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Economic parameters in the evaluation studies focusing on building energy efficiency: a review of the underlying rationale, data sources, and assumptions

Sergio Copiello[a]*

[a]*IUAV University of Venice, Dorsoduro 2206, 30123 Venice, Italy*

Abstract

A growing literature has highlighted the variables and parameters that most affect the technical feasibility and the economic viability of the measures meant to improve building energy efficiency. This paper discusses the results of a literature review, which focuses on the studies that deal with three economic parameters: the price to be paid for the energy supply, the energy inflation rate, and the discount rate used to convert future cash flows to a present value, namely, an upfront lump-sum equivalent. A specific co-occurrence analysis of terms is performed on the titles and abstracts of the examined documents. The representation of the results allows recognizing several significant clusters and network relationships. Moreover, that literature review enables to identify two well-established research strands. The first involves the relationship between energy prices and the profitability of efficiency-related investments. The second research branch points at the pivotal role played by the discount rate when evaluating the investments in energy-efficient measures.

Keywords: Building energy efficiency; Energy price; Inflation rate; Discount rate

* Corresponding author. Tel.: +39 041 257 1387; fax: +39 041 257 2424.
E-mail address: copiello@iuav.it

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1. Introduction

The issue of building energy efficiency has gained interest during the last years and, more broadly, over a time span of four decades or so [**1**] (**Fig. 1**). Energy efficiency is a prominent topic on the agenda due to the need of taking fuel consumptions under control and reducing their environmental impact. Under this framework, the construction sector plays a pivotal role because buildings largely contribute to primary energy demand and consumption, as well as to greenhouse gas emissions [**2-4**]. Concerning the evaluation of the measures aiming at improving building energy efficiency, a growing literature is available. The results of several field studies, although sometimes conflicting, have the merit of having highlighted the variables and parameters that most affect the technical feasibility and the economic viability of those measures. As far as the latter is concerned, a summary list of the most influential parameters should include, at least, the following items [**1,5**]: contingent and long-term geo-climatic conditions [**6,7**]; building type and physical characteristics of the constructions [**8,9**]; consumers' preferences and occupants' behavior [**10-13**]; prices of energy supply and their changes over time [**14-16**]; investment costs to be incurred and the corresponding expected return and payback time [**17-19**].

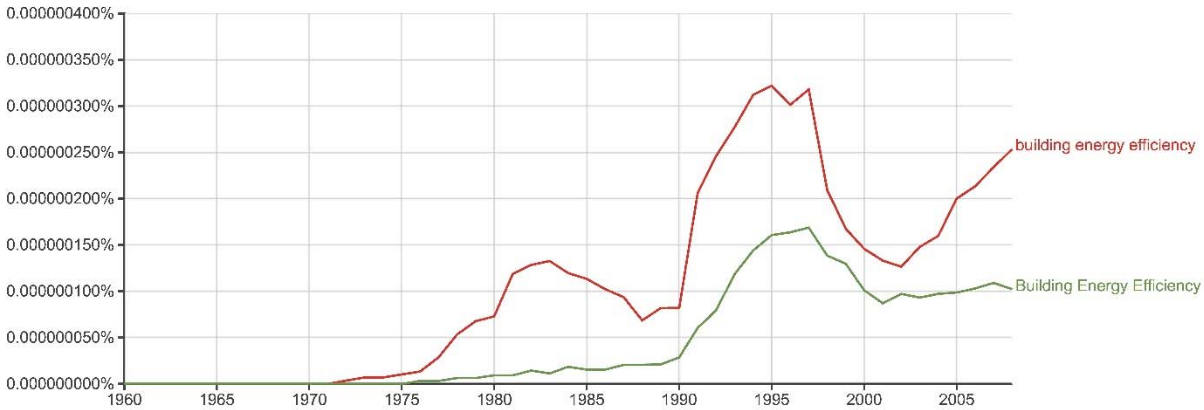


Fig. 1. Growing interest for building energy efficiency (source: *Google Ngram Viewer*).

