e.g., information asymmetries, uncertainties, TCs), the perception of risk translates into high discount rates for future savings that inhibit adoption (cf. Gately, 1980; Kahneman et al., 1991; Qiu, Colson, & Grebitus, 2014; Sutherland, 1991; Train, 1985). The PAYS® system provides participants with a significant level of consumer protection. Repayments are suspended if a measure breaks down or fails, and only resume once it has been repaired. Limiting repayment periods to 75–80% of the expected lifetime of the measure is another risk-reduction mechanism. Finally, the utility company or program administrator acts as a mediator between contractors, which gives consumers a stronger voice.[11]

Split-incentive problem: This term (also called the *principal–agent problem*) is often used to refer to the situation where the homeowner and its occupier are not the same economic agent (i.e., landlords and tenants) and thus have different objectives or pursue different actions related to energy use (Jaffe & Stavins, 1994). An example of the split-incentive problem is when the landlord (the investor) bears the costs of efficient technologies, but the tenant (the user) enjoys a lower energy bill. As costs and benefits are split between the two parties, the landlord has no incentive to invest in energy efficiency measures as she/he has no return on the

investment, except in terms of increased property value (Longstreth, 1986; Schleich, 2009; Szumilo & Fuerst, 2015). As property owners tend to believe that markets undervalue energy efficiency improvements, there is little incentive to make investments (Guertler & Royston, 2013; Tuominen, Klobut, Tolman, Adjei, & de Best-Waldhober, 2012). In theory, this barrier is addressed in the PAYS® system by the basic rule that repayments are made by the beneficiary of reduced energy costs. Upfront costs are borne by the utility company or a third party, and financial responsibility for their reimbursement is shifted from the landlord to the tenant who pays the bills, but also enjoys the benefits of the installed measure(s).

Transaction costs for consumers: The concept of TCs has been largely developed by the NIE, of which TCs analysis is a fundamental element (Menard & Shirley, 2008; Williamson, 2010). TCs relate to *ex ante* negotiations and drawing up contracts, and *ex post* execution and enforcement costs incurred by market agents (Furubotn & Richter, 2010; Matthews, 1986; McCann, Colby, Easter, Kasterine, & Kuperan, 2005; Venkatachalam, 2008).[12] From a consumer perspective, for example, they relate to the search for information and contract negotiations (Björkqvist & Wene, 1993; Jaffe & Stavins, 1994; Mundaca, Mansoz, Neij, & Timilsina, 2013). Although customer TCs cannot be completely eliminated, in theory PAYS® aims to reduce them as far as possible. The cost of searching for information is (potentially) minimized, as the utility company or a certified contractor provides information about technologies, together with estimates of costs, benefits, and energy savings. The offer to install and finance the recommended measure(s) is tailored to the customer's property.

Transaction and administrative costs for providers: The search for information, marketing, due diligence, contract negotiations, program administration, monitoring of energy use, and cost savings are all sources of provider-side TCs that can make energy savings economically unfeasible (Kiss, 2016). Furthermore, the small scale of energy efficiency projects in private households means that TCs are relatively high compared to the overall investment (Guertler & Royston, 2013). A second consideration is administrative costs, which are understood here as direct costs related to producing the contract (Joskow & Marron, 1992; Ostertag, 1999).[13] Under PAYS®, these costs are potentially reduced by a streamlined, simple design. As PAYS® is a template for OBF programs, finance takes the form of a service. Time spent on credit assessments and contract negotiations is reduced or eliminated.[14] A basic prerequisite of the PAYS® system is that providers can leverage energy efficiency potentials cost-effectively; therefore, minimizing their TCs is critical.[15]

High cost of finance: Providing energy efficiency services with no upfront costs and spreading repayments over a long period remains a new idea for many banks. The (perceived) risk is a crucial factor when determining the appropriate interest rate, and utilities or program administrators can struggle to access low-cost finance (Campiglio, 2016; Guertler & Royston, 2013; Schleich, 2009). Under PAYS®, the risk for the lender is reduced as the utility company guarantees to repay the loan, and is responsible for collecting outstanding debt from customers. Customers have a strong incentive to make payments as if they do not, the company can disconnect the service (EEI, 2014), resulting in a low default rate. Tying repayment obligations to the electricity or gas meter is another key feature to "de-risk" the investment, as

the new residents are liable for any outstanding charges (Bell et al., 2011; Cillo & Lachman, 2013).

Case Studies

*The How$mart® Program in Kansas (United States)*—Midwest Energy introduced the How$mart® program as a pilot scheme in Kansas in 2007. The company is a local electric and gas cooperative that serves 48,000 electricity and 42,000 gas customers in central and western Kansas.[16] The How$mart® program was based on the PAYS® system and the company's long-standing experience with energy efficiency services, which they had promoted since the early 1980s as a tool to manage complaints about high bills and improve customer satisfaction (Volker & Johnson, 2008).

Midwest Energy's aim was to provide a financing program that could overcome barriers in the rental and low-income markets. It saw PAYS® as an effective tool to address high upfront costs, capital constraints, long repayment periods, conflicts of interest between landlords and tenants, and consumer education (Volker & Johnson, 2008). By the end of 2012, the company had invested US$4.8 million in energy efficiency measures in 858 locations. By August 2014, 1,184 projects had been completed. How$mart® measures must be permanently attached to the building and portable measures, such as highly efficient refrigerators, are excluded (Johnson et al., 2012). In the residential sector, installed measures mostly comprise new heating systems. Other measures include air conditioners, air sealing, insulation of the building shell, and geothermal loop projects. How$mart® Light offers efficient lighting solutions to the commercial and industrial sectors. From a project lifecycle perspective, the main contractual steps of the program are summarized in Appendix A.

From a financing point of view, How$mart® was originally designed as an OBR program. However, Midwest Energy lobbied at state level for a change in legislation to allow the utility to restructure the financing from a loan to a tariff-based service. In August 2008, legislative changes meant that How$mart® could be fully implemented in all 41 counties as an OBF program (Burr, 2013; Johnson et al., 2012). Under the program, all measures are eligible if the monthly repayments do not exceed 90% of energy cost savings. Furthermore, the repayment period cannot exceed 15 years, or 75–80% of the expected life of the measure.

The Green Deal (United Kingdom)—The Green Deal was introduced in the United Kingdom as an energy efficiency financing program in January 2013. It aimed to overcome key barriers associated with increased energy efficiency in households (e.g., high upfront costs, the split-incentive problem) (Rosenow & Eyre, 2016). The scheme was labeled as the government's "flagship piece of legislation, which will deliver energy efficiency to homes and buildings" (Hough & White, 2014). It was designed to address three challenges. First, the observation that U.K. households "wasted" £2–3 billion per year on energy, as a result of poorly insulated homes and inefficient appliances (DECC, 2011b). Second, in order to achieve the national target of a 80% reduction in carbon emissions by 2050 (compared to 1990), a cut of 29% compared to 2008 levels was needed in the residential sector by 2022 (DECC, 2010, p. 7).[17] Third, the need to meet the government's goal of eradicating fuel poverty[18]

by 2016 in England and Scotland, and by 2018 in Wales. Furthermore, policy makers had realized that low-cost measures delivered by energy companies under the flagship Carbon Emissions Reduction Target (CERT) instrument would be saturated by 2020. Given fiscal austerity plans and the (possible) lack of public finance, it was seen as essential to bring private capital into the energy efficiency market.

Against this background, the U.K. government sought to design innovative, market-based measures to overcome energy efficiency barriers (DECC, 2010). It assumed that high upfront costs, paired with long repayment periods, and split landlord–tenant incentives were the major problems (DECC, 2012a).[19] According to a Department for Energy and Climate Change (DECC) representative,[20] the Green Deal was partly triggered by the report prepared by the Green Buildings Council (UK-GBC, 2009), while the previous government had launched a pilot program that ran from November 2009 to July 2011 (Rosenow, Eyre, Rohde, & Bürger, 2013).[21] Based on the 2011 Energy Act, five Implementing Regulations were introduced that created the legislative framework. Further details were laid down in the Codes of Practice for Green Deal Assessors, Providers, and Installers, and the Green Deal Arrangements Agreement between Electricity Suppliers, Green Deal Providers, and Finance Parties.[22] This made the United Kingdom the first European country to introduce a policy framework that encouraged private actors to offer on-bill models to residential customers. Accredited providers were usually energy service companies (ESCOS) that in many cases had been already selling energy savings under previous energy company obligation (ECO) schemes. Energy suppliers have been obliged to collect customers' payback on the energy bill, even though they have not necessarily been the initiator of the Green Deal.[23] From a project lifecycle perspective, the main contractual steps of the program are summarized in Appendix A.

From a financial point of view, the Green Deal was designed as an OBR model offered by accredited providers at commercial interest rates. A core feature was the Golden Rule: the expected energy cost savings must be equal to or greater than the Green Deal repayments attached to the energy bill. This principle naturally sets the upper limit for Green Deal finance available for the installation of energy efficiency measures (DECC, 2012b). The U.K. government assumed that a lack of capital was the major barrier to energy efficiency improvements in the residential sector. Gregor Barker (Minister for Energy and Climate Change at the time) announced that 14 million homes would be refurbished under the Green Deal by 2020, and another 12 million by 2030 (DECC, 2011b). Investments were estimated to be £7–11 billion per year (Holmes, 2011). However, the Impact Assessment for the Green Deal and the ECO scheme,[24] published in 2012, lowered these expectations. It predicted that the Green Deal would draw in private finance amounting to £300 million in the first year and exceed £400 million in the following five years; only a small fraction of the expected amount (DECC, 2012a).

It should be noted that the U.K. government decided to stop funding the Green Deal Finance Company (GDFC) that provided loans to Green Deal providers for energy efficiency improvements. The Green Deal Home Improvement Fund (HIF) is also closed to new applications. However, the decisions did not affect existing finance plans or applications. Private companies can continue to use the Green Deal financing model, although there is no longer any public funding. In fact, the

GDFC stopped receiving new applications for Green Deal Plans, which basically terminated the scheme in practical terms (Rosenow & Eyre, 2016).

Data Sources

Our research started with a critical review of the literature on on-bill programs worldwide. Both academic and gray material (government websites, reports, or publications from nongovernmental organizations, and so forth) were examined. As no on-bill programs for energy efficiency refurbishments of residential buildings were identified outside the United States and the United Kingdom (UK), the geographical scope was narrow. The initial review led to the selection of the How$mart® program in Kansas (United States) and the Green Deal (United Kingdom) as cases for an *ex post* analysis.

Official Green Deal statistics were collected for 2013–15 and complemented by a survey sent out to 45 providers. Six responses were received. A similar survey was sent to Midwest Energy, the utility company that runs the How$mart® program in the United States.

Twelve semistructured interviews were carried out with experts on the PAYS® system and the How$mart® program (in the United States), and government and private-sector stakeholders (in the United Kingdom). To gain a better understanding of the PAYS® system, Harlan Lachman (from the EEI) was interviewed by telephone. For the evaluation of the How$mart® program, Michael Volker (former Director of Regulatory and Energy Services at Midwest Energy) was interviewed and responded to further questions by email. With regard to the evaluation of the Green Deal in the United Kingdom, various face-to-face interviews took place with three providers, together with a representative from the GDFC, and a representative of the former DECC. A researcher and senior consultant at Ricardo-AEA Group (also a former DECC employee) who was involved in the development of the Green Deal responded to questions about design choices. Finally, a representative from Energy Efficiency Policy Officer at the WWF-UK and the Director for Public Affairs at Knauf Insulation Northern Europe were also interviewed.

