Exploring transaction costs in passive house-oriented retrofitting

Kiss, Bernadett; Mundaca, Luis

Published in:
Sustainable Energy Policy and Strategies for Europe

2014

Paper presented at the 14th International Association for Energy Economics (IAEE) European Conference. Italian Association of Energy Economics, Rome, Italy, October 28-31, 2014

Exploring transaction costs in passive house-oriented retrofitting

Bernadett Kiss* & Luis Mundaca

International Institute for Industrial Environmental Economics at Lund University
P.O. 196, SE-221 00 Lund, Sweden

Abstract

In order to tap the energy saving and climate mitigation potential of the building sector, transaction costs of implementing energy efficient technologies need to be better understood and ultimately reduced. The objective of this paper is to identify and analyze the nature and scale of transaction costs resulting from the application of the passive house concept in energy efficient renovations. Related conceptual choices are also discussed. Our study explores measures to promote learning and knowledge development as potential strategies to reduce transaction costs. It focuses on transaction costs borne by building owners and building developers in the planning and implementation phases of a passive house-oriented renovation in Sweden. Results reveal three main sources of transaction costs: due diligence, negotiations and monitoring. The analysis shows that transaction costs are non-negligible, and for individual cost sources the scale can be 200% higher than for conventional renovations. To reduce transaction costs, various strategies such as study visits, demonstration projects, new forms of meetings and new channels of (written) information were found.

Key words: Transaction costs, Energy efficiency, Passive house

* Corresponding author: Tel.: +46 46 222 02 27; Fax: +46 46 2220240. E-mail address: bernadett.kiss@iiiee.lu.se

1. Introduction

The building sector in Europe accounts for approximately 40% of the total energy use and 36% of all energy-related CO_2-emissions (BPIE, 2011). In order to meet the ambitious EU "20-20-20" target by 2020, energy efficiency in buildings needs to be improved[1]. A major part of the European building stock was built when building energy performance requirements were scarce (BPIE, 2011), thus the need for energy efficient renovation in existing buildings is vast. Numerous building retrofit projects have demonstrated that energy efficiency improvements are not only technically feasible and socially favoured, but also provide cost-effective reductions of primary energy and greenhouse gas emissions (Ürge-Vorsatz, Harvey, Mirasgedis, & Levine, 2007; Ürge-Vorsatz, Koeppel, & Mirasgedis, 2007). The potential energy savings for heating in high performance retrofitting, for example by applying the passive house concept[2], is as high as 70-92% (Ürge-Vorsatz et al., 2012). Despite many good examples, energy efficient retrofitting is still not a common practice due to a number of barriers[3].

Recent studies have shown that high investment costs and unforeseen transaction costs are two of the main barriers to energy efficiency in buildings (Levine et al., 2007; WBCSD, 2009; Ürge-Vorsatz et al., 2012). Initial investment costs of energy efficient buildings can be 4-16% higher than for conventional buildings (Audenaert, De Cleyn, & Vankerckhove, 2008) and transaction costs have been estimated to be as high as 20% of the investment cost (Ürge-Vorsatz et al., 2012). In all, the high upfront investment costs and transaction costs hinder the implementation of energy efficient technologies in the building sector and prevent real estate developers from entering the energy efficiency market (Lee & Yik, 2002).

The passive house concept is a standard for state-of-the-art energy efficient buildings. Since 1990, the introduction of the first passive house in Kranichstein (Darmstadt, Germany), the number of passive houses has dramatically increased, and at the end of 2012 the estimated number of passive buildings worldwide reached up to 40 000 (IPHA, 2012). The additional investment cost of newly built passive houses has been in the range of 0-17% of the total construction costs (Audenaert et al., 2008; Hermelink & Hübner, 2003; Jürgen Schnieders & Hermelink, 2006). Nevertheless, literature on the passive house experience shows that the high investment costs of energy efficient buildings can be reduced over time. Since the 1990s, the additional costs to meet the Passive House standard for new buildings have been reduced by a factor of 5-7. This is due to the increased availability of passive house technologies, such as improved insulation, energy efficient windows and highly efficient ventilation systems and due to accumulated experience in passive building methods (Feist, 2006; Harvey, 2009). In Germany, Austria and Switzerland, with a high number of passive houses, the average additional cost of building a passive house went down to 5-8% of the conventional construction cost (Passive-On, 2007; PHI, 2012; Ürge-Vorsatz et al., 2012). In Sweden, the additional investment cost of low-energy buildings (of passive house standard) is estimated to be less than 10% of conventional building costs (Blomsterberg, 2009).