This paper aims to present the results of a systematic literature review, with regard to the studies that use economic parameters to assess the feasibility of energy efficiency measure in the building industry. The literature review purposely focuses on the following three economic parameters: the price to be paid for the energy supply; the inflation rate, especially as far as energy sources are concerned; the discount rate used to convert future values to present values, so to calculate the upfront lump-sum equivalent of the expected cash flows.

The structure of this paper is as follows. The next section describes the source used to gather information and the method followed to identify the relevant literature. The subsequent paragraph provides an overview of the results, with specific reference to these issues: topics addressed in the studies, data sources, and estimated values or assumptions as far as the economic parameters are concerned. A further part of the text is devoted to identify and discuss two main, well-established research strands: the role played by energy prices in techno-economic evaluations is the former, the prominence of the discount rate in the same evaluations is the latter. Finally, the last section draws the conclusions.

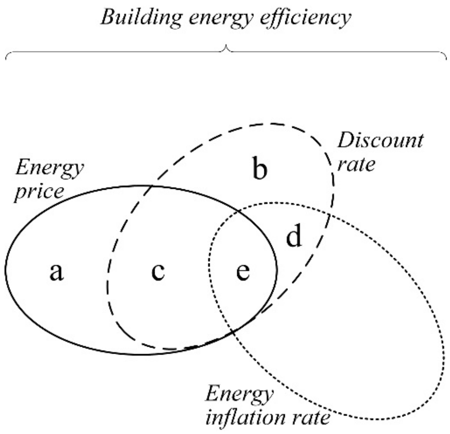
2. Method

The literature review discussed in this study is based on bibliographic research, which has been performed using the indexing and abstracting database Scopus, provided by Elsevier. Although some limitations and other issues are known to affect the selected source [**20-23**], it has been chosen due to its wider coverage in comparison to others such as the Clarivate Analytics' platform Web of Science [**24-26**]. In accordance with the three core economic parameters that constitute the focus of this study - namely, energy price, energy inflation rate, and discount rate - the search string used here is as follows:

- (ALL (“Building energy efficiency”) AND TITLE-ABS-KEY (“Energy price”) OR TITLE-ABS-KEY (“Inflation rate”) OR TITLE-ABS-KEY (“Discount rate”)).

In other words, a general key expression (“building energy efficiency”) is adopted to define the boundaries of the analysis. That key is used to search all the abstracting database fields. In addition, three specific expressions (“energy price”, “inflation rate”, and “discount rate”) are adopted to refine the search within titles, abstracts, and keywords. The search returns a result of 65 published items. That number does not reflect the whole amount of studies that, somehow, make use of the three analyzed parameters. Indeed, several other indexed documents base their analysis on economic parameters without explicitly reporting them in the abstract or among the keywords. As a case in point, let us consider that searching for the three key expressions (“energy price”, “inflation rate”, and “discount rate”) in all the abstracting database fields - without limiting the search to titles, abstracts, and keywords - would produce 188 results. However, I take into account the 65 results of the search string mentioned above relying on the assumption that mentioning an economic parameter in the abstract or among the keywords reveals that it takes on high significance in the research work and the related publication.

It deserves mentioning a partial overlap of the results (Fig. 2). Although most of the analyzed studies deal only with the parameter of the energy price or, in a subordinate position, exclusively with the discount rate, a certain number of publications consider two parameters (i.e., the energy supply cost and the discount rate, or the energy inflation rate and, again, the discount rate). Other few studies present empirical applications, if not even theoretical reflections, which involve all the three parameters considered here.



a	*Energy price* only	44 items
b	*Discount rate* only	4 items
c	*Energy price* and *Discount rate*	7 items
d	*Energy inflation rate* and *Discount rate*	5 items
e	*Energy price* and *Energy inflation rate* and *Discount rate*	5 items

Fig. 2. Summary of the bibliographic search in Scopus.

The items are characterized by a publication window of about two decades, from 1996 to 2018. However, only two articles date back to the late nineties, while all the other documents have been published after the year 2007. What is more, nearly 70% of the documents have been authored during the last five years. Concerning the publication venue, the results are mostly journal articles (72%) and conference papers (23%), while only three (5%) are book chapters. As far as the publication outlets are concerned, the journal *Energy and Buildings* hosts nine articles, eight other papers have been published in *Energy Policy*, and five each in *Energy* and *Journal of Cleaner Production*.