Results

Effectiveness in Reducing Consumer-Side Market and Behavioral Barriers

Overcomes Inertia?—About 55% of customers who were actively approached under How$mart® agreed to efficiency improvements, despite a lack of additional incentives in the form of grants or rebates (Cillo & Lachman, 2013). Most appeared to regard it as an attractive and beneficial mechanism. However, a major limitation is the need for Midwest Energy, contractors, or social service agencies to initiate the process, which is focused on customers with above-average energy use. Only 1.3% of customers had participated within the first three years (Hayes et al., 2011)—an annual rate of 0.43% of the total customer base.

With respect to the Green Deal, as of July 2015 only 2.8% of households who received an assessment had signed up (DECC, 2015b).[25] This suggested that the

scheme failed to overcome inertia. Furthermore, of as July 2015 the overall participation rate was only 0.06%.[26] There are several reasons for these numbers. First, most Green Deal Assessments were done as a result of the ECO in order for households to obtain energy efficiency measures but with no intention of ever taking a Green Deal loan.[27] In fact, customers who decided to invest in energy efficiency (and represented a larger share of those who had an assessment done) used ECO finance (Rosenow & Eyre, 2016). Second, it was unclear who was responsible for promoting the program. While the government's intention was to develop "a program, which is owned by the industry" (Great British Refurb Campaign, 2011), market participants expected the government to promote the Deal more actively.[28] Third, and as a result of this lack of coordination, providers struggled to implement an appropriate marketing strategy. Research commissioned by DECC (2014f) found that most relied on their website, and the Green Deal Oversight and Registration Body's (GD ORB) database, which meant that it was up to consumers to initiate contact with providers. Fourth, there was both apathy and a lack of awareness among end-users (Marchand, Koh, & Morris, 2015), which were reinforced by high TCs (details in the Reduces Sources of Transaction Costs? section). Whereas policymakers paid great attention to financial savings, much less (if any) was given to nonfinancial barriers, discouraging households from increasing energy efficiency (Rosenow & Eyre, 2013). Although this is consistent with previous research related to energy efficiency policy in the U.K. domestic sector (Mundaca, 2007) it is remarkable, as households' annual electricity bills in England and Wales had increased by 170%, and gas bills by 218% compared to 2004 as a result of market liberalization (DECC, 2014a). This suggests that energy users did not respond to higher energy prices as rational choice economic theory predicts in order to induce efficiency improvements.[29] In turn, this highlights that relative price changes can have marginal effects in fostering efficiency improvements given behavioral anomalies (e.g., limited attention drives "price invisibility") and TCs.[30] Another explanation might be the historical practice of energy companies providing efficiency measures at reduced or no cost (e.g., under the Energy Efficiency Commitment [EEC]) (Rosenow, 2012; Rosenow & Eyre, 2016), meaning that consumers tend to expect subsidies. Early research had already shown that (additional) subsidies were required to effectively address fuel poverty (Guertler, 2012). Finally, high interest rates, the need for (incremental) capital, and the complexity of the program undermined the demand for energy efficiency among households (more details below).

Addresses Lack of Capital or Liquidity?—How$mart® was designed to overcome this barrier for cost-effective energy efficiency measures. Midwest Energy (Bell & Nadel, 2012) bears full costs for households that are not in energy debt, and where 90% of the total cost of efficiency improvements are covered by energy savings. This provides customers with a 10% safety margin in case actual savings are below those expected. Although the margin is lower than the 25% recommended under PAYS®, it was chosen in order to be able to offer more aggressive investments (Volker & Johnson, 2008). The situation changes when the threshold is exceeded. In this case, Midwest Energy still bears costs up to the 90% threshold, but customers cover all incremental costs.[31] It is estimated that property owners or landlords have contributed to two-thirds of the financing of measures. By the end of 2012, it was estimated

that customers had invested US$1.4 million, in addition to the US$4.8 million provided by Midwest Energy, with an average value of US$7,489 per project.[32]

While the initial idea underlying the Green Deal was to leverage energy efficiency potentials without additional subsidies, the calculations carried out during the Impact Assessment showed that many efficiency measures could not be financed under the Green Deal alone, if the Golden Rule was to be respected. Consequently, additional sources of capital were introduced: the Energy Companies Obligation (ECO), the Cashback Scheme,[33] and the HIF.[34] Our study found that only about one third of total investment costs were covered. Even when providers had access to ECO subsidies, these were often insufficient and third-party financing was needed (DECC, 2014f). The small number of eligible measures is not only a consequence of a lack of highly cost-effective energy saving potentials, which allows for an on-bill payback below financial savings, but also a result of high financing costs for Green Deal loans (see the Provides Access to Low-Cost Capital? section). Customers who could access Green Deal finance faced the challenge of a lack of funding for more costly technologies and a bigger package of efficiency measures. All of these aspects (particularly the number of additional sources of capital) also created additional sources of TCs for customers (details in the Reduces Sources of Transaction Costs? section).

Although the payback obligation was linked to the property, credit checks were carried out (as the Green Deal was designed as a loan). A Green Deal Plan therefore affected customers' credit scores and limited their ability to seek finance for other purposes (DECC, 2014f). This was a significant barrier for households that were already in fuel poverty and in the biggest need of efficiency improvements. The government acknowledged this problem and introduced the Affordable Warmth scheme (component 3 of the ECO). This complementary source of funding was targeted at households that could neither finance efficiency improvements themselves, nor access Green Deal finance (DECC, 2012a).[35] This is consistent with Bird and Hernández (2012), who argue that OBF schemes require extra policy interventions (e.g., incentives for landlords) to effectively encourage efficiency improvements in low-income households.

Tackles Long Repayment Periods?—Tying payments to the building's electricity or gas meter rather than the individual consumer is a crucial element in both schemes, as repayments can be shifted to the next owner or tenant (i.e., because the consumer moves to another property before the repayment period ends). We found that this barrier was overcome for customers whose measures were *fully* financed, either by Midwest Energy (in the case of How$mart®) or by the Green Deal (DECC, 2012a, p. 138). However, only in a very limited number of cases, savings allowed for full financing without a capital injection by the customer.

Under How$mart®, the property owner must inform the new owner or tenant of any How$mart® charges, and must pay the remaining balance within 30 days. Customers who move ask Midwest Energy to close their accounts; at this point, the company reminds them of the disclosure procedure. A growing problem of sellers who failed to notify purchasers of their obligations led the company to adopt a policy of filing a commercial lien in the form of a Uniform Commercial Code with the County Register of Deeds. This means that property itself can be used as collateral

to protect Midwest's interests (Volker & Johnson, 2008). How$mart® deviates from PAYS® in this respect. Under the latter, the disclosure of payment obligations is solely based on the contract signed by program participants.[36]

Under the Green Deal, neither owners nor tenants can be held liable for repayments if they move out or sell the improved property. To strengthen their legal position, repayments are disclosed in the property's Energy Performance Certificate (EPC), which owners must order before marketing a property for sale or rent. Estate agents are legally obliged to either disclose the EPC in full, or the EPC asset rating for a domestic property that is for sale (DECC, 2012a).[37] Furthermore, the owner or landlord needs to obtain a written acknowledgement from the new resident stating that they are aware that Green Deal repayments must be made, and understand that they can be held liable (DECC, 2011c).

Mitigates Risks Resulting from Technical Failure?—We found that the two cases did not follow the structural design elements considered in the original PAYS® system. Risks related to potential technical failures were not mitigated. Under the How$mart® program, risk is borne by the customer and not the utility company (Cillo & Lachman, 2013). Both customers and contractors prefer to avoid having Midwest Energy act as an intermediary in the case of technical or mechanical problems (Burr, 2013). Nevertheless, the company requires certain quality standards from contractors[38] and has developed very close relationships with them, for example, by offering training in efficiency technologies (Volker & Johnson, 2008).

Under the Green Deal, the U.K. government originally proposed that warranties should apply to efficiency measures for the entire repayment period.[39] This proposal was met with concerns from suppliers. While such a guarantee was reasonable for inert measures such as insulation, the costs would have been prohibitively high for mechanical and electrical measures; for example, it would have almost doubled the cost of a boiler (DECC, 2012a). This motivated the government to limit the guarantee to "five years and an extended 10 year guarantee to cover any consequential building damage sustained as a result of the measures being installed" (DECC, 2012b, p. 21).[40] The extension to building damage was expected to increase the overall cost of a Green Deal package by 1% to 2.5%. It was hoped that Green Deal providers would be able to reduce costs by negotiating extended warranties from manufacturers and installers (DECC, 2012a). Adding to quality assurance issues, the decision to stop funding to the GDFC was also driven by concerns about "industry standards" and the fact that "11% of Green Deal assessors and 14% of Green Deal installers have been suspended or withdrawn from the scheme due to non-compliance with the Green Deal scheme requirements" (Green Deal & ECO Team, 2015).

These issues may have also been influenced by the need (and shortage) of qualified contractors, and the adequacy and effectiveness of technical training as such (e.g., *how* energy efficiency professionals communicate results and recommendations to householders) (cf. Brown, 2001; Goldman, Peters, Albers, Stuart, & Fuller, 2010; Ürge-Vorsatz et al., 2012).

Lessens the Split-Incentive Problem Between Landlords and Tenants?—Overall, our findings strongly suggest that both schemes are effective in overcoming the split-

incentive problem, particularly for measures that can be fully refinanced through on-bill tariffs.[41] The impact seems to be slightly more tangible under the How$mart® program than the Green Deal.

Under the How$mart® program, 14% of projects concerned rental properties. This is consistent with the demographic characteristics of Midwest Energy's service area, where 14.6% of properties are tenanted (Johnson et al., 2012). For measures where costs cannot be fully recovered via energy bill charges, the landlord is required to provide additional capital. In practice, the only cost borne by tenants is the surcharge on the energy bill.

At the time our research was carried out, no reliable data were available for the Green Deal. Three out of five providers reported that rented accommodation accounted for more than 25% of properties. Given that less than 30% of householders are tenants (Dieckhöner, 2012), our results suggest that the rental sector is adequately represented. However, more research is needed to evaluate this issue.

Reduces Sources of Transaction Costs?—The requirements for participation in the scheme play a key role in determining potential sources of TCs. The How$mart® program has been kept relatively simple, which has reduced potential sources of TCs—unlike the Green Deal, which is far more complex.

There is a five-step process for How$mart® customers to access an efficiency measure financed by Midwest Energy. If the measure is fully financed, the customer only has to deal with two actors, Midwest Energy and the chosen contractor. If they choose a measure where additional funding is needed, and they are unable or unwilling to inject their own capital, a private bank might become involved. The utility company identifies potential energy savings, calculates costs and benefits, and seeks third-party finance. Therefore, TCs that would normally be met by consumers are shifted to the provider. The literature review and interviews suggested that the customers encountered no significant obstacles and suggests that TCs were lower for How$mart® clients than others who had to organize the installation and financing of efficiency improvements themselves.

A contractual sequence chart was developed to identify the main transactions under How$mart®. See Figure 2.