In recent years, the passive house concept has also been applied to the retrofit of existing buildings. An example from Germany shows that the cost of multi-family dwelling retrofits according to the

[1] The "20-20-20" initiative is based on the energy goals of the EU, adopted by the Council in 2007. These goals aim to reduce GHG emissions by 20%, increase the share of renewable energy to 20% and improving energy efficiency by 20%(BPIE, 2011).

[2] The passive house concept is based on greatly improved thermal performance of the building envelope (high insulation and air tightness levels) coupled with a mechanical ventilation system with efficient heat recovery. As heat energy is needed only occasionally, the heating system can be kept very simple, e.g. electric heating or a heat pump (see e.g. Feist, Schneiders, Dorer, & Haas, 2005; Hastings, 2004; J. Schnieders, 2003; Jürgen Schnieders & Hermelink, 2006).

[3] Barriers to energy efficiency in the building sector include, for example, imperfect information, lack of knowledge and barriers more specifically related to the introduction and development of (new) energy efficient technologies such as cumbersome (regulatory, administrative and planning) processes, uncertainty and risk, limited access to technologies, split incentives, high upfront investment costs, limited access to capital, lack of monitoring and transaction costs (CarbonTrust, 2005; Levine et al., 2007). Some of these barriers can be defined as market failures (Levine et al., 2007; Sutherland, 1991). Market failures are flaws of market operation in opposition to theoretically perfect markets of neoclassical economics. Direct market failures are flaws hindering cost-effective measures. Market failures have been the focus of an academic debate since the 1980s. The main issues are a) what are direct market failures and b) to what extent shall these be addressed by policy instruments. In the past decade, the debate has been extended, including aspects such as the introduction and the development of new technologies.

passive house standard (with >90% energy savings) can be 27% higher than conventional renovations (HausderZukunft, 2007). Other studies show that additional costs of energy-related renovation can add up to 35-50% of the total retrofitting costs (Enseling & Hinz, 2009; IBB, 2010). In the first passive house-oriented retrofit project in Sweden (Brogården), approximately 30% of the total retrofit costs were energy-related (Hellberg, 2012). To the author´s knowledge, no studies have been devoted so far to analyse transaction costs related to renovations based on the passive house concept. The knowledge gap is very explicit when reviewing the literature on transaction costs associated to energy efficiency technologies (details in Section 2). In order to find the most feasible approaches to reduce transaction costs of energy efficient renovations in the future, transaction costs must be better understood.

This study aims to identify the nature (origin) and scale (order of magnitude) of transaction costs in passive house-oriented retrofit projects. Further, it aims to explore the potential for reducing these transaction costs by identifying approaches promoting learning and knowledge development. Such approaches include actors´ strategies, i.e. leadership, procurement, training and meeting platforms, demonstration practices, community meetings, educative seminars and newsletters. These approaches are also of interest in terms of designing and supporting future policies related to the passive house technologies.

In order to explore transaction costs and provide empirically contextualized evidence for the origin and the scale of transaction costs, case study methodology was applied to Brogården, the first passive house-oriented retrofit project in Alingsås (Sweden). The case was explored based on a review of the literature describing the case and 14 semi-structured deep interviews with actors involved in the renovation project. The focus of the interviews was on the presence, nature, scale[4] and attribution of transaction costs in the different phases of the renovation process. In this study, special attention is given to the building owner and building developer in the planning and implementation phases. The Brogården case was chosen because it is the first passive house-oriented renovation in Sweden and the experience yielded by this case study is applicable to an additional 350 000 similarly constructed apartments in many Swedish cities, representing almost 8% of existing apartments (Berggren, Janson, & Sundqvist, 2009; SCB, 2010).

The outline of this paper is as follows: Section 2 provides the key analytical components for the study at hand, namely a review of transaction costs in the energy field and overview of the case study. Section 3 provides the results of the research, highlighting the nature and scale of transactions costs. Section 4 discusses the identified approaches promoting learning and knowledge development for energy efficient retrofitting as potential strategies to reduce transaction costs. Conclusions are drawn in Section 5.