3. Summary of the results

Tables 1 to 4 summarize the results (in chronological order) by reporting, for each study, the publication venue, the economic parameter(s) considered, and the synthetic description of the topic. Besides, the number of citations (as of April 2018) is meant to act as a proxy of the attention gained, although a low number of citations is likely to characterize the studies published in the last couple of years. In absolute terms, the most cited study is that authored by Newell, Jaffe, and Stavins (test of the Hicks's induced innovation hypothesis on energy-using consumer durables), published in 1999 in *The Quarterly Journal of Economics* [**28**]. Other highly-cited documents are those by Zhao, Li, and Ma (decomposition analysis of urban energy consumptions in China) and by Kumbaroğlu and Madlener (evaluation of optimal retrofit investment options using Monte Carlo simulation), both published in 2012 [**37,38**]. Out of the 65 analyzed studies, nine are not included in the tables due to their limited relevance, namely, the fact that they only incidentally deal with at least one of the economic parameters which this study focuses on.

Table 1. Summary of the results (first part).

Year	First author and reference	Venue (1)	Economic parameter: Energy price	Inflation rate	Discount rate	Topic	Citations
1996	Levine, M.D. [**27**]	ja	x			Gap between energy prices and the full costs of energy production due to subsidies, which disincentive investments in energy efficiency	7
1999	Newell, R.G. [**28**]	ja	x			The relationship between product innovation and energy price in the field of energy-using consumer durables	377
2008	Scott, M.J. [**29**]	ja	x			Net savings of the US building energy efficiency programs considering UN IPCC warming scenarios (reduced need for heating and increase in space cooling demand)	12
2009	Cao, J. [**30**]	ja	x			Influence of the energy price on the economic viability of a retrofit measure, showing that contradictions affect China's energy price system	9
2009	Wu, Y. [**31**]	cp	x			Energy prices are among the parameters to consider for the building energy management to be effective and efficient	2
2010	Parfomak, P.W. [**32**]	bc	x			Policies need to address the energy price risks: uncertainty about future energy prices hinders the assumption of investment decisions about building efficiency	0
2010	Zwettler, G. [**33**]	cp	x			Energy costs are among the parameter considered in an optimization software meant to assist the design of energy efficient buildings	2
2011	Jeong, J. [**34**]	ja	x			Heating energy usage patterns in the light of the substitute/complementary relationship between gas and electricity and according to energy price and household characteristics	13
2011	Ouyang, J. [**14**]	ja	x	x	x	Life cycle cost analysis on the upgrade of aging residential buildings in China, it is shown that growing energy prices and subsidies do not lead to a satisfactory economic viability	19
2011	Parfomak, P.W. [**35**]	bc	x			[see above the item 2010, Parfomak, P.W.]	0
2012	Haney, A.B. [**36**]	bc	x			International comparisons of demand-side management strategies and policies to improve energy efficiency, and their relationships with energy prices	6
2012	Zhao, X. [**37**]	ja	x			Decomposition of China's residential energy use, showing that consumptions are shifting towards a more energy-intensive model and price reforms contribute to energy savings	83

(1) ja: journal article; cp: conference paper; bc: book chapter.

Table 2. Summary of the results (second part).