Conversely, Green Deal customers had a much longer journey (see Figure 3). We found that rather than providing a streamlined procedure, the Green Deal was very complex. This prevented households completing the process of organizing and obtaining finance (National Audit Office, 2016a). The aim of providing a "one-stop-shop" with a "smooth transition between stages" (DECC, 2012b, p. 36) was not met.

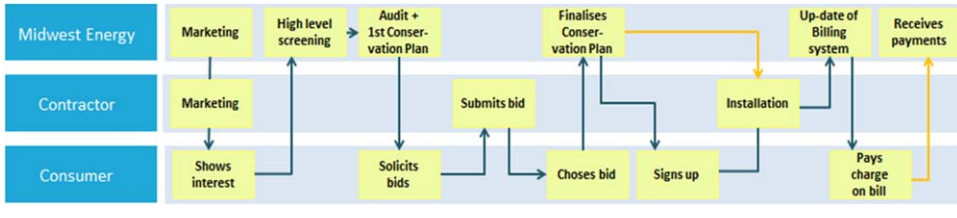

Figure 2. Key Activities in the How$mart® Customer's Journey. Blue Arrows Depict Transactions. Yellow Lines Represent Monetary Flows

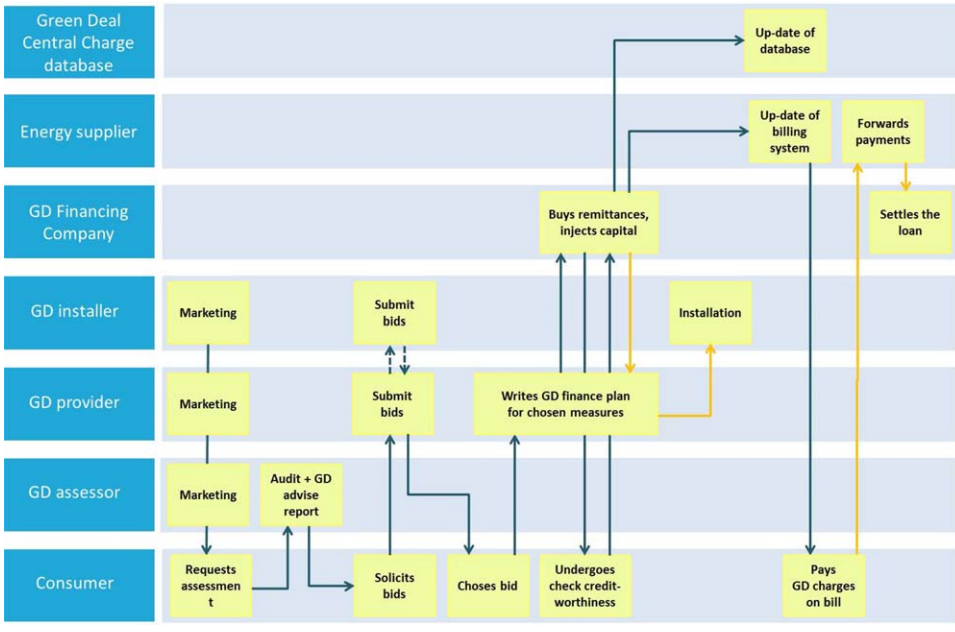

Figure 3. Key Activities in the Green Deal Customer's Journey. Blue Arrows Depict Transactions. Yellow Lines Represent Monetary Flows

It was up to the customer to establish the first contact. Consumers reported that they had to call up to 20 providers until they found a company that was able and willing to undertake the work (DECC, 2014f). This observation was supported by official figures from the GDFC (GDFC, 2014), which show that only 38 Green Deal providers were actively selling plans, out of a 151 registered providers in July 2014 (DECC, 2014d). Customers that had used an independent Green Deal assessor to identify energy saving potentials often found that providers were unwilling to use the report that was produced. While some providers simply did not respond to enquiries from customers with reports from external assessors, others required the assessor to revise the report (DECC, 2014f). Furthermore, by linking the Green Deal to the ECO, Cashback, and the former HIF, the customer had to interact with up to five actors (the assessor, provider, installer, HIF, and potentially a private bank). Blending Green Deal funding with Cashback and a private loan required three application procedures. According to the National Audit Office (2016a, p. 11), "only 50% of loan applications ultimately resulted in one being arranged."

Effectiveness in Reducing Provider-Side Market Barriers

Reduces Administrative and Transaction Costs?—Midwest Energy introduced How$mart® to increase customer satisfaction, even though the company could not gain a comparative advantage from this, as it operates in a regulated market without competitors (Volker & Johnson, 2008). Still, the company faced several drivers that determined overall program costs that the utility tried to reduce. Major components are marketing, energy audits, administrative costs (such as the entry of How$mart®

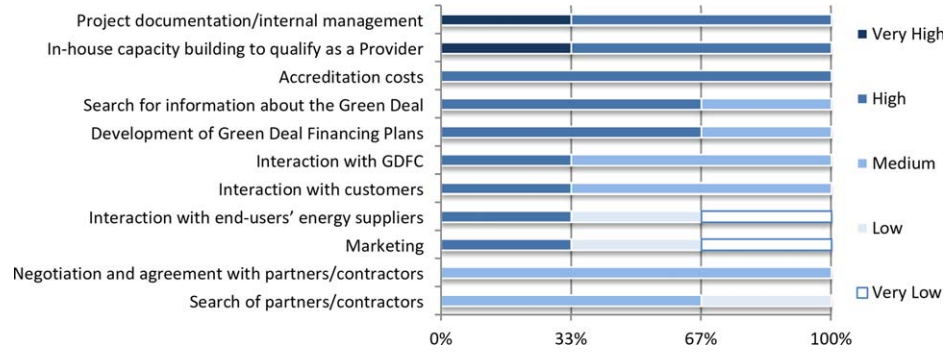

Figure 4. Main Cost Drivers Faced by Green Deal Providers When Selling Green Deal Plans

charges into the billing system), and TCs related to the time spent developing a contractor network and due diligence. The company's accounting system cannot provide a breakdown of program costs into specific components. At the end of 2012, overall program costs amounted to US$207,000 (Cillo & Lachman, 2013). Compared to total investments in energy efficiency technologies (US$4.8 million from Midwest Energy and US$1.4 million from program participants), program expenses account for 3% of total capital costs. When spread over the 858 energy efficiency service packages, expenses amount to US$241 per project. Figures from other PAYS® programs are similar.[42] Unfortunately, no quantitative data were available to make a detailed assessment of the distribution of administrative and TCs.

In relation to the Green Deal, the analysis showed that both administrative and TCs were high. This was due to the overly complex design of the instrument, the number of actors involved, multiple and partly competing sources of finance, and time-consuming procedures. Costs mainly related to accreditation; searching for information; interacting with the GDFC; and due diligence in relation to customers, energy suppliers, and business partners. Project documentation and internal management, which can be regarded as administrative costs, were identified as the main drivers (Figure 4).

In three out of five cases, aggregated administrative and TCs (e.g., contract negotiation) met by providers equaled or exceeded investments in technology and installation (see Figure 5). Face-to-face interviews revealed that the accreditation process was regarded as lengthy and complicated, and the process of becoming a provider was a principal cost driver.[43] Providers estimated that one employee worked full time on accreditation for five to six months, costing the company £15,000–£20,000. On top of this, providers were required to pay £15,000–£20,000 in the form of accreditation fees. One provider indicated that they had spent an additional £10,000 on software. Overall, most providers reported that burden of administrative and TCs, combined with low customer demand, failed to make an attractive business case for selling Green Deal financing plans.[44]

Provides Access to Low-Cost Capital?—In the case of How$mart®, Midwest Energy succeeded in accessing low-cost capital from various sources, such as the Kansas Housing Resources Corporation, stimulus funds through the Efficiency Kansas program,[45] and the Rural Economic Development Loan from the Department of

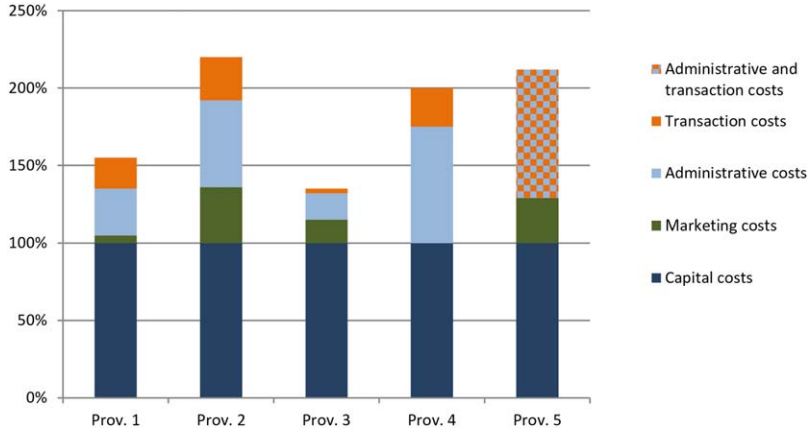

Figure 5. Estimates from Green Deal Providers of Marketing, Administrative, and TCs as a Share of Investment Costs for All Measures Installed Under Green Deal Plans

Agriculture (Cillo & Lachman, 2013). At the time this research was carried out,[46] the blended cost of capital was 2%, and the company could pass on low interest rates to their customers (Bell & Nadel, 2012). In recent years, rates for residential customers have been 3%, while commercial customers have paid 4.5%. Access to low-interest finance has been one of the key factors in the relatively high consumer uptake of How$mart®[47] as the low interest rate has had a positive impact on the portfolio of measures that can be fully financed. Lowering the rate by one percentage point allows an additional investment of around US$450 in a standard measure.[48]

In the United Kingdom, one of the core goals of the Green Deal was to facilitate private finance without government support. The idea was to provide access to capital to a wide spectrum of households through low-cost private finance (DECC, 2010). During the preparatory phase, the government actively engaged with banks. These efforts were not successful. According to a former DECC employee, a major concern for private banks was liability if the customer or the provider defaulted. In the end, banks regarded the Green Deal as an "untried scheme" and the number of variables made it hard to quantify the risks. A particular issued revolved around loans that could be passed on to new customers whose credit status was unknown.[49]

Given this reluctance, two other options were considered. First, the government could have provided guaranteed loans to lower financing costs. However, this approach proved to be politically unfeasible at a time where reducing the national deficit was a high priority (Rosenow, 2012). A second option would have been to oblige energy suppliers to provide Green Deals to their customers, placing liability with the supplier. While some suppliers saw the introduction of the Green Deal as a new market opportunity, others were reluctant to take on debt that could negatively impact their balance sheets.[50] A third approach was chosen. The GDFC was established as a not-for-profit body responsible for financing and administering Green Deal Plans. The government secured a capital injection of £244 million for GDFC from the Green Investment Bank, DECC, and 54 public and private sector organizations (DECC, 2014c; GDFC, 2014). The hope was that the GDFC could be

self-financed in the long run once a loan volume of £450–500 million was reached (Rosenow & Eyre, 2016). However, the GDFC's loan book was estimated to be worth only £17 million by the end of 2014, which was very low compared to the DECC's forecasts of £695 million (National Audit Office, 2016b). Given its poor performance, the GDFC could not cover its operational costs (Rosenow & Eyre, 2016). Ironically, and despite the government's clear intention to side-step any public subsidy, the GDFC was bailed out with a £34 million public loan in November 2014 (Vaughan, 2015). According to the National Audit Office (2016b, p. 9), DECC "decided a £34 million loan was necessary to fund demand for Green Deal finance until just after the 2015 General Election."