2. Analytical framework

2.1. Transaction costs

The concept of transaction costs originates from Coase (1937) and has been further developed in the framework of New Institutional Economics (NIE) (Williamson, 1993, 1996)[5]. Transaction cost analysis is a fundamental element of NIE. It assesses activities in the economic system, such as how they are organized and carried out, and what effects they have on the performance of the projects and/or the actors involved through transactions with involved market actors (Commons, 1931). These transactions are often based on imperfect information, bounded rationality and lack of monitoring (Douglass, 1990; Ménard, 2004; Selten, 1990). Transaction costs are related to financial operations, they are costs not directly involved in the production of goods or services, but unavoidable and often unforeseeable costs emerging from contracting activities essential for the trade of such goods and

[4] The scale of transaction costs are estimates reflected in additional resources, such as time (hours) and/or money (SEK), which are put into the project due to passive house renovation and thus surrounded by high uncertainty.
[5] NIE incorporates the theory of institutions into economics with the purpose of explaining institutions, including their evolution, performance and impact over time. (Institutions, in this case, are defined by (North, 1990, pp. 3–4).

services (Coase, 1960). In the field of technology change, transaction costs are often referred to as unmeasured costs that prevent the adoption of new technologies. In this context, transaction costs are also understood as costs occurring ex-ante to the arrangement and implementation of technologies and ex-post to their monitoring and enforcement (Matthews, 1986). Regarding the specific case of energy efficiency, imperfect information may hinder market actors´ purchase or installation of energy efficient technologies, and thus can decrease the financial gains from improved energy efficiency (Sanstad & Howarth, 1994; Sioshansi, 1991).

Transaction costs have been analyzed in the field of energy efficiency and have mostly been characterized by their origin (nature) and order of magnitude (scale). Transaction costs of energy efficient technologies originate throughout the life-cycle of projects. Transaction costs can be categorized as costs of a) due diligence (search for and assessment of information), b) negotiation, c) approval and certification, d) monitoring and verification and e) trading (Mundaca, Mansoz, Neij, & Timilsina, 2013). Transaction costs associated with the implementation of energy efficiency projects typically arise as a result of searching for and assessing information, project preparation, finding partners, contracting, persuading, negotiating and coordinating with partners, decision-making, implementing and following-up investment actions, for example, through maintenance or validating data. For more information on transaction costs on searching for and assessing information see Björkqvist and Wene (1993), Hein and Blok (1995), Mundaca and Neij (2007), Sanstad and Howarth (1994), Sathaye and Murtishaw (2004), Sioshansi (1991), for project preparation, see Bleyl-Androschin, Seefeldt and Eikmeier (2009), for finding partners, contracting, and persuading, see Mundaca (2007), for negotiating with and coordinating partners, see Bleyl-Androschin, et al. (2009), Mundaca (2007), Ostertag (1999), for decision-making, see see Björkqvist and Wene (1993), Hein and Blok (1995), for implementing and following-up investment actions, see Bleyl-Androschin, et al. (2009), Hein and Blok (1995), Mundaca (2007), Qian, Chan and Choy (2013), Sathaye and Murtishaw (2004), for maintenance, see Ostertag (1999) and for validating data, see Mundaca (2007). The research focus of transaction costs, according to existing literature, has been mostly on industry, i.e. energy intensive or energy companies involved in energy saving programmes (Hein & Blok, 1995; Joskow & Marron, 1992; Mundaca & Neij, 2006; Ostertag, 1999). Studies focused on the residential sector include energy companies implementing energy efficiency measures in households (Bleyl-Androschin et al., 2009; Mundaca & Neij, 2007; Mundaca, 2007) or end-users investing in energy efficient household appliances (Björkqvist & Wene, 1993; Sathaye & Murtishaw, 2004). Only a few studies identify the order of magnitude of transaction costs (see e.g. Björkqvist & Wene, 1993; Bleyl-Androschin et al., 2009; Mundaca, 2007).

Regarding the scale of transaction costs, several studies have attempted to provide empirical estimates for the building sector. The scale of transaction costs is most often expressed in proportion (%) to the total (investment) cost, but sometimes in monetary terms (e.g. SEK) or in work load (e.g. time, hours) (Björkqvist & Wene, 1993). For instance, transaction costs for lighting technologies are estimated to be 10%, for improved cavity wall insulation 30%, and for energy efficiency measures carried out by ESCOs in the residential sector in the range of 20%-40% (EastonConsulting, 1999; Mundaca, 2007). In Sweden, transaction costs related to energy efficiency in the building sector have been estimated to be 20% of the total investment costs (Ürge-Vorsatz et al., 2012). Estimates of transaction costs are subject to uncertainty due to the performance of the technology, accountability, reliability and accuracy of data sources and the methods of monitoring and quantifying transaction costs (Mundaca et al., 2013).