Year	First author and reference	Venue (1)	Economic parameter: Energy price	Inflation rate	Discount rate	Topic	Citations
2012	Kumbaroglu, G. [**38**]	ja	x		x	Case study of building retrofit addressing uncertainty in energy prices through Monte Carlo simulation, showing that their changes significantly affect the profitability of the investments	66
2013	Cajias, M. [**39**]	ja	x			Financial performance of German housing: energy efficiency affects tenant decisions (0.76 Eur/m2 higher rent) and the performance of investor portfolios (up to 3.15% higher return)	30
2013	Cox, M. [**40**]	ja			x	Revision of the projected investments in energy-efficient equipment and related energy consumptions in the US according to different levels of the discount rate	16
2013	Egging, R. [**41**]	ja	x			Discussion on the drivers and uncertainties in the recent and future energy market trends, especially as far as energy prices are concerned	6
2014	Wu, W. [**42**]	ja	x			Techno-economic analysis of a combined heat supply system, linking heating period, energy price, and payback period	11
2014	Deng, Q. [**43**]	ja	x			Analysis and discussion of a simulation-based decision model to design contract period in the field of Energy Performance Contracting	17
2014	Yan, X. [**44**]	ja	x		x	Techno-economic analysis of energy storage systems: the sensitivity analysis reveals that the discount rate has the largest influence on the viability of the analyzed systems	20
2014	Qian, D. [**45**]	ja	x		x	Development of a revenue-sharing bargaining model within Energy Performance Contracting and analysis of the impacts of energy prices and risk-adjusted discount rates	16
2014	Bonakdar, F. [**46**]	ja		x	x	Analysis of the cost-optimum level of renovation in a multi-story residential building according to different discount rates and energy prices	19
2014	Adika, C.O. [**47**]	ja	x			Approach to the development of an automated appliance scheduling system for household energy management including expected energy prices	81
2015	Guo, L. [**48**]	cp	x			Optimization methodology to minimize the energy cost under energy price uncertainty: random price changes with a known underlying distribution	2
2015	Wu, L. [**49**]	ja			x	Environmental, economic analysis of a water supply facility incorporating climate externalities: a higher discount rate counteracts the effectiveness of the carbon cost factor	8
2015	Lin, B. [**50**]	ja	x			Analysis of building energy consumptions and building energy efficiency in light of urbanization process and energy price trends	32
2015	Deng, Q. [**51**]	ja	x	x	x	Energy cost savings model, meant to improve Energy Performance Contracting, which accounts for energy price fluctuation using Monte Carlo simulation	14
2015	Deng, Q. [**52**]	ja	x			Simulation-based model to maximize the facility owner's profit and satisfy the ESCo's expected rate of return	7

(1) ja: journal article; cp: conference paper; bc: book chapter.

Table 3. Summary of the results (third part).

Year	First author	Venue (1)	Economic parameter: Energy price	Economic parameter: Inflation rate	Economic parameter: Discount rate	Topic	Citations
2015	Lin, B. [**53**]	ja	x			Analysis of the substitution relationship between each input factor including energy in China's food industry, showing that a direct rebound effect partially offsets energy savings	4
2016	Lin, B. [**54**]	ja	x			Analysis of energy rebound effect in China's light industry considering the effects of energy prices on energy consumptions	11
2016	Roshchanka, V. [**55**]	ja	x			Feedbacks about the use of Energy Performance Contracts and the development of the ESCos' business model in the Russian Federation	4
2016	Liu, X. [**56**]	ja			x	Model meant to determine the optimal value of the discount rate that enables to take emissions under controls in building procurement contracts	0
2016	Ameer, B. [**57**]	ja	x		x	Impact of heavily subsidized energy prices for the residential building sector in Kuwait: need to increase the electricity price to improve energy savings and efficiency in building	8
2016	Good, N. [**58**]	ja	x			Techno-economic framework for the assessment of business cases of low carbon technologies, with a focus on multiple energy systems and vectors	19
2016	Krarti, M. [**59**]	ja	x		x	Analysis of the cost-effectiveness potential of net-zero energy residential buildings in the Middle East and North Africa region, which is found to strongly depends on energy prices	11
2016	Brandão de Vasconcelos, A. [**60**]	ja			x	Cost-optimal analysis of several refurbishment scenarios accounting for different discount rate using sensitivity analysis	3
2016	Liu, H. [**61**]	ja	x			Analysis of the impacts of technological advancement on energy consumption in China's building industry in light of the direct rebound effect	6
2016	He, L. [**62**]	ja	x			Analysis to test the hypothesis that the relative energy price and not the absolute one is the most important to explain energy consumptions	1
2017	Miezis, M. [**63**]	cp	x			Algorithm for model predictive control (MPC) in multi-family buildings, including energy prices as constraints, with application to a case study in Latvia	3
2017	Copiello, S. [**1**]	ja	x			Review of the paradoxes affecting the research topics focusing on building energy efficiency, one of which relates to the relationship between investments and energy prices	14
2017	Khabdullin, A. [**64**]	cp	x			Analysis of the possible use of electricity as a source for district heating systems considering electricity price in comparison with heat energy price	0
2017	Krarti, M. [**65**]	ja	x		x	Evaluation of economic and environmental impacts of energy efficiency programs for new and existing buildings in Saudi Arabia under conditions of highly subsidized energy prices	1
2017	Weeber, M. [**66**]	cp	x			Overview and discussion of opportunities, risks, and trends associated with the topic of energy flexibility in a context of fluctuating energy prices	0
2017	Simona, P.L. [**67**]	cp	x			Study on increasing energy efficiency in collective residential buildings by acting on their thermal insulation	0