As a result of this situation, interest rates (ranging from 7 to 10%) offered by the Green Deal were very unattractive. In May 2013, the GDFC started offering fixed-rate loans at 6.96% for up to 25 years (GDFC, 2014). However, pilot studies of a PAYS® scheme had already indicated that lower interest rates were required (Rosenow & Eyre, 2016). The relatively high interest rate had a significant impact on the range of measures that could meet the Golden Rule. For example, a hard-to-treat cavity wall insulation with installation costs of £1,875 and further costs of £400 would have just been able to meet the Golden Rule at an interest rate of 3%. In this case, savings amount to £133 per year, compared to annual repayments of £131 over 25 years. However, at a rate of 6.96% the latter increases to £194.[51] This highlights that a 1% interest rate increase required energy cost savings to rise by 10% in order to meet the Golden Rule. Even within the pure financial arena, the lack of *ex-ante* evaluation is identified, which also fuelled the failure of the scheme (National Audit Office, 2016a).

Conclusions

Our findings suggest that carefully designed programs that treat the installation and financing of energy efficiency measures as a service can help to overcome market failures and behavioral anomalies, and thus support the commercialization and dissemination of low-carbon technologies. Barriers that can be potentially addressed in an effective manner include high upfront costs, lack of finance, and the split-incentive dilemma. The study found that the two key issues are the need to have a third-party cover that can meet upfront costs, and linking repayments to the building's energy meter.

Within the different subcategories of on-bill models, preference should be given to designing the product as a service (OBF) and not as a loan (OBR). Waiving credit assessments related to taking out a loan should reduce TCs on the customer's and the provider's side. It also confronts behavioral anomalies, as many consumers are reluctant to take on debt for investing in energy efficiency, even if their financial situation allows for it. Furthermore, basing the eligibility of program participants on an assessment of energy saving potentials rather than a check of customers' economic status has the potential to improve access to finance for energy efficiency improvements for lower income groups as well as small and middle-sized enterprise. These groups often struggle to access conventional capital markets.

Although not all consumers respond to economic incentives, aligning the timing of cost and benefits, and seeing an immediate benefit in the form of lower energy bills helps to overcome disincentives created by long repayment periods. If total costs can be recovered through energy savings, there is no need for the consumer to invest. However, this was found to be the case for a limited number of highly cost-effective measures. Whether a program overcomes consumers' risk aversion is highly dependent on warranties and other protection mechanisms. The experience with the Green Deal suggests that subsidy-free financing schemes are unlikely to be effective in addressing fuel poverty. The study also highlights that despite the financial incentives on offer, *ceteris paribus*, consumers remain passive and participation rates are low. This suggests that the effectiveness of public or utility-driven on-bill programs depends on how successful (other) policy instruments are in, for instance, addressing apathy, heuristics, present bias, lack of awareness, and internalizing energy pricing externalities.

A prerequisite for successful, unsubsidized on-bill programs is that the cost of energy efficiency measures and program costs can be financed through energy cost savings. Policy makers and operators should therefore focus on reducing transaction and administrative costs by implementing simple, streamlined programs. Access to low-cost capital is another crucial factor. In the United States, for all programs where data were available (including How$mart®), there was access to low-cost capital (e.g., via a governmental loan program), which made it possible to pass on relatively low interest rates to the customer (see Appendix B). In contrast, financing costs were not significantly lowered in the United Kingdom and providers struggled to sell Green Deal financing plans. The relatively high interest rate (6.95%) had a significant negative impact on the business case as most energy cost savings were insufficient to cover technology, installation, administrative, transaction, and financing costs. As long as private lenders attach a high-risk premium to capital, such programs are unlikely to be purely market-driven in the near future. In addition, on-bill programs that require energy cost savings to be equal to, or exceed, repayments are unlikely to be seen as a suitable instrument to encourage expensive, deep retrofits. This is because repayment periods can exceed 20 or 30 years, and returns on investment are too low to allow for a financial benefit for all stakeholders: the customer, the energy service provider, and potentially a financial investor. Therefore, without further public policy support, the impact of on-bill programs can be expected to be limited once the most cost-effective savings have been realized.

OBF programs introduce a new business paradigm that challenges structural issues and profit maximization associated with energy use. Providing energy efficiency services is usually new to utilities. If the return on investments of energy efficiency measures is not increased (e.g., due to rising energy prices), it is unlikely that many utilities will voluntarily introduce on-bill programs for their customers without additional policy incentives. This increases the need for "decoupling" revenues from sales to encourage utilities to become energy service providers. Given that the core competences of utilities are in the provision of energy (and not in energy saving), it is also unclear to what extent utilities have strong incentives (or expertise) to reduce information asymmetries. Likewise, one can speculate about how well-prepared utility accounting systems are in order to effectively track and manage resource costs of efficiency programs. Even if utilities (or contractors) are

sometimes fully aware of the existence of the (major) TCs of efficiency improvements, no accounting takes place.[52] Effective management of the contractor network also becomes critical for utilities. As a whole, we argue that the degree of utility commitment to the success of on-bill programs remains a critical condition for achieving energy savings at least possible cost (i.e., cost-effectiveness) and in determining whether these programs maximize net benefits for the society (i.e., economic efficiency).

Ultimately, it appears that OBF models should not be regarded as a "silver bullet" for encouraging behavioral change and leveraging finance into energy efficiency markets. Our study has identified various opportunities, risks, and challenges. If implemented effectively and efficiently, OBF should be seen as an innovative mechanism that may complement the existing portfolio of policies, particularly given multiple market failures and behavioral anomalies that prevent efficiency improvements.

Acknowledgments

The authors are very grateful to two anonymous reviewers for their very valuable and constructive comments. Luis Mundaca acknowledges financial support from the Swedish Energy Agency, grant no. 38263-1.

Notes

1 Note that in the United States, OBF programs were mostly created as an alternative (or replacement) for the "Property Assessed Clean Energy" (PACE) financing. PACE allows property owners to fund energy efficiency improvements and renewable energy technology at minimum or no upfront costs (DOE, 2016). PACE assessments (i.e., debt of property) are repaid via property tax bills and can also be transferred across property owners. However, OBF/OBR schemes emerged as an important alternative to PACE programs when Fannie Mae and Freddie Mac (important mortgage agents in the U.S. housing market) declined to allow PACE loans to work as first lienholder if a homeowner defaults (Hiskes, 2010). This is because a lien is placed on the property when a PACE loan is established, which takes priority over the mortgage (Dale & Schweiger, 2014). The Federal Housing Finance Agency (FHFA) stated that PACE programs "present significant safety and soundness concerns" (FHFA, 2010, p. 1). Among various aspects, the FHFA argued that this situation posed "unusual and difficult risk management challenges for lenders, services, and mortgage security investors" and that PACE loans "do not have the traditional community benefits associated with taxing initiatives" (FHFA, 2010, p. 1). The situation led to many states to close or withdraw PACE programs, which triggered the development of OBF/OBR schemes. At all events, PACE programs still exist (DOE, 2016) and recent *ex-post* policy assessments have shown that they have been highly effective; particularly for the deployment of residential solar PV (Ameli, Pisu, & Kammen, 2017; Kirkpatrick & Bennear, 2014).

2 Personal communication with H. Lachman (2014).

3 This relates to a specific policy framework for energy efficiency improvements in homes and businesses. It should not be confused with the "Green New Deal" discourse about the green economy and stimulus packages.

4 Note that an OBF legislation was launched in New York State in 2012. The program was implemented via the New York State Energy Research & Development Authority (NYSERDA) with support from New York Utilities. However, there were basically no incentives for municipalities to implement OBF schemes in New York due to high administration and TCs related to such a small scale level of intervention. More importantly, municipalities had no funding for implementation. Thus, while this program was opt-in, basically not one municipality incorporated it. Likely driven by this situation, the program was modified in 2016 and it is now mandated through utilities via NYSERDA (n.d.). However, interest rates for non-low income households can be considered

relatively high (e.g., 6–7% for a household size of four with an annual income above US$108,000) (NYSERDA, n.d.) compared to other OBR/OBF schemes in the United States (see Appendix B). Whereas it remains to be seen the level of market uptake, a reviewer indicated that also a lack of dissemination efforts regarding the existence of such a scheme can be discerned in practice.

5 Since its origins back in the 1930s, and particularly following Chen (1990), applications of theory-driven evaluations have grown rapidly and there are numerous case studies and methodological contributions in the literature. Advocates include a growing number of international institutions (e.g., The United Nations Evaluation Group, The World Bank). See Coryn and others (2011) for a comprehensive review and meta-analysis of theory-driven evaluations.

6 In the literature, an *outcome* is understood as participants' response to policy instruments (e.g., adoption of new technologies, development of new business plans). An *impact* is understood to be the societal and environmental changes generated by an outcome (e.g., energy consumption, health problems) (see e.g., Fischer, 1995; Hildén et al., 2002; Vreuls et al., 2005).

7 The developers provided design and consulting services to five utilities that introduced OBF programs based on the PAYS® system (Lachman, 2013). For further details, see http://eeivt.com/wordpress/. To protect the model's intellectual property rights, the EEI trademarked the name and acronym in the United States.

8 Several approaches exist to decouple utility profits from energy sales. For a review of decoupling mechanisms in the United States, see Morgan (2013). Eto, Stoft, and Belden (1997) argue that decoupling the link between revenues and sales is not a silver bullet; however, it is a critical policy condition to encourage utilities to become providers of energy services.

9 In the United Kingdom, a household is considered to be fuel poor if (a) "they have required fuel costs that are above average (the national median level)," and (b) "were they to spend that amount, they would be left with a residual income below the official poverty line" (DECC, 2015a, p. 8).

10 See endnote 2.

11 See endnote 2.

12 Note that the first challenge in TCs analysis is conceptual rather than empirical. In the particular case of energy efficiency technologies, there are a variety of conceptual approaches. For a meta-analysis, see Mundaca and others (2013).

13 In the literature, administrative and TCs are sometimes viewed as interchangeable (Joskow & Marron, 1992; Stiglitz, 1986). Although we acknowledge that distinguishing between them is difficult, we do so to improve the resolution of our results.

14 See endnote 2.

15 See endnote 2.

16 Midwest Energy also owns the transmission system. Electricity is generated from company-owned sources or procured contractually. The gas system is not vertically integrated and the company does not operate upstream transmission pipes or production facilities (Johnson et al., 2012; Volker & Johnson, 2008).

17 The U.K. Climate Change Act 2008 introduced an overall carbon budget of 3,018 Mt CO_2e for 2008–12, 2,782 Mt CO_2e for 2013–17, and 2,544 Mt CO_2e for 2018–22. This translates into a 21% CO_2 emissions reduction by 2008 and a 34% reduction by 2022, compared to 1990 levels (DECC, 2010). High CO_2 emissions in buildings are largely related to the combustion of fossil fuels for space heating. Heating rooms and water with gas-fired boilers is responsible for three quarters of British households' energy consumption (DECC, 2010). In 2011, 59% of homes with cavity walls, but only 1% with solid walls, had an insulation measure installed (DECC, 2011a).