In this study, transaction costs associated with application of the passive house concept were assessed in relation to the life-cycle of the building project, including the planning, implementation, operation and follow-up phases. Transaction costs considered were those identified in earlier studies described above. Transaction costs have also been attributed to relevant actors.

2.2. Case Study: Brogården passive house renovation

Brogården is the first passive house renovation project in Sweden. The 16 building blocks include 300 apartments (19 500 m^2) and were built in 1971-73 in Alingsås, a city of 40 000 inhabitants located in the western part of Sweden. Brogården is one of the districts of the "One million programme" in Sweden; one million apartments were constructed during 1965-1975 to meet a high demand for housing.

The renovation of Brogården is being implemented in six stages over six years (2008-2014), each stage having a life-cycle of three phases: a) planning, b) implementation and c) operation and follow-up. The first stage (two buildings) serves as a demonstration for the rest of the stages. Each stage includes two to five buildings; the stages are typically overlapping.

The planning phase of the Brogården renovation project included feasibility studies and conceptual design, based on which project requirements, targets and technical suggestions were formulated and tendered[6]. The planning phase, in a broad sense, lasted for six years, counting from the first time Alingsåshem started to plan the renovation of Brogården. In a strict sense, the actual planning took a year and a half (2005-2007), from the pre-study to procurement. The procurement lasted approximately for half a year (2006-2007). The activities and results originating from the planning phase are essential as they greatly influence the life-cycle of the entire renovation project in all six stages.

The implementation phase covers activities related to construction and installation, led by the building developer, for instance detailed planning of the building process (e.g. costs, schedules, testing), subcontracting, carrying out the construction and commissioning the building. The detailed planning included additional activities not needed in a conventional renovation project, for instance, the procurement of subcontractors under the partnering collaboration and searching for technical solutions for the passive house concept. The timeline of the implementation phase of the entire renovation project is 2008 – 2014; the timeline of the demonstration project (18 demonstration apartments in two staircases of a three-storey-building) was one year.

The operation phase includes operation and maintenance routines of passive houses and monitoring and verifying the implementation of the passive house concept. Monitoring and follow-up are additional activities related to passive house-oriented renovation on top of conventional renovation processes and thus costs arising in this phase are additional costs of the project. In Brogården, monitoring has been split among many actors and being a development project, it is often financed by R&D. For instance, technical requirements such as thermal comfort, ventilation and indoor environment are verified with measurements after each renovation stage. In addition, the indoor environment is checked through tenant questionnaires.

The total cost of the renovation, including investment, maintenance and rent shortfall is approximately SEK 380 million. On average, the total cost of renovation is SEK 1.28 million per apartment, out of which SEK 0.36 million (28%) is for energy improvements[7], 0.6 million (47%) for extension and accessibility, 0.24 million (19%) for maintenance, and 0.08 million (6%) for rent shortfall. These cost items do not include transaction costs identified in this study.

Due to the passive house nature of the project, the renovation is carried by partnering, whereby the building owner, the building developer and some subcontractors closely collaborate during the renovation process. Partnering, as described by the literature and re-enforced by the interviewees, is characterized by a common long-term and holistic perspective of participating actors, a framework

[6] The procurement process, in general, includes the preparation of tender calls, assessment and approval of the applications and preparation of the contracts.

[7] It is around EUR 154 000 for the total renovation cost and approximately EUR 43 000 for the energy improvements. 1 SEK=0.12056 EUR (www.oanda.com, 14 March 2013)

contract[8], open books (open cost accounting) and continuous feed-back in terms of evaluation and improvements (Kadefors, 2011).

Alingsåshem *(the building owner)*, a municipally-owned housing company administers around 3 000 apartments in the municipality of Alingsås. Alingsåshem has extensive experience in renovations and a management committed to sustainability issues. Skanska Housing *(the building developer),* one of the largest construction companies in Sweden, was procured through tendering for the Brogården project. Skanska has substantial experience in building renovation and supports the passive house concept at top management levels. Out of eight *subcontractors* in the Brogården project, Alingsåshem and Skanska signed five-year partnering collaborations with four: Alingsås Rör (piping), Elteknik (electricity), Bravida (ventilation) and Sandå måleri (painting). In addition, *consultants* were contracted for architecture (efem, Hans Eek, Kerstin Nilsson), structural engineering (WSP), electricity (Picon), heating and ventilation systems (Andersson och Hultmark), monitoring and evaluation (Lund University, SP, Chalmers University). It was recognized early on that *tenant* involvement is essential to further improve the renovation process.