(1) ja: journal article; cp: conference paper; bc: book chapter.

Table 4. Summary of the results (fourth part).

Year	First author	Venue (1)	Economic parameter: Energy price	Inflation rate	Discount rate	Topic	Citations
2017	Di Giuseppe, E. [**68**]	cp		x	x	Characterization of the stochastic inputs of a probabilistic Life Cycle Cost Analysis: inflation and discount rate are among the most influential parameters	0
2017	Dodoo, A. [**69**]	ja		x	x	Renovation of a multi-story residential building: real discount rate and energy price increase have a significant impact on the cost-effectiveness and profitability of the measures	2
2017	Copiello, S. [**5**]	ja	x	x	x	Life-Cycle Cost and Monte Carlo simulation: the discount rate is a prominent source of uncertainty and affects the results four times as much as the energy price	2
2017	Das, P. [**70**]	ja		x	x	Case-study retrofitting of Swedish attics: increments in energy costs and discount rates can impact the optimal design option	0
2017	Cui, T. [**71**]	ja	x			Co-scheduling problem of Heating, Ventilation and Air Conditioning (HVAC) and Hybrid Electrical Energy Storage (HEES) systems under dynamic energy prices	0
2017	Copiello, S. [**4**]	ja	x			Analysis of building energy consumption: the role played by both energy price and household income is worth attention with respect to the direct rebound effect	0
2017	Li, M.-J. [**72**]	ja	x			Cointegration analysis of the relationship between energy consumption and its underlying explanations including energy price, economic development, and industrial structure	0
2017	Balin, A. [**73**]	ja	x			Fuzzy multi-criteria decision making (MCDM) method to determine the best renewable energy alternatives for Turkey	4
2017	Zhang, Y. [**74**]	ja	x		x	Design of an integrated system including thermal energy storage and building cooling, heating and power: its operation strategy highly depends on natural gas and electricity prices	1
2017	Lei, Y. [**75**]	cp	x			Assessment of three residential space heating options: ground source heat pump, air source heat pump, and wall-hung gas boiler	0
2018	Dodoo, A. [**76**]	ja		x	x	Cost-effectiveness of the energy renovation measures for a district heated building: the economic viability is sensitive to discount rates and energy price increase	0
2018	Agliardi, E. [**77**]	ja	x	x	x	Techno-economic evaluation method for deep renovation of buildings based on the real option theory, modeling energy price uncertainty through a mean-reverting stochastic process	0
2018	Liu, Y. [**78**]	ja	x	x	x	Case study of cost-benefit analysis for energy retrofit of existing buildings: energy price is found to be the most sensitive factor	1

(1) ja: journal article; cp: conference paper; bc: book chapter.

The topics vary in a well-defined range. Several papers directly tackle problems related to energy prices and energy supply costs. Earlier publications mostly address issues pertaining to energy policies and energy-related incentive programs [**27,29,32,35-37**], while recent documents, especially during the last decade, are more prone to focus their attention on case studies, providing techno-economic analyses of investments in specific energy efficiency measures and solutions [**14,38,42,44,46,58,60,67,69,70,75-78**]. As far as those investments are concerned, the issue of uncertainty is addressed [**5,41,48,68**], and decision support systems are proposed [**43,52,73**]. The relationship between the discount rate and the environmental aspects, notably greenhouse gas emissions, represents a kind of niche topic among the analyzed studies [**49,56**].

