# Energy Efficiency Financing: A review of risks and uncertainties

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Extended Abstract†
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## 1 Overview

Over the last 30 years, a growing body of literature has identified five interrelated barriers to energy efficiency (EE) investment, namely market, institutional, technical, motivational, and financial barriers. Of these, financial barriers pose a significant hurdle in mobilizing private capital for EE projects. The factors involved range from market-specific (e.g. lack of appropriate financing vehicles or debt instruments, regulatory risks, volatile energy prices), investor-specific (e.g. risk aversion, behavioral bias, perceived lack of collateral), to project-specific barriers (e.g. high initial costs, long payback periods, uncertainty of technology). In other words, investors remain skeptical of EE projects due to a number of risks and uncertainties specific to EE investments and attribute higher-than-usual discount rates to EE investments. Consequently, there is a scarcity of viable EE financial products on the market.

Nevertheless, there is a general consensus among experts and policymakers that a specialized EE asset class is one viable pathway to accelerating investments and market growth. And while a substantial body of literature exists concerning the factors involved in financial barriers, efforts to summaries, integrate and synthesis the key findings across studies have failed to keep pace. The aim of this paper, therefore, is to address this gap by conducting a comprehensive review of published research on financial barriers to EE investments and, in particular, the risks involved. The overarching research questions are: what are the risks typically attributed to EE financing identified in the literature, what attempts are made to account for those risks in financial models, and what innovative financing models have been identified in the literature?

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## 2 Methods

A systematic search of the academic literature was undertaken using a number of bibliographic databases in the social, economic and environmental sciences (e.g. ScienceDirect, JSTOR, SpringerLink), as well as other search engines and online resources. Search keywords used include *energy efficiency investment*, *energy efficiency financing*, *energy efficiency risk*, *energy efficiency market*, and variants thereof. Publications from non-academic or non-governmental institutions (e.g. IEA, OECD), national research laboratories and institutes (e.g. LBNL, DIW Berlin), and proceedings from energy-related conferences (e.g. IAEE, ECEEE Summer Study) were also examined.

The search was confined to studies conducted in mostly European but also North American countries, written in English, and published since the late 1970s. Studies from non-Western countries were excluded due to potentially significant differences in the barriers private investors face in developing countries (i.e. unstable governments, lack of trust in the financial system, corruption). Studies conducted before the 1970s were also excluded due to developments in financial regulations in North America and Europe over the past four decades that may have an impact on the generalizability of this review. That said, a vast majority of the studies included were published since the early 2000s; those prior to this provided mostly theoretical or historical background material.

## 3 Findings

The review classifies EE investment risks into five categories, namely economic and financial; behavioral and operational; measurement and verification (M&V); contextual and technology; and regulatory risks. Economic/financial risks can manifest as construction cost increases, interest rate, volatile energy prices, or loan default (An and Pivo, 2017; Kaza et al., 2014; Meier and Eide, 2007; Mills et al., 2006; Tuominen and Seppänen, 2017). Behavioral/operational risks include behavioral biases, the rebound effect, faulty equipment operation or maintenance, and unexpected consumption patterns (Frederiks et al., 2015; Guerra Santin, 2013; Haldi et al., 2017; Linares and Labandeira, 2010; van Raaij and Verhallen, 1983a,b). M&V risks manifest as inconsistencies in measurement, poor data quality, or modeling errors Kromer (2007); Lee et al. (2015); Meyers and Kromer (2008); Xia and Zhang (2013). A special consequence of M&V issues is a barrier to standardization of EE projects, which has a compounding effect with the other risks. Contextual and technology risks are project- or equipment-specific and less generalizable than those discussed thus far. They can manifest as poor project design, installation delays, insufficient information of facilities, poor equipment design or lack of trust in new technology, and poor performance (Hu and Zhou, 2011; Lee et al., 2015; Mills et al., 2006; Stevens et al., 2018; Xia and Zhang, 2013). Regulatory risks include changes in grant or subsidy programs, conflicting or inconsistent EE standards or building codes, or unfavorable financial regulation (Hu and Zhou, 2011; Stevens et al., 2018).

Most of the literature focuses on the discount rate for risk assessment in financial or decision-making models. A seminal study (Thompson, 1997) proposes a modification of the net present value (NPV) model in which two cost streams are discounted separately and then subtracted. Other studies develop comprehensive frameworks to account for risk (Schleich et al., 2016); analyze the influence of behavioral biases on EE investment decisions (Häckel et al., 2017); utilize multi-objective optimization decision trees to account for risk (Diakaki et al., 2010); or cost-benefit

analysis to identify co-benefits not normally realized by the investor (Jakob, 2006). Risk mitigation is less developed in the literature, mainly in the form of energy-savings insurance (Mills, 2003) or actuarial pricing models (Mathew et al., 2005; Mills et al., 2006).

Studies concerning the third-party financing of energy savings are scarce; notable exceptions include a comprehensive study from SEE Action (SEE Action, 2015) in the US, an OECD (Della Croce and Yermo, 2013) report on institutional investors and infrastructure financing, and the seminal paper on third-party financing for EE (Peretz, 2009). Other studies present or analyze innovative financing solutions in the market: a comprehensive review of financing models in Europe, North America and Asia (Schlein et al., 2017); alternative financing schemes from the US, UK and France (Bullier and Milin, 2013); revolving funds in the UK (Gouldson et al., 2015); innovative financing models or programs in the EU (Vanstraelen et al., 2015).

## 4 Conclusions

What is clear from the findings is that nearly all of the studies identified in the review take the perspective of an investor who is also the decision-maker (e.g. homeowner). Largely neglected is the role of the institutional investor (e.g. pension funds, insurance companies), arguably an important factor when considering the development of a specialised EE asset class. In general, this review has shown that there remains a significant gap in knowledge concerning, not only the role of institutional investors, but also pathways to accessing the secondary markets as a capital source for EE projects. Further research is necessary to fill this gap.

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