18 According to official statistics, 2.35 million households live in fuel poverty in England (DECC, 2015a). The World Health Organization (WHO Europe, 2011) estimates that cold housing caused 9,532 deaths per year between 1991 and 2005. Older people are at particular risk. According to data from the National Health Service (NHS, 2013), two-thirds of people with hypothermia are over 60 years old.

19 The policy-making approach taken in the United Kingdom assumed that households were going "to respond rationally to economic incentives and that the major barrier to action was a lack of capital" (Rosenow & Eyre, 2016, p. 143). Thus, it was assumed that once economic incentives were provided, market failures and behavioral anomalies would be (automatically) overcome or reduced. However, although a survey carried out by the DECC itself did not provide sufficient evidence for this approach, the Green Deal was implemented anyway (National Audit Office, 2016a).

20 Personal communication with DECC officer (2014).

21 It should be noted that the PAYS pilot was not consistent with the original PAYS® system developed by the EEI. For example, there was no provision that estimated energy cost savings had to exceed repayments. Under the pilot program, households were provided with up to £20,000 per property at a 0% interest rate (Rosenow et al., 2013).

22 See The Green Deal Framework (Disclosure, Acknowledgement, Redress, and so forth) Regulations 2012. The five Implementing Regulations are: The Green Deal Framework (Disclosure, Acknowledgment, Redress, and so forth) Regulations 2012 SI 2012 No. 2079, The Green Deal (Energy Efficiency Improvements) Order 2012 SI 2012 No. 2106, The Green Deal (Qualifying Energy Improvements) Order 2012 SI 2012 No. 2105, The Green Deal (Acknowledgement) Regulations 2012 2012 No. 1660, The Green Deal (Disclosure) Regulations 2012 SI 2012 No. 1660.

23 There were also Green Deal providers were new on the market, such as young start-ups, often with an engineering/installation or financial services background. Other companies, such as installers of renewable energy systems, property maintenance, and construction companies, as well as retailers and wholesalers and energy companies themselves, decided to extend their business area by becoming authorized Green Deal providers (DECC, 2014f).

24 The ECO replaced the previous EEC and, later, the CERT. It covers all gas and electricity suppliers with more than 250,000 customers. Suppliers are not only obligated to help their customers achieve energy savings, but also have to meet certain requirements regarding the type of measures installed and household segments. The rationale was to provide funding for economically less-attractive measures, such as insulating solid and hard-to-treat cavity walls (component 1), and to support vulnerable households (components 2 and 3). The costs are borne by energy suppliers and distributed across all customers regardless of whether they have benefited from efficiency improvements (DECC, 2012a; Rosenow & Eyre, 2013; Rosenow & Galvin, 2013). The legislative framework is provided by the *Electricity and Gas (Energy Companies Obligation) Order 2012*, which was passed by Parliament on December 4, 2012 and ran until March 2015 (Gov.uk, 2014).

25 A total of 590,039 properties had received Green Deal Assessments as of July 2015 and only 16,456 agreed to proceed after receiving a quote from a Green Deal provider (DECC, 2015b).

26 This is based on a total of 16,456 participating households (DECC, 2015b) out of the total population of 26.7 million homes in the United Kingdom (DECC, 2011a).

27 We acknowledge the key input from one reviewer regarding this particular issue.

28 Personal communication with Green Deal providers (2014).

29 There is extensive literature on the role of prices and dynamic pricing in the context of energy efficiency and load shifting (see e.g., Alexander, 2010; Birol & Keppler, 2000; Borenstein, 2005; Faruqui & Sergici, 2010; Gillingham, Newell, & Palmer, 2009; Sutherland, 1991; Tietenberg, 2009).

30 Kolstad and others (2014) provide a summary of relevant "misoptimization" mechanisms that drive energy users to undervalue energy costs (e.g., present biased).

31 A capital injection from the customer is usually needed to replace heating, ventilation, and air conditioning equipment (HVAC), unless the existing equipment is very old or inefficient and huge energy savings can be made. Combining the exchange of HVAC equipment with highly cost-effective thermal insulation is frequently used to reduce the capital required from program participants.

32 Based on data from Cillo and Lachman (2013).

33 The Cashback scheme was set up with a capital injection of £40 million. From January 2013 to June 2014 grants of up to £4,000 were distributed to households on a first come, first served basis. The prerequisite was to carry out a Green Deal assessment and to agree to a quote submitted by a provider. However, customers were not required to take out Green Deal finance to qualify for the grant (DECC, 2014e). In total, 16,438 Cashback vouchers were issued. Most were used for replacement boilers (DECC, 2014d).

34 In June 2014, the HIF replaced the Cashback scheme. £50 million was passed on to consumers in the form of grants for energy efficiency measures. By combining solid wall insulation with other efficiency measures, households in England and Wales could receive up to £7,600. Due to unexpected demand, the HIF could accept no more applications just two months after its introduction (DECC, 2014b). In line with the decision to stop funding for the GDFC, the HIF was also closed to new applications in July 2015.

35 Affordable Warmth replaced the previous fuel poverty program in England, the so-called "Warm Front." The Association for the Conservation of Energy (ACE) calculated that the introduction of the Green Deal and ECO caused a reduction of available funding for households in fuel poverty by 29% (ACE, 2012).

36 Personal communication with H. Lachman (2014). Midwest Energy has also cooperated with local state realtors to ensure the inclusion of How$mart® charges in "Seller Disclosure Forms" (Volker & Johnson, 2008).
37 There are some exceptions, for example, stand-alone buildings with total useful floor space of under 50 m^2, industrial sites, workshops, nonresidential agricultural buildings, and holiday accommodation.
38 For example, with regard to insulation materials blown in cellulose or foam are allowed, while fiberglass bats or blown in fiberglass is not. Personal communication with M. Volker (2014).
39 The guarantee was required to be backed by an insurance company and underwritten by an "A" rated company.
40 As cost-effective guarantees for solid wall and cavity wall insulation already existed in the market, the guarantee for improvements and consequential building damage was extended to 25 years for these measures.
41 Bird and Hernández (2012) provide an extensive discussion on the role of OBF mechanism to reduce the split-incentive problem for low-income tenants.
42 See endnote 2.
43 The official requirements were: "In order to operate as GD Providers, applicants are also required to: [1] Hold a Category A CCA licence, which enables them to lend money to consumers (the terms of GD Finance mean that the GD Provider is technically the lender). [2] Sign up to the Green Deal Arrangements Agreement (GDAA), which sets out the terms and conditions associated with the Green Deal Central Charge Database. [3] Obtain access to the Green Deal Central Charge Database (GDCC), which facilitates the collection (and remittance) of GD payments via the electricity meter. [4] Obtain access to the EPC Register, since GD Providers must update EPCs following the installation of measures under the GD. [5] Join the Green Deal Ombudsman and Investigation Service, which provides a redress scheme for consumers under the GD" (DECC, 2014f, p. 11).
44 The survey revealed that providers applied different interpretations of the term "total capital cost." Some only reported capital invested via Green Deal finance, while others reported capital invested from all sources of finance. All respondents were contacted and asked to review their data based on a clearer definition (the total amount of money that was invested into measures under Green Deal plans). This reflected total capital injected by the provider (through Green Deal finance or ECO), the consumer, Cashback scheme grants, or Home Improvement Funding.
45 In 2010 and 2011, Midwest Energy received state funding under the "Efficiency Kansas" program. This is a revolving loan fund based on US$37 million accessed through the American Recovery and Reinvestment Act (ARRA).
46 Personal communication with M. Volker (2014).
47 See endnote 46.
48 Midwest Energy decided to lower the interest rate to a rate below its authorized rate of return. Consequently, incoming flows from program participants do not fully recover program costs. However, How$mart® remains highly regarded as a good deal for the company due to very high levels of customer satisfaction; it is "seen as a customer service expense, not really a profit center" (M. Volker, personal communication, 2014).
49 Personal communication with K. Neale (2014).
50 See endnote 49.
51 This calculation is based on data taken from the Green Deal's Impact Assessment (DECC, 2012a, p. 138). Note that there is a caveat as it is not clear if in-use factors have been applied in the Impact Assessment. If they have not been applied, repayments clearly exceed savings in both cases. It is also questionable if consumers are willing to take on a loan for such a long time period without seeing immediate savings. This calculation should therefore be regarded as simply an illustration of the impact of finance costs on total costs.
52 This is sometimes referred as the "Utility Accounting Problem" in the energy efficiency and TC literature (Joskow & Marron, 1992; Mundaca, 2007).
53 See endnote 46.
54 See endnote 46.
55 See endnote 46.
56 For domestic properties, accredited assessors are required to use the "Reduced Data Standard Assessment Procedure," which was developed by the Building Research Establishment (BRE) and

is currently used to generate EPCs. The methodology is based on the National Calculation Method and standards set by the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO) (Booth & Choudhary, 2013). The "Simplified Building Energy Model" is applied to nondomestic properties; this was also developed by the BRE Group (BRE, 2014; DECC, 2012b).

57 The so-called "Appendix Q process" enabled market participants to suggest new measures to be included in the list. DECC assisted companies by covering some of the costs of the accreditation process (DECC, 2012b).

58 The design of EPCs differs from country to country according to regulatory requirements. In the United Kingdom, an EPC rates properties from A (most efficient) to G (least efficient) and is valid for ten years. It provides information about a property's energy use and typical energy costs, together with recommendations related to reduced energy use and how to save money (Gov.uk, 2014).

59 The government's decision to designate Gemserv as the GD ORB and run the Green Deal Central Charge database was criticized. Critics argued that as the big six energy companies (British Gas, Scottish & Southern, ScottishPower, nPower, E.ON, and EDF) were Gemserv's largest shareholders, the Green Deal risked being biased against small companies. The government defended its choice on the basis that it had followed the competitive tendering process specified under EU procurement rules (ClickGreen, 2012).

60 There is a levelization mechanism in place to ensure that Green Deal providers do not pay more than 1p/day/plan. Therefore, larger suppliers receive slightly less to finance a higher rate for smaller suppliers. These fees are invoiced every three months to reduce the administrative burden (DECC, 2012a).

61 Establishing the legal basis for tying the loan to the meter and automatically transferring it to new residents was a major challenge in the development of the Green Deal (personal communication with DECC officer, 2014).

About the Authors

Luis Mundaca is Professor of Low-carbon and Resource-Efficient Economics and Policy at the International Institute for Industrial Environmental Economics (IIIEE), Lund University, Sweden. Luis is an environmental economist who works in the fields of climate change mitigation, energy, transaction costs, resource efficiency, behavioral change, and development. He has served as a Lead Author for the IPCC Fifth Assessment Report on Climate Change Mitigation (Working Group III) and the Global Energy Assessment (Cambridge University Press).

Sarah Kloke is a Policy Officer who works at the German Federal Ministry for the Environmental, Nature Conservation and Nuclear Safety. Her focus lies on European Climate and Energy Policy.

References

Association for the Conservation of Energy [ACE]. (2012). *National fuel poverty budgets*. London, UK: Author.

Alexander, B. (2010). Dynamic pricing? Not so fast! A residential consumer perspective. *The Electricity Journal*, *23*(6), 39–49.