Building on a corpus of text data, namely the titles and abstracts of the examined publications, a co-occurrence analysis of terms has been performed using the software *VOSviewer* [**79,80**]. Recurring terms have been analyzed according to a binary counting method; namely, only their presence does matter, while the overall number of their occurrences is not considered. The minimum number of occurrences has been set to five, finding 69 terms that meet the threshold. The resulting network representation (**Fig. 3**) considers the 60% most relevant items, hence 41 terms.

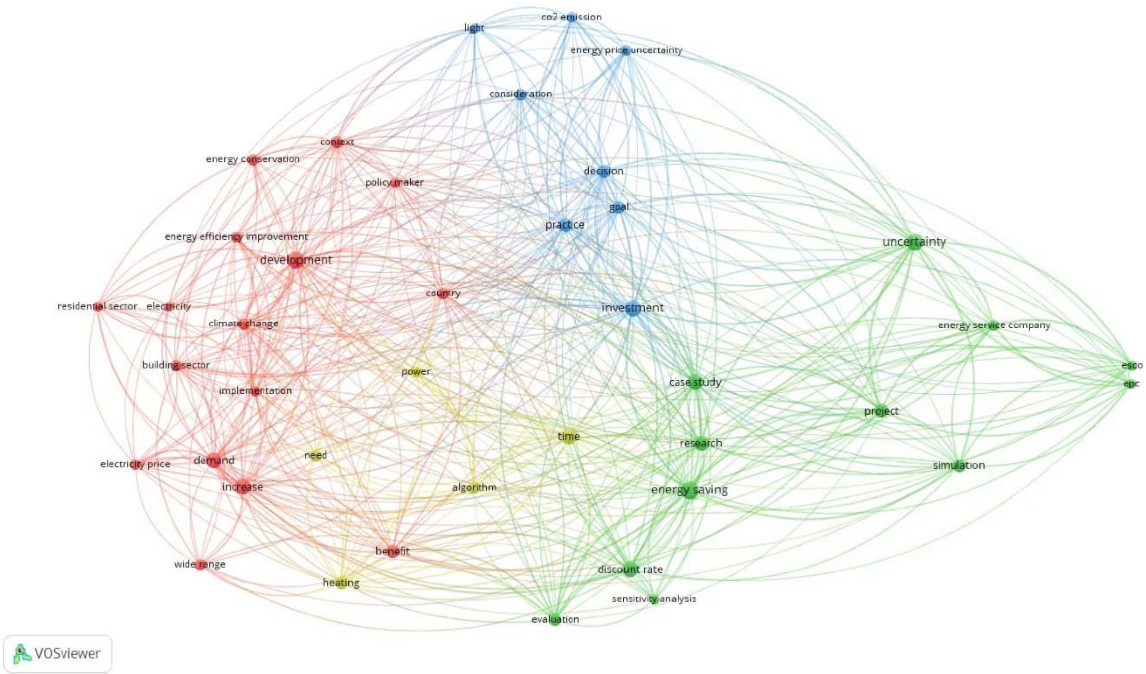


Fig. 3. Network representation of the co-occurrence analysis of terms.

Recognizing at least three significant fuzzy clusters of recurrent terms or expressions is possible. The first one (red dots in **Fig. 3**) is arranged around the terms "development" (15 occurrences), "demand", and "increase" (12 occurrences each). It is worthwhile to notice that the same cluster includes several other relevant terms, which contribute to define its shape and boundaries. The focus is mainly on "energy efficiency improvement" and "energy conservation" (six and seven occurrences, respectively), in buildings and specifically in the "residential sector", with a remarkable interest in "electricity" as an energy source and its price. The environmental concerns are subsumed under to topic of "climate change". The second cluster (blue dots in **Fig. 3**) features a core set made of few, interconnected terms or expressions. The main term is "investment" (14 occurrences), which is also near to terms such as "goal" and "decision". Finally, the most representative terms and expressions of the third cluster (green dots in **Fig. 3**) are "energy saving" (16 occurrences) and "uncertainty" (13). The first item is near to "case study" analyses, wherein the "discount rate" parameter (12 occurrences) is significant. The second item recalls other terms fitting the cluster, such as "evaluation", "sensitivity analysis", and "simulation". Within the cluster, a kind of subset refers to the "energy service company", often identified with the acronym "esco", under the framework of "epc" which stands for energy performance contracting.