3. Transaction Costs of Brogården Passive House Renovation

Transaction costs of passive house renovation have been assessed through the case study of Brogården, Alingsås. The assessment includes the identification and categorization of the different sources of transaction costs. In comparison to conventional renovation projects, passive house renovations face higher investment costs and higher and additional transaction costs. These occur in all three phases of the renovation process (planning, implementation and operation) and at different actors´ stakes. In addition, the study shows that the scale of transaction costs varies greatly among renovation phases, among categories and among which actor the transaction costs are attributed to.

3.1. The nature of transaction costs

The identified transaction costs of any renovation, including passive house renovations, fall into three categories: due diligence, negotiation and monitoring. All were found in all phases of the life-cycle of the building project, including i) planning, ii) implementation, and iii) operation and follow-up, see Table 1. In this study, due diligence costs include the search for and the assessment of information on, for instance, the form of collaboration, partners, technically and economically feasible passive house solutions, and assessment methods. Negotiation costs arise in the procurement process, during preparation for procurement, contracting, assessment and approval. Monitoring costs include the follow-up on installed technologies, energy use and savings as well as related costs.

In comparison to conventional renovation projects, the transaction costs identified are higher due to the application of the passive house concept. In this paper, the transaction costs are attributed to the actors involved; this study focuses on the building owner and the building developer because most of the cost reduction is assumed to be achieved by these two actors.

[8] As an example of a long-term incentive, the framework contract, apart from the Brogården project, includes additional potential future construction projects.

Table 1 Conceptual categorization of the nature of transaction costs – based on Brogården passive house-oriented renovation

Nature of TCs/ Renovation phases	Due diligence	Negotiation	Monitoring and verification
Planning	Extended pre-study	Project formulation	
	Procurement of building developer: - search for the form of collaboration; preparation of the call; assessment of applications	Target setting	
		Procurement of building developer: - preparation for the call	
Implementation	Search for passive house technology solutions*		
	Procurement of subcontractors: - assessment of subcontractors*	Procurement of subcontractors: contracting*	
Operation & follow-up	Search for methods and practices of assessment and monitoring*	Contracting evaluators*	Monitoring (equipment, energy savings, costs)
	Assessment of methods and practices of assessment and monitoring*		Maintenance

** Transaction costs in addition to transaction costs of conventional renovations. The other transaction costs are present in conventional renovations, but are lower.*

3.1.1. Due diligence[9]

Transaction costs of due diligence, specific to passive houses and additional to conventional renovations, occur in all three phases of the renovation project. In the planning phase, transaction costs were identified in relation to the extended pre-study and the tendering procedure for the building developer, i.e. search for the form of collaboration, and preparing and assessing the applications. These transaction costs were borne by the building owner. In the implementation phase, transaction costs were identified in connection with searching for passive house technology solutions and the tendering procedure for the subcontractors, i.e. assessment and approval of subcontractors. These transaction costs are borne by both the building developer and the building owner. In the operation and follow-up phase, transaction costs were identified in relation to searching for and assessing methods and practices of monitoring and evaluation. These transaction costs are attributed to various actors involved in the monitoring process. The scale of transaction costs related to due diligence is estimated to be between 10% and 200% more than for conventional renovations.

Extended pre-study. Renovation processes often include pre-studies consisting of building status investigations and drawings to guide the implementation of the construction, but rarely concrete technical solutions as in the Brogården project. In Brogården, the investigation of the building itself was more extensive than it is in a conventional project; it included the status of insulation, airtightness of the building envelope, moisture content of building materials and indoor acoustics. The investigation was carried out by the SP Technical Research Institute of Sweden where two people worked on it over a one month period (Janson, 2010). The pre-study was carried out by efem Architect Agency and took one full-time person-year, which is estimated to be 50% more (in

[9] Due diligence, here, refers to the investigation of information, including the search for and the assessment of the acquired information.

monetary terms roughly 300-400 000 SEK more[10]) compared to a traditional renovation project. Both the extended investigation and in particular the detailed pre-study including technical solutions extended the planning phase and was as an additional cost for Alingsåshem[11].

Search for the form of collaboration. In Brogården, the procurement process took longer, than in a traditional renovation project due to the decision-making process - partly about the form of collaboration and partly on the extent of the contract. Although, the idea of partnering was discussed in the first planning meeting (2005), in order to gain more experience Alingsåshem did an extensive literature review, organized study visits and experience sharing meetings during 2005 and 2006[12] before the final decision on the form of collaboration. In addition, the framework contract included potential future constructions. The actual time Alingsåshem spent searching for the form of the collaboration is estimated to be roughly two months, while the whole decision-making process stretched over a year.