Ameli, N., Pisu, M., & Kammen, D. (2017). Can the US keep the PACE? A natural experiment in accelerating the growth of solar electricity. *Applied Energy*, *191*, 163–169.

Anderson, S., & Newell, R. (2004). Information programs for technology adoption: The case of energy-efficiency audits. *Resource and Energy Economics*, *26*(1), 27–50.

Bachrach, D., Carter, S., & Jaffe, S. (2004). Do portfolio managers have an inherent conflict of interest with energy efficiency? *The Electricity Journal*, *17*(8), 52–62.

Bell, C., & Nadel, S. (2012). *On-bill financing: Exploring the energy efficiency opportunities and diversity of approaches current on-bill landscape*. Presented at the ACEEE Summer Study on Energy Efficiency in Buildings. Pacific Grove, CA: American Council for an Energy-Efficient Economy.

Bell, C., Nadel, S., & Hayes, S. (2011). *On-bill financing for energy efficiency improvements: A review of current program challenges, opportunities, and best practices* (Research Report No. E118). Washington, DC: American Council for an Energy-Efficient Economy.

Bemelmans-Videc, M. (1998). Policy instrument choice and evaluation. In M. Bemelmans-Videc, R. Rist, & E. Vedung (Eds.), *Carrots, sticks and sermons* (pp. 1–18). New Brunswick, NJ: Transaction Publishers.

Berlo, K., Durand, A., Höfele, V., Nanning, S., Meyer, S., Clausnitzer, K.-D., & Hoffmann, N. (2011). *Erschließung von Minderungspotenzialen spezifischer Akteure, Instrumente und Technologien zur Erreichung der Klimaschutzziele im Rahmen der Nationalen Klimaschutzinitiative (EMSAITEK)*. Saarbrücken, DE: Institut für ZukunftsEnergieSysteme (IZES), Bremer Energie Institut (BEI), Wuppertal Institut for Climate, Environment and Energy GmbH.

Bird, S., & Hernández, D. (2012). Policy options for the split incentive: Increasing energy efficiency for low-income renters. *Energy Policy*, *48*, 506–514.

Birol, F., & Keppler, J. (2000). Prices, technology development and the rebound effect. *Energy Policy*, *28*(6), 457–469.

Björkqvist, O., & Wene, C. (1993). *A study of transaction costs for energy investments in the residential sector*. In Proceedings of the eceee 1993 Summer Study Conference. Stockholm, SE: The European Council for an Energy Efficient Economy.

Blumstein, C., Goldstone, S., & Lutzenhiser, L. (2000). A theory-based approach to market transformation. *Energy Policy*, *28*(2), 137–144.

Bobinaite, V., & Tarvydas, D. (2014). Financing instruments and channels for the increasing production and consumption of renewable energy: Lithuanian case. *Renewable and Sustainable Energy Reviews*, *38*, 259–276.

Booth, A. T., & Choudhary, R. (2013). Decision making under uncertainty in the retrofit analysis of the UK housing stock: Implications for the Green Deal. *Energy and Buildings*, *64*, 292–308.

Borenstein, S. (2005). The long-run efficiency of real-time electricity pricing. *The Energy Journal*, *26*(3), 93–116.

Borgeson, M., Zimring, M., & Goldman, C. (2012). *The limits of financing for energy efficiency*. In ACEEE 2012 Summer Study on Energy Efficiency in Buildings, Pacific Grove, CA. Retrieved from http://escholarship.org/uc/item/10b8d9zs.pdf

BRE. (2014). *SBEM: Simplified Building Energy Model*. Building Research Establishment. Retrieved from http://www.bre.co.uk/page.jsp?id=706

Briedenhann, J., & Butts, S. (2005). Utilization-focused evaluation. *Review of Policy Research*, *22*(2), 221–243.

Brown, M. (2001). Market failures and barriers as a basis for clean energy policies. *Energy Policy*, *29*(14), 1197–1207.

Burr, M. S. (2013). *Aligning incentives: Financial models for promoting energy efficiency renovations in American apartment buildings*. Lund, Sweden: International Institute for Industrial Environmental Economics.

Campiglio, E. (2016). Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics*, *121*, 220–230.

Carley, S. (2011). The era of state energy policy innovation: A review of policy instruments. *Review of Policy Research*, *28*(3), 265–294.

Committee on Climate Change [CCC]. (2009). *Uptake of energy efficiency in buildings on behalf of Committee on Climate Change: Final report*. Cambridge, UK: Author.

Chen, H. T. (1990). *Theory-driven evaluations*. Newbury Park, CA: Sage Publications.

Cillo, P. A., & Lachman, H. (2013). *Status report for programs based on the Pay As You Save® (PAYS®) system*. Colchester, VT: Energy Efficiency Institute, Inc. Retrieved from http://eeivt.com/wordpress/wp-content/uploads/2013/02/PAYSstatus2_21_13.pdf

ClickGreen. (2012). "Independent" Green Deal regulator is owned by the Big 6 energy firms. Retrieved from http://www.clickgreen.org.uk/news/national-news/123806-%5Cindependent%5C-green-deal-regulator-is-owned-by-the-big-6-energy-firms.html

Commons, J. R. (1934). *Institutional economics: Its place in political economy*. New Brunswick, NJ: Transaction Publishers.

Coryn, C., Noakes, L., Westine, C., & Schröter, D. (2011). A systematic review of theory-driven evaluation practice from 1990 to 2009. *American Journal of Evaluation*, *32*(2), 199–226.

Dale, D., & Schweiger, W. (2014). Can cities lead the way in innovative energy retrofits for single-family homes? *Community Development Investment Review*, *10*(1), 117–121.

Department for Energy and Climate Change [DECC]. (2010). *Green Deal summary proposals*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2011a). *Estimations of home insulation levels in Great Britain: October 2011* (pp. 1–8). London, UK: Author.

Department for Energy and Climate Change [DECC]. (2011b). *Greg Barker speech: Green Deal and Big Society event*. Retrieved from https://www.gov.uk/government/speeches/greg-barker-speech-green-deal-and-big-society-event

Department for Energy and Climate Change [DECC]. (2011c). *Research summary: Understanding potential consumer response to the Green Deal*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2012a). *Final stage impact assessment for the Green Deal and Energy Company Obligation*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2012b). *The Green Deal and Energy Company Obligation: Government response to the November 2011 consultation*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2012c). Green Deal Arrangements Agreement. London, UK: Department for Energy and Climate Change (DECC). Retrieved from https://www.gov.uk/government/publications/green-deal-arrangements-agreement-version-1

Department for Energy and Climate Change [DECC]. (2014a). *Annual domestic energy bills. Statistical data set*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2014b). *Applications to the Green Deal Home Improvement Fund close*. Retrieved from https://www.gov.uk/government/news/applications-to-the-green-deal-home-improvement-fund-close

Department for Energy and Climate Change [DECC]. (2014c). *Green Deal Arrangements Agreement*. London, UK: Department for Energy and Climate Change (DECC). Retrieved from https://www.gov.uk/government/publications/green-deal-arrangements-agreement-version-1

Department for Energy and Climate Change [DECC]. (2014c). *Green Deal and Energy Company Obligation (ECO): Monthly statistics (January 2014)*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2014d). *Green Deal and Energy Company Obligation (ECO): Monthly statistics (July 2014)*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2014e). *Green Deal cashback*. London, UK: Department for Energy and Climate Change. Retrieved from https://gdcashback.decc.gov.uk/

Department for Energy and Climate Change [DECC]. (2014f). *Research on the Green Deal provider market*. London, UK: Author.

Department for Energy and Climate Change [DECC]. (2015a). *Annual fuel poverty statistics report, 2015* (No. URN:15D/165, p. 116). London, UK: Author. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/468011/Fuel_Poverty_Report_2015.pdf

Department for Energy and Climate Change [DECC]. (2015b). *Green Deal and Energy Company Obligation (ECO): Monthly statistics (November 2015)*. London, UK: Author. Retrieved from https://www.gov.uk/government/statistics/green-deal-and-energy-company-obligation-eco-headline-statistics-november-2015

Dieckhöner, C. (2012). Does subsidizing investments in energy efficiency reduce energy consumption? Evidence from Germany. *SOEPpaper on Multidisciplinary Panel Data Research*, *527*. Berlin: DIW Berlin, The German Socio-Economic Panel (SOEP).

Department of Energy [DOE]. (2016). *Best practice guidelines for residential PACE financing programs*. Washington, DC: Author. Retrieved from https://energy.gov/sites/prod/files/2016/11/f34/best-practice-guidelines-RPACE.pdf

EEI. (2014). *PAYS® essential elements & minimum program requirements*. Retrieved from http://eeivt.com/wordpress/pays-essential-elements-minimum-program-requirements-2/

Ekins, P., & Medhurst, J. (2006). The European structural funds and sustainable development: A methodology and indicator framework for evaluation. *Evaluation*, *12*(4), 474–495.

Eto, J., Stoft, S., & Belden, T. (1997). The theory and practice of decoupling utility revenues from sales. *Utilities Policy*, *6*(1), 43–55.

Faruqui, A., & Sergici, S. (2010). Household response to dynamic pricing of electricity: A survey of 15 experiments. *Journal of Regulatory Economics*, *38*(2), 193–225.

FHFA. (2010). *FHFA statement on certain energy retrofit loan programs*. Retrieved from https://www.fhfa.gov/Media/PublicAffairs/Pages/FHFA-Statement-on-Certain-Energy-Retrofit-Loan-Programs.aspx

Fischer, F. (1995). *Evaluating public policy*. Belmont, CA: Wadsworth Group.

Furubotn, E. G., & Richter, R. (Eds.). (2010). *The new institutional economics of markets*. Cheltenham, UK: Edward Elgar.

Gately, D. (1980). Individual discount rates and the purchase and utilization of energy-using durables: Comment. *The Bell Journal of Economics*, *11*(1), 373–374.

Gates, R. W. (1983). Investing in energy conservation: Are homeowners passing up high yields? *Energy Policy*, *11*, 63–72.

GDFC. (2014). *GDFC ends early repayment charges*. Retrieved from http://thegreendealfinancecompany.com/

Gillingham, K., Newell, R. G., & Palmer, K. (2009). Energy efficiency economics and policy. *Annual Review of Resource Economics*, *1*(1), 597–620.

Goldman, C., Peters, J., Albers, N., Stuart, E., & Fuller, M. (2010). *Energy efficiency services sector: Workforce education and training needs* (No. LBNL-3163E, p. 73). Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL), Research Into Action Inc. Retrieved from http://escholarship.org/uc/item/94j234gj

Gov.uk. (2014). *Helping households to cut their energy bills*. Retrieved from https://www.gov.uk/government/policies/helping-households-to-cut-their-energy-bills

Great British Refurb Campaign. (2011). *Green Deal webinar—One year and counting*. Retrieved from http://www.youtube.com/watch?v=8-8fRJaBG4s

Green Deal & ECO Team. (2015). *Changes to green home improvement policies announced today*. Retrieved from https://decc.blog.gov.uk/2015/07/23/changes-to-green-home-improvement-policies-announced-today/

Guertler, P. (2012). Can the Green Deal be fair too? Exploring new possibilities for alleviating fuel poverty. *Energy Policy*, *49*, 91–97.

Guertler, P., & Royston, S. (2013). *Financing energy efficiency in buildings: An international review of best practice and innovation*. London, UK: ACE.