Turning to the data sources, as well as to the estimates and the assumptions about the economic parameters, a summary of empirical evidence is reported in **Table 5**. Concerning the historical series of energy prices and their change rates, commonly used data source are IEA (International Energy Agency) and EIA (Energy Information Administration).

Table 5. Summary of the results: sources, data, and assumptions.

Year	First author and reference	Sources	Data and assumptions
2011	Ouyang, J. [**14**]	Central Bank; National Bureau of Statistics; Government data	Inflation rate: 3%; Increase rate of electricity price: 2%; Discount rate: 6%
2012	Kumbaroglu, G. [**38**]	Historical time series (1999–2010) of real energy prices and price change rates	Discount rate: 4.22% (estimates within the range 2.17-7.87%)
2013	Cajias, M. [**39**]	German Investment Property Databank; Federal Statistical Office	
2013	Cox, M. [**40**]	Energy Information Administration	
2013	Egging, R. [**41**]	Eurostat; Int. Energy Agency; Energy Inf. Administration	
2014	Deng, Q. [**43**]	US Department of Energy; Energy Information Administration	
2014	Yan, X. [**44**]	Central Bank; Government data; other literature	Discount rate: 9%
2014	Qian, D. [**45**]	Yearbooks; other literature	
2014	Bonakdar, F. [**46**]	National Energy Agency; other literature	Energy price increase: 2%; Discount rate: 1%, 3%, 5%
2015	Wu, L. [**49**]	Government data	Discount rate: 6%
2015	Lin, B. [**50**]	National Bureau of Statistics	
2015	Deng, Q. [**51**]	Government data; other agencies	Energy price: $26.03/MMBTU; Discount rate (Expected return): 10%
2015	Deng, Q. [**52**]	US Department of Energy	
2015	Lin, B. [**53**]	Yearbooks	
2016	Lin, B. [**54**]	Yearbooks	
2016	Roshchanka, V. [**55**]	International Energy Agency; Government data	Energy price: $0.087 per kWh (residential consumers)
2016	Ameer, B. [**57**]	Government data; other literature	Energy price: $0.007/kWh (residential consumers); Discount rate: 5%
2016	Krarti, M. [**59**]	Other literature	Energy prices: 0.094 $/kWh and 0.162 $/m3; Discount rate: 5%
2016	Brandão de Vasconcelos, A. [**60**]	Government data; other literature	Discount rate: 3% (2-4% and 6%), 6% (5-7% and 10%)
2016	Liu, H. [**61**]	Yearbooks	
2017	Krarti, M. [**65**]		Energy price: $0.05/kWh (residential customer); Discount rate: 3%
2017	Di Giuseppe, E. [**68**]	Central Bank; Energy Inf. Administration; US Dept. of Energy	Inflation rate: 1.9%; Interest rate: 4.09%
2017	Dodoo, A. [**69**]		Energy price increase: 1%, 2%, 3%; Discount rate: 1%, 3%, 5%
2017	Copiello, S. [**5**]	Other literature	Energy price 0.05-0.146€/kWh; Infl.: 0-4.5%; Discount rate: 0-15%
2017	Zhang, Y. [**74**]	Central Bank; other literature	Discount rate: 10%
2018	Dodoo, A. [**76**]	Other literature	Energy price increase: 1%, 2%, 3%; Discount rate: 1%, 3%, 5%
2018	Agliardi, E. [**77**]	Company data; other literature	Energy price: 0,95€/m3; 0,18€/kWh; Inf: 8%; Interest rate: 3%
2018	Liu, Y. [**78**]		Energy price increase: 5%, 10%, 15%, 20%