Preparation of the call for a building developer. The preparation of the call took longer than in a conventional renovation process. This was due to the inclusion of the partnering contract assessment, which had been used in the Karlstad renovation project, and drafting the partnering framework contract. In addition, the Building Research Council funded consultants to develop qualities and requirements for passive house renovation, which were then also included in the procurement material. Alingsåshem contracted a consultant for the preparation of the procurement material and the call. The drafting took approximately two months.

Assessment of the building developers´ applications. The estimated length of the assessment and approval process is 25 hours (30%) more than in case of a traditional tender evaluation. It is not common practice to require detailed curricula and the applicants´ personal views, for instance, on sustainability and aesthetics in the call[13]. This process included a couple of meetings and interviews with around thirty professionals. The evaluation was carried out by a group of five people from Alingsåshem.

Assessment and approval of subcontractors. Most building developers have established networks of professionals to work with, thus procuring subcontractors, contracting consultants and getting them approved by the building owner were additional activities specific to this project[14]. Alingsåshem was involved in the final selection of the four subcontractors included in the partnering contract; the approval of the applications took approximately three person-hours.

Search for passive house technology solutions. Additional costs related to the application of new technologies are very common. In Brogården, additional transaction costs arose from two main sources: a) the search for energy efficient *products* and b) the search for *new solutions*, such as applying already existing energy efficient products in new context, i.e. in renovation instead of new buildings. These costs are mostly attributed to the building developer.

In terms of *products*, it was time-consuming to find energy efficient doors and roof hatches. Air-tightness combined with safety (peep-hole) and accessibility (door-bell)[15] features seemed to be a new combination of parameters for door producers. The required U-value of 0.6 W/m^{2}K was not available on the market; the installed entrance doors have now a U-value of 0.75 W/m^{2}K. Airtight and well-insulated hatches providing access to the roof, were also difficult to find on the market. The

[10] It is in the range of EUR 36 000 and 48 000. 1 SEK=0.12056 EUR (www.oanda.com, 14 March 2013)
[11] Alingsåshem applied and got funding from the Swedish Energy Agency, the funding covered "additional costs" in the project for the planning process, detailed design solutions, management of the project during the building process, additional support from experts and monitoring of the renovated building with measurements and experiences from the building process.
[12] Alingsåshem relied heavily on the experience of the Tuggelite project in Karlstad.
[13] These special requirements made both the assessment time and interview time longer. One interview was estimated to take an hour and a half, out of which roughly half an hour was dedicated to sustainability principles.
[14] See the details of procurement under negotiations.
[15] Peep-holes and door-bells decrease the air-tightness of doors.

search for these products took an estimated two to three week per product for the building developer (together with the respective subcontractors).

In terms of *new solutions*, the slab insulation, the wall construction and the ventilation system required additional resources from the building developer and the building owner. The decision to apply PIR (polyisocyanurate foam) insulation to the foundation led to a new research project aiming to show whether and how PIR can be applied in passive house renovations (Skanska, 2012). In terms of outer wall construction, Skanska developed and tested three models as well as educated craftsmen for special installation of the plastic layer. The development of the outer wall construction was estimated to take 10% more time for Skanska due to the additional requirements of passive construction. Designing the ventilation system was an additional resource input specific to passive house renovations, where the ventilation system replaces the traditional heating system. A central ventilation system was designed based on experience from the demonstration buildings. The development of a new ventilation solution for renovated passive houses was estimated to take two to three times longer than the application of an already designed ventilation solution in newly built passive houses.

Search for methods of assessment and monitoring. Monitoring is not necessarily part of conventional renovations; it is often an additional cost when implementing energy efficient technologies. Brogården is a development project, with many actors involved, and monitoring and transaction costs related to the search for monitoring and assessment methods are split among the actors. Some of the most time demanding searches were finding methods for a) calculating and monitoring project financing (attributed to Alingsåshem), b) monitoring energy use and energy savings (attributed to Alingsås Energi and Lund University) and c) developing the process for quality assurance (attributed to SP). These transaction costs are part of the ongoing development project, so no time estimate has yet been made for them.

3.1.2.Negotiations

Transaction costs of negotiations occur in all three phases of the renovation project. In the planning phase, transaction costs were identified in relation to project formulation and target setting. Both project formulation and target setting was a long and complex process including frequent and lengthy meetings and negotiations leading to a stretched decision-making processes; it is partly due to the application of the passive house concept in renovation. In addition, transaction cost was accounted in the procurement procedure, in relation to the preparation for the main call. In the implementation phase, transaction costs were identified in connection to subcontracting and meetings, related to passive house principles and the partnering contract type. In the operation and follow-up phase, transaction costs were identified in relation to agreement negotiations with monitoring partners. The scale of transaction costs related to negotiations can be as high as 200% more than in conventional renovations.