Gupta, S., Harnisch, J., Barua, D., Chingambo, L., Frankel, P., Garrido, R., … Massetti, E. (2014). Cross-cutting investment and finance issues. In O. Edenhofer et al. (Eds.), *Climate change 2014: Mitigation of climate change. Contribution of Working Group III to the fifth assessment report of the intergovernmental panel on climate change* (pp. 1207–1246). Cambridge, UK: Cambridge University Press.

Hayes, S., Nadel, S., Granda, C., & Hottel, K. (2011). *What have we learned from energy efficiency financing programs?* Washington, DC: American Council for an Energy-Efficient Economy.

Hildén, M., Lepola, J., Mickwitz, P., Mulders, A., Palosaari, M., Similä, J., … Vedung, E. (2002). *Evaluation of environmental policy instruments: A case study of the Finnish pulp and paper and chemical industries* (Monographs of the Boreal Environment Research 21). Retrieved from http://www.environment.fi/download.asp?contentid=13368&lan=en

Hiskes, J. (2010, July 7). Fannie and Freddie to clean-energy program: Drop dead. *Grist Cities*. Retrieved from http://grist.org/article/2010-07-06-fannie-and-freddie-to-clean-energy-program-drop-dead/

Holmes, I. (2011, May 24). *Financing the Green Deal: Carrots, sticks and the Green Investment Bank*. London, UK: E3G.

Hough, D., & White, E. (2014). *The Green Deal*. London, UK: Library House of Commons.

Hudson, D. (2015). *Global finance and development*. Abingdon, UK: Routledge.

Jackson, E. (2013). Interrogating the theory of change: Evaluating impact investing where it matters most. *Journal of Sustainable Finance & Investment*, *3*(2), 95–110.

Jaffe, A. B., & Stavins, R. N. (1994). The energy-efficiency gap: What does it mean? *Energy Policy*, *22*(10), 804–810.

Johnson, K., Willoughby, G., Shimoda, W., & Volker, M. (2012). Lessons learned from the field: Key strategies for implementing successful on-the-bill financing programs. *Energy Efficiency*, *5*(1), 109–119.

Joskow, P. L., & Marron, D. B. (1992). What does a negawatt really cost? Evidence from utility conservation programs. *The Energy Journal*, *13*(4), 41–75.

Kahneman, D., Knetsch, J., & Thaler, R. (1991). Anomalies: The endowment effect, loss aversion, and status quo bias. *The Journal of Economic Perspectives*, *5*(1), 193–206.

Kahneman, D., & Thaler, R. H. (2006). Anomalies: Utility maximization and experienced utility. *The Journal of Economic Perspectives*, *20*(1), 221–234.

Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica: Journal of the Econometric Society*, *47*, 263–292.

Khandker, S. (1998). Micro-credit programme evaluation: A critical review. *IDS Bulletin*, *29*(4), 11–20.

Kirkpatrick, A., & Bennear, L. (2014). Promoting clean energy investment: An empirical analysis of property assessed clean energy. *Journal of Environmental Economics and Management*, *68*(2), 357–375.

Kiss, B. (2016). Exploring transaction costs in passive house-oriented retrofitting. *Journal of Cleaner Production*, *123*, 65–76.

Kolstad, C., Urama, K., Broome, J., Bruvoll, A., Cariño Olvera, M., Fullerton, D., … Mundaca, L. (2014). Social, economic and ethical concepts and methods. In O. Edenhofer et al. (Eds.), *Climate change 2014: Mitigation of climate change. Contribution of Working Group III to the fifth assessment report of the intergovernmental panel on climate change*. Cambridge, UK: Cambridge University Press.

Krarup, S., & Russell, C. S. (2005). *Environment, information and consumer behaviour*. Cheltenham, UK: Edward Elgar Publishing Ltd.

Lachman, H. (2013). *Pay as you save: Tariffed on-utility bill efficiency system*. Presented at the Hawaii Energy Webinar, Vermont.

Lam, P., & Law, A. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20.

Lewis, D., Provencher, B., & Beardmore, B. (2015). Using an intervention framework to value salient ecosystem services in a stated preference experiment. *Ecological Economics*, *114*, 141–151.

Longstreth, M. (1986). Impact of consumers' personal characteristics on hedonic prices of energy-conserving durables. *Energy*, *11*(9), 893–905.

Lucon, O., Ürge-Vorsatz, D., Zain, A., Akbari, H., Bertoldi, P., Cabeza, L., … Vilariño, M. (2014). Buildings. In O. Edenhofer et al. (Eds.), *Climate change 2014: Mitigation of climate change. Contribution of Working Group III to the fifth assessment report of the intergovernmental panel on climate change* (pp. 671–738). Cambridge, UK: Cambridge University Press.

Lutzenhiser, L. (1994). Innovation and organizational networks barriers to energy efficiency in the US housing industry. *Energy Policy*, *22*(10), 867–876.

Marchand, R., Koh, S., & Morris, J. (2015). Delivering energy efficiency and carbon reduction schemes in England: Lessons from Green Deal pioneer places. *Energy Policy*, *84*, 96–106.

Matthews, R. C. (1986). The economics of institutions and the sources of growth. *The Economic Journal*, *96* (384), 903–918.

McCann, L., Colby, B., Easter, K. W., Kasterine, A., & Kuperan, K. V. (2005). Transaction cost measurement for evaluating environmental policies. *Ecological Economics*, *52*(4), 527–542.

Menard, C. (Ed.). (2005). *The foundations of the new institutional economics*. Cheltenham, UK: Edward Elgar.

Menard, C., & Shirley, M. (Eds.). (2008). *Handbook of new institutional economics*. Berlin: Springer.

Mickwitz, P. (2003). A framework for evaluating environmental policy instruments: Context and key concepts. *Evaluation*, *9*(4), 415–436.

Morgan, P. (2013). *A decade of decoupling for US energy utilities: Rate impacts, designs, and observations* (p. 98). Lake Oswego, OR: Graceful Systems LLC. Retrieved from https://www.nmlegis.gov/lcs/handouts/WNR%20072715%20Item%206%20A%20Decade%20of%20Decoupling%20for%20US%20Energy%20Utilities.pdf

MRA. (2018). *Green Deal. Master Registration Agreement*. Retrieved from https://www.mrasco.com/green-deal/green-deal-central-charge-database/

Mundaca, L. (2007). Transaction costs of Tradable White Certificate schemes: The energy efficiency commitment as case study. *Energy Policy*, *35*(8), 4340–4354.

Mundaca, L., Mansoz, M., Neij, L., & Timilsina, G. R. (2013). Transaction costs analysis of low-carbon technologies. *Climate Policy*, *13*(4), 490–513.

National Audit Office. (2016a). *Green Deal and Energy Company Obligation* (No. HC 607, p. 56). London, UK: National Audit Office. Retrieved from https://www.nao.org.uk/wp-content/uploads/2016/04/Green-Deal-and-Energy-Company-Obligation.pdf

National Audit Office. (2016b). *Investigation into the Department of Energy & Climate Change's loans to the Green Deal Finance Company* (No. HC 888, p. 27). London, UK: Author. Retrieved from https://www.nao.org.uk/wp-content/uploads/2016/04/Investigation-into-the-Department-of-Energy-and-Climate-Changes-loans-to-the-Green-Deal-Finance-Company.pdf

Navarro, P. (1996). The simple analytics of performance-based ratemaking: A guide for the PBR regulator. *Yale Journal on Regulation*, *13*(1), 105–161.

NHS. (2013). *Hypothermia*. Retrieved from http://www.nhs.uk/conditions/hypothermia/pages/introduction.aspx

New York State Energy Research & Development Authority [NYSERDA]. (n.d.) *Residential financing options*. Albany, NY: Author. Retrieved from https://www.nyserda.ny.gov/All-Programs/Programs/Residential-Financing-Options

Ostertag, K. (1999, May 5–7). *Transaction costs of raising energy efficiency*. Presented at the IEA International Workshop on Technologies to Reduce Greenhouse Gas Emissions: Engineering-Economic Analyses of Conserved Energy Carbon, Washington, DC. Retrieved from http://www.isi.fraunhofer.de/isi-wAssets/docs/x/de/publikationen/econserv.pdf

Oxford Dictionaries. (2016). Inertia - Definition of inertia in English from the Oxford Dictionary. Retrieved from http://www.oxforddictionaries.com/definition/english/inertia

Pathania, R., & Bose, A. (2014). An analysis of the role of finance in energy transitions. *Journal of Sustainable Finance & Investment*, *4*(3), 266–271.

Pawson, R., & Tilley, N. (1997). *Realistic evaluation*. London, UK: Sage Publications.

Qiu, Y., Colson, G., & Grebitus, C. (2014). Risk preferences and purchase of energy-efficient technologies in the residential sector. *Ecological Economics*, *107*, 216–229.

Rogers, P. J. (2000). Program theory: Not whether programs work but how they work. In D. Stufflebeam, G. Madaus, & T. Kellaghan (Eds.), *Evaluation models* (pp. 209–232). Boston: Kluwer Academic.

Rosenow, J. (2012). Energy savings obligations in the UK—A history of change. *Energy Policy*, *49*, 373–382.

Rosenow, J., & Eyre, N. (2013). The Green Deal and the Energy Company Obligation. *Energy*, *166*(EN3), 127–136.

Rosenow, J., & Eyre, N. (2016). A post mortem of the Green Deal: Austerity, energy efficiency, and failure in British energy policy. *Energy Research & Social Science*, *21*, 141–144.

Rosenow, J., Eyre, N., Rohde, C., & Bürger, V. (2013). Overcoming the upfront investment barrier: Comparing the German CO2 Building Rehabilitation Programme and the British Green Deal. *Energy & Environment*, *24*(1–2), 88–104.

Rosenow, J., & Galvin, R. (2013). Evaluating the evaluations: Evidence from energy efficiency programmes in Germany and the UK. *Energy and Buildings*, *62*, 450–458.

Sanstad, A. H., & Howarth, R. B. (1994). Normal markets, market imperfections and energy efficiency. *Energy Policy*, *22*(10), 811–818.

Schleich, J. (2009). Barriers to energy efficiency: A comparison across the German commercial and services sector. *Ecological Economics*, *68*(7), 2150–2159.

Shogren, J. F., & Taylor, L. O. (2008). On behavioral-environmental economics. *Review of Environmental Economics and Policy*, *2*, 26–44.

Stiglitz, J. E. (1986). *Economics of the public sector*. London, UK: W.W. Norton.

Sutherland, R. J. (1991). Market barriers to energy-efficiency investments. *The Energy Journal*, *12*(3), 15–34.

Szumilo, N., & Fuerst, F. (2015). Who captures the "green value" in the US office market? *Journal of Sustainable Finance & Investment*, *5*(1–2), 65–84.

Thaler, R. H. (1999). Mental accounting matters. *Journal of Behavioral Decision Making*, *12*(3), 183.

Tietenberg, T. (2009). Reflections—Energy efficiency policy: Pipe dream or pipeline to the future? *Review of Environmental Economics and Policy*, *3*(2), 304–320.

Train, K. (1985). Discount rates in consumers' energy related decisions: A review of the literature. *Energy*, *10* (2), 1243–1253.