The other economic parameters are often estimated according to information conveyed by the National Institutes of Statistics, Central Banks, and Governments. Sometimes, the estimates are integrated with data gathered from specialized publications, such as various kind of yearbooks, or the previous literature. As regards the discount rate parameter, levels of 3%, 5%, and 6% are common among the examined studies. However, it should be stressed that the values above do not usually stem from the use of estimation methods such as the Capital Asset Pricing Model

(CAPM) or the Weighted Average Cost of Capital (WACC) [**81**]. On the contrary, they are most of all assumptions based on plausible ranges according to the pertinent literature.

4. Overview of the well-established research strands

Building on the bibliographic search above, there arise at least two significant research strands: the relationship between energy prices and the profitability of efficiency-related investments is the former, the pivotal role played by the discount rate when evaluating the investments in energy-efficient measures is the latter.

As far as energy prices are concerned, the reviewed literature points that more attention should be paid to the following relationship: the lower the energy prices, the lower are the incentives to invest in energy efficiency [**14,59,62,65,78**]. That is a significant issue since energy prices are often lower than energy production costs, primarily due to government subsidies [**27,30,37,50,57,61**]. Besides, failing to address the uncertainty that is inherent in future energy prices [**41,43,48,51,52**] negatively affects efficiency-related investments [**32,35,38**].

A related issue may be described as follows. Energy efficiency investments are expected to reduce effective energy prices. Cheaper energy sources - in relative terms, at least - lead to the substitution of input factors not only in production processes and, ultimately, are likely to incentivize companies and households to adopt more energy-intensive behavior [**53,54,61**]. Therefore, the same energy efficiency investments are expected to disincentivize further subsequent improvements [**1**]. Accordingly, the literature highlights the importance of delving into the substitute/complementary relationship between different energy sources [**34,74**], the price elasticity of the demand for energy [**4**], and the demand-side management strategies and policies to improve energy efficiency [**36**].

With respect to the second research strand, the prominence of the discount rate in energy efficiency-related evaluations is recognized by several authors, as it strongly affects the projected investments in energy-efficient equipment and related energy consumptions [**40**], the viability of the energy efficiency measures to be adopted [**5,44,68-70,76**], as well as the present value of the carbon cost factor used to account for climate externalities [**49,56**]. Some authors draw explicitly the conclusion that investment in energy efficiency solutions and low discount rates go hand in hand [**60**].

5. Conclusions

The corpus of literature on building energy efficiency is steadily growing starting from, at least, the oil shocks of the seventies. Accordingly, the need for a systematization of knowledge is perceived to have increased in recent years. Under the above framework, this study performs a literature review adopting a specific focus. The central question it tries to answer is as follows: how the research on building energy efficiency deal with three economic parameters, namely, the energy price, the energy inflation rate, and the discount rate. A total of 65 publications have been analyzed with regard to the issues they address, the commonly used data sources, the estimates and assumptions. As far as the topics are concerned, a representation of the primary items, their clusters, and the network relationships stems from a co-occurrence analysis of terms. Moreover, two well-established research strands have been identified. The first concerns the energy price parameter and its relationships with the willingness to adopt energy efficiency solutions. The second refers to the role played by the discount rate parameter, which is likely to strongly affect the economic viability of the investments in efficiency-related measures and solutions.

It is worthwhile to stress some limitations of this study, which pave the way to further developments. In particular, the number of analyzed documents is somewhat limited by some choices that drive the literature search. On the one hand, the data source is the abstracting and indexing Scopus, while other similar services are not considered. On the other hand, the search keys concerning the three economic parameters - namely, energy price, inflation rate, and discount rate - are searched only in the titles and abstracts, not in the full text. Although there are appropriate reasons for those choices, as discussed in the previous section 2, they are also likely to shorten the list of results. Therefore, the literature review presented here lends itself to be expanded, which is expected to strengthen further the empirical findings discussed so far.

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