Project formulation. The project formulation in Brogården, from the introduction to the acceptance of the passive house concept, lasted four years (2001-2005) form the very first meeting between an independent consultant-architect and the managing director of Alingsåshem. These negotiations are also common in conventional renovation projects, except that introducing a new concept and persuading different actors to implement them takes more meetings and more time. Considering the management commitment of Alingsåshem, the total time dedicated to negotiations and decision-making would be greatly underestimated if only meeting hours were reported. The time the development director of the municipality spent on project formulation is, for example, estimated to be around 10% of his working time over the project period, totaling SEK 500 000[16].

Target setting.The major targets of the Brogården renovation were specified early on; they were formulated based on municipal housing policies, earlier experiences and tenants´ complaints. Targets in relation to energy efficiency are, for instance, a) enhancing indoor comfort, by improving U-values

[16] It is approximately EUR 60 000. 1 SEK=0.12056 EUR (www.oanda.com, 14 March 2013)

and installing mechanical ventilation (with heat exchangers) with the possibility for the tenants to influence their indoor climate and energy use, b) lower energy use, c) easy-to-use and -maintain technology, and d) active involvement of tenants (in the renovation process and in the user-phase). The renovation targets were set by Alingsåshem. There is no estimate available of resources spent on the complex procedure of target setting.

Preparation for the main call. Preparing for the detailed call took more time for the applicants than in conventional renovation projects. Skanska, the procured building developer, spent approximately three times longer on preparing for this call than on conventional renovation tenders. It was partly due to the fact that this was the first time for Skanska to participate in a partnering procurement for renovation and partly due to the sustainability principles (including energy efficiency and the passive house concept) on which Alingsåshem had required the detailed views of applicants.

Subcontracting under partnering. Most building developers have established networks of subcontractors, thus (re-)procuring subcontractors and consultants was an additional activity specific to this project. Skanska (re-)procured and contracted four subcontractors for painting, electrical work, plumbing and landscaping for the partnering collaboration under the terms and conditions of the framework contract. The (re-)procurement of subcontractors took an estimated three weeks (120 man hours) for the building developer.

3.1.3. Monitoring

Monitoring is not typically part of conventional renovations and thus represents additional costs in passive house renovations. Transaction costs of monitoring occur in the operation and follow-up phases of the renovation project. Among the transaction costs identified in this phase were monitoring of energy saving equipment, energy savings, costs and cost savings as well as maintenance of (new) technologies used in passive houses. Monitoring activities are split among multiple actors. For instance, Alingsåshem[17] is responsible for monitoring the performance of ventilation system and finances, Skanska for the moisture content, Alingsås Energi for the energy demand for space heating, domestic hot water, and electricity, Lund University for energy, airtightness and tenants´ satisfaction, SP for the monitoring process and quality assurance, and the Tenants´ Association for the needs and preferences of the tenants. As the renovation is still on-going, the available results are partial and often related to certain stages of the renovation and not the entire process. The current monitoring costs are estimated to be very high in Brogården[18]. Monitoring is expected to be required by legislation in the future, thus monitoring-related costs will no longer be additional transaction costs of passive house renovations.

3.2. Estimated scale of transaction costs

The results of this study indicate that the scale of transaction costs related to the implementation of passive house renovation is non-negligible and can be 200% higher than for conventional renovations (see Table 1). Although it has been difficult to find comparable data on the scale of different nature of transactions costs, this study indicates the importance of considering these costs. This also indicates a need to find ways to reduce them (see Section 4).

In general, project formulation and target setting have shown to be too complex to reliably estimate resources allocated to them. On the contrary, for the extended pre-study, activities related to procurement processes and the search for passive house technology solutions, estimated costs are available - at least in terms of time spent on the activities. The majority of transaction costs arising in the planning phase are naturally attributable to the building owner while transaction costs arising in the implementation phase are mostly borne by the building developer and transaction costs of the operation and follow-up phase are shared among various actors.

[17] For instance, it was found that the lack of specification on the monitoring requirements made it difficult for the building owner to follow-up additional costs of energy efficient and passive house technologies per building and/or per apartment.
[18] The quantification of monitoring costs was not the focus of this study; it is however strongly recommended to estimate monitoring costs (with special attention to maintenance costs) once the project is completed.

Table 2 Estimated transaction costs of the demonstration stage of Brogården passive house-oriented renovation (source, scale, attribution)

Renovation phase	Source of TCs	Scale of TCs	Actor bearing TCs
Planning	extended pre-study: - building investigation (consultant) - architecture work (consultant)	Approx. 2 person-months work 300 000-400 000 SEK[19] *(1.5 times more in comparison with a conventional renovation project)*	Building owner
	project formulation: - (Alingsåshem) - (municipality)	n/a 500 000 SEK[20]	Building owner
	target setting	n/a	Building owner
	search for the form of collaboration	Approx. 2 person-months work	Building owner
	call preparation : - call drafting (consultant) - application (Skanska)	Approx. 2 person-months work *(3 times more spent in comparison with a conventional renovation project)*	Building owner Building developer
	application assessment	*(1.33 more spent compared to a conventional renovation project)*	Building owner
Implementation	subcontracting (Skanska)	Approx. 3 person-weeks	Building developer
	assessment of subcontractors (Alingsåshem)	Approx. 3 person-hours	Building owner
	search for passive house technology solutions (Skanska): - products (subcontractors) - new solutions (consultants), e.g. - ventilation - wall construction	Approx. 2-3 person-weeks per product *(For ventilation 2-3 times longer and for wall construction 1.1 times longer than in a conventional renovation project)*	Building developer
Operation and follow-up	search for methods of assessment and monitoring (e.g. Alingsåshem, Alingsås Energi, Lund University, SP)	n/a	Building owner
	monitoring and assessment (idem)	n/a	Building owner and contracted partners
	maintenance	n/a	Building owner

The type of collaboration has an influence on the nature and scale of transaction costs in passive house renovations. Partnering form was chosen for the collaboration because of the application of the passive house concept. Therefore, some activities related to partnering have been considered as transaction costs of implementing the passive house concept as these costs would not have occurred for other types of collaboration. These costs arise throughout all the three phases of the renovation process and in all natures of transaction costs. For example, it occurs in the form of due diligence,

[19] It is in the range of EUR 36 000 and 48 000. 1 SEK=0.12056 EUR (www.oanda.com, 14 March 2013)
[20] It is approximately EUR 60 000. 1 SEK=0.12056 EUR (www.oanda.com, 14 March 2013)

such as call preparation and assessment of applicants, in the form of negotiations, such as project formulation and target setting and in the form of monitoring. In general, most of the actors state that partnering is time-demanding. Skanska, for instance, estimates that the Brogården project, due to partnering and being a development project, requires half a position more (project management hours) than a traditional renovation project. Other activities related to partnering, however, were encountered here as strategic measures for learning (see Section 4.)

4. Strategic measures for knowledge development and learning

As revealed in the previous section, the passive house renovation project, in comparison to conventional renovation projects, required additional resource inputs and/or measures in the different project phases. These measures were often encountered as resource inputs and costs, which by facilitating knowledge development and learning, intend to lead to resource and cost reductions. The study at hand found that the renovation of Brogården included such measures to reduce construction costs and, supringsingly transaction costs as such. These strategic measures are elaborated below.

4.1. Study visits and demonstration projects

Introducing the passive house concept for renovation, in comparison to conventional renovation projects, increases the need for advanced information and knowledge intake. For this reason, in the Brogården project, study visits were organized in the planning and the implementation phases. In the planning phase, the focus of the study visits was on the type of collaboration and the nature of the passive house concept. The partnering contract, for instance, was based on a previously developed partnering contract in Karlstad. These study visits were initiated by Alingsåshem. In the implementation phase, in order to strengthen the common understanding, the study visits concentrated on passive house technologies and addressed different groups of professionals. These visits were organized by Alingsåshem and Skanska – together and/or separately. They took an estimated 72 person-hours from Alingsåshem and Skanska. In the operation and follow-up phase, a demonstration (or showcase) apartment was set up to serve as a subject of a continuous dialogue between tenants and Alingsåshem. In addition, it functioned as a stakeholder meeting point - for example, for site visits and for project and tenant meetings. The showcase apartment, in addition to open house weekends, had regular opening hours. The demonstration apartment was a common project of Alingsåshem and the Tenants´ Association on which each actor spent roughly estimated 220 man hours.

4.2. New forms of meetings

A renovation process traditionally requires meetings during all phases: in the implementation phase, the focus includes building planning, building process, time-scheduling and financing; in