Tuominen, P., Klobut, K., Tolman, A., Adjei, A., & de Best-Waldhober, M. (2012). Energy savings potential in buildings and overcoming market barriers in member states of the European Union. *Energy and Buildings*, *51*, 48–55.

UK Green Building Council [UK-GBC]. (2009). *Pay As You Save: Financing low energy refurbishment in housing*. London, UK: Author.

United Nation Environment Programme [UNEP]. (2010). *Green economy—Driving a green economy through public finance and fiscal policy reform* (p. 34). France: Author. Retrieved from http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_Working_Paper_Public_Finance.pdf

United Nation Environment Programme [UNEP]. (2011a). *Cities—Investing in energy and resource efficiency* (p. 42). France: Author. Retrieved from http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_12_Cities.pdf

United Nation Environment Programme [UNEP]. (2011b). *Towards a green economy: Pathways to sustainable development and poverty eradication. A synthesis for policy makers* (p. 52). France: Author. Retrieved from http://www.unep.org/greeneconomy/Portals/88/documents/ger/GER_synthesis_en.pdf

United Nation Environment Programme [UNEP]. (2015). *The financial system we need—Aligning the financial system with sustainable development* (p. 112). Geneva: Author. Retrieved from http://web.unep.org/inquiry

Ürge-Vorsatz, D., Eyre, N., Graham, P., Harvey, D., Hertwich, E., Jiang, Y., … Novikova, A. (2012). Chapter 10—Energy end-use: Building. In *Global energy assessment—Toward a sustainable future* (pp. 649–760). Cambridge, UK: Cambridge University Press. Retrieved from www.globalenergyassessment.org

Vaughan, A. (2015, July). Government kills off flagship green deal for home insulation. *The Guardian*. Retrieved from http://www.theguardian.com/environment/2015/jul/23/uk-ceases-financing-of-green-deal

Vedung, E. (2009). *Public policy and program evaluation* (4th ed.). New Brunswick, NJ: Transaction Publishers.

Venkatachalam, L. (2008). Behavioral economics for environmental policy. *Ecological Economics*, *67*(4), 640–645.

Volker, M., & Johnson, K. (2008). *Breaking down the barriers to efficiency improvements in the rental housing market: One utility's approach*. Hays, KS: Midwest Energy, Market Development Group.

Vreuls, H., Grotte, W., Bach, P., Bosseboeuf, D., Celi, O., Kim, J.-K., … Roosenburg, M. (2005). *Evaluating energy efficiency policy measures & DSM programmes* (p. 170). Paris Cedex, France: International Energy Agency—DSM & SenterNovem. Retrieved from http://62.121.14.21/ViewTask.aspx?ID=17&Task=99&Sort=1

WHO Europe. (2011). *Environmental burden of disease associated with inadequate housing: A method guide to the quantification of health effects of selected housing risks in the WHO European Region*. M. Braubach, D. E. Jacobs, & D. Ormandy (Eds.). Copenhagen, Denmark: WHO Regional Office for Europe.

Williamson, O. (2000). The new institutional economics: Taking stock, looking ahead. *Journal of Economic Literature*, *38*(3), 595–613.

Williamson, O. (2010). Transaction cost economics: The natural progression. *American Economic Review*, *100*(3), 673–690.

Woolf, T., & Michals, J. (1995). Performance-based ratemaking: Opportunities and risks in a competitive electricity industry. *The Electricity Journal*, *8*(8), 64–73.

Zundel, S., & Stieß, I. (2011). Beyond profitability of energy saving measures: Attitudes towards energy saving. *Journal of Consumer Policy*, *34*(1), 91–105.

Appendix A—Key Contractual Steps Under On-Bill Financing Schemes

How$mart® program in Kansas (United States):

1. *Customer persuasion*: This aims to trigger demand from potential customers. For instance, end-users are actively approached by Midwest's contractors. Other customers with concerns or complaints about their energy bill become familiar with the program through contacting the utility company. Customers are also informed about the program by social service agencies when they are unable to finance efficiency improvements themselves.
2. *Energy performance screening and audit*: Once an initial contact has been established, customers receive more detailed information, and a high-level evaluation of energy usage. This can lead to a comprehensive on-site assessment performed by one of Midwest's auditors. The audit can include the following: an air infiltration test, an infrared scan, a duct leakage test, and a furnace combustion test. Midwest charges a fee of $200 if the customer decides to stop the process at this stage. If the auditor cannot identify any improvements resulting in a lower energy bill, the company covers the costs and the process stops. If the audit reveals the potential for cost-effective energy efficiency measures and the customer is still interested, a preliminary Conservation Plan is developed. This consists of recommended efficiency measures, together with estimated costs and expected energy savings, translated into cost savings.
3. *Bid invitation, selection, and contract*: If the customer is interested in signing up for the program, he or she requests binding bids from a list of Midwest's approved contractors. Once a bid has been selected, the final Conservation Plan is developed (Johnson et al., 2012; Volker & Johnson, 2008). It should be noted that the cost of efficiency improvements to the building's shell (e.g., a new façade) can be difficult to unbundle from modernization costs that are usually borne by the building's owner. Under How$mart®, there is no procedure in place to differentiate the incremental and full costs of a measure. If savings allow for it, Midwest Energy bears the full costs of the measure.[53]
4. *Implementation*: Contractors implement the agreed efficiency measures. The customer informs Midwest Energy when the chosen measure or package of measures has been satisfactorily installed. The company carries out a post-retrofit audit to check that all measures have been implemented as prescribed in the Conservation Plan.[54]
5. *On-bill payment*: In the final step, Midwest Energy pays the contractor and sets the customer's monthly tariff (Johnson et al., 2012). While some customers only receive electricity, others are only provided with gas, or both. However, all customers are eligible for energy-saving electricity and gas measures. Payment streams under How$mart® are based on net utility bill savings, which are not necessarily Midwest Energy's utility bill savings.[55]

The Green Deal in the United Kingdom:

1. *Customer persuasion*: This focused on Green Deal providers, assessors, or installers marketing any type of informative instrument (e.g., via the press) designed to stimulate consumer interest in the Green Deal.
2. *Energy audit*: The customer chooses a certified Green Deal assessor, who carries out an energy audit and gives advice on measure(s) that can be installed cost-effectively. The assessor is only allowed to recommend products from the Green Deal Measures List.[56] Eligible measures range from insulating the shell, to hot water controls, to

replacing fossil fuel-based heating systems with renewable energy systems (DECC, 2014a).[57] The assessor is required to state the results of the audit in a Green Deal Advice Report, which contains a Green Deal occupancy assessment, information on the householders' specific energy use, and an EPC.[58] The latter specifies the physical dimensions of the building, the type of construction, the nature of the heating and ventilation systems, lighting, and existing energy efficiency measures (DECC, 2012a).

3. *Request for bids*: Armed with a Green Deal Advice Report, the customer can approach one or more Green Deal providers. In response, the provider submits a quote setting out costs (investment, interest, and further fees) and how these costs are repaid, via the energy bill, over a certain period of time. Typically, providers add their costs to the quote provided by installers. These are then bundled together and offered to the potential customer (DECC, 2014b). If costs exceed £10,000, customers are required to obtain at least three quotes from different providers (DECC, 2011c).
4. *Green Deal finance and contract*: Once the customer has selected a company to work with, the provider develops a detailed Green Deal Finance Plan (i.e., the contract between the Green Deal provider and the bill payer) (DECC, 2012a). The GDFC, which acts as the lender to the provider, checks the customer's credit score on behalf of the provider. This comprises: (i) confirmation of the customer's credit rating, (ii) a check for any debt arrears related to energy use, and (iii) a check of whether the customer is a "politically exposed person." GDFC finance was limited by the "Golden Rule": expected energy savings must be equal to or greater than repayments made through the energy bill in the first year. This principle naturally establishes the upper limit for finance, while repayments were set to increase by 2% per year (DECC, 2012b). Green Deal policy did not require that installed measures were entirely financed through energy savings. The Golden Rule only set the limit for Green Deal finance, and the customer could choose to seek additional sources of finance for less cost-effective measures (DECC, 2012b). In July 2015, the GDFC stopped accepting applications for new Green Deal Plans, although providers could still seek private finance.
5. *Implementation*: When the homeowner or landlord signs up to their Green Deal Plan, the energy efficiency measure(s) are implemented by an accredited installer. The installer is often the same company as the provider.
6. *Remuneration of providers and installers*: Following installation, the GDFC purchases remittances from the Green Deal Plan, meaning that both the provider and installer were remunerated. The GDFC notified the new Green Deal to the Green Deal Central Charges database run by the Master Registration Agreement (MRA) (MRA, 2018).[59] The GDFC also notified the energy supplier, who receives 1p/plan/day (2p/plan/day for small providers) as compensation for administrative costs (DECC, 2012a).[60]
7. *On-bill payment*: Postinstallation, the Green Deal Plan switches from "pending" to "live" and the energy supplier collects repayments along with the customer's usual payments for consumption (DECC, 2010, 2012a). The supplier forwards these payments to the Green Deal provider, or directly to the GDFC. The supplier acts as a trustee for the provider and is responsible for recovering any debt. The supplier is obliged to recover Green Deal arrears in the same way as they recover consumption arrears. This means that nonpayment can result in disconnection (DECC, 2012c). Once all repayments have been made, the GDFC settles the loan. The customer can switch to a new energy supplier, even if the initial supplier was a Green Deal provider. In this case, the obligation to collect

outstanding repayments passes to the new supplier (DECC, 2012a). Like the PAYS® system, financial responsibility is tied to the building's electricity or gas meter, rather than an individual.[61] If the first Green Deal participant moves out, repayment obligations are transferred to the new user.

Appendix B—Financing Costs of OBR and OBF Programs in the United States

Program Name	Type	Capital Source	Target Sector	Loan Size (US$)	Interest Rate (%)	Max. Payback
Electric Cooperatives South Carolina: Rural Energy Savings	OBR	USDA's Rural Economic Loans and Grants Program (REDLG)	Residential Commercial	<$740,000	2.5	10 years
Clean Energy Works Oregon	OBR	Seed capital ARRA funds, CDFI loan fund	Residential	$12,633 (median)	5.99	20 years
Connecticut: United Illuminating	OBR	Seed capital ARRA funds, Revolving loan fund	Commercial	$8,000–$12,000 (avg.)	0	24–36 months
California Investor-Owned Utilities: SoCal Edison OBF	OBR	Ratepayer funds, Revolving loan fund	Commercial	<$1,000,000	0	
Massachusetts, New Hampshire, Rhode Island: National Grid	OBR	Seed capital from ratepayer and shareholder funds, Revolving loan fund	Residential Commercial Industrial	N/A	0	N/A
New Hampshire Electric Co-op: NHEC SmartSTART	OBF	Ratepayer funds, Revolving loan fund	Commercial Industrial	$10,000 (avg.)	5.41	5 years
Midwest Energy: Kansas How$mart®	OBF	Kansas Housing Resources Corporation, Efficiency Kansas program, Rural Economic Development Loan	Residential Commercial Industrial	$7,489 (avg.)	0–8	15 years
Electric Cities of Georgia: OBF	OBF	Federal funding source, Revolving Loan fund	Residential	>$5,000	0	5 years

Sources: Bell & Nadel (2012); Bell and others (2011); Cillo & Lachman (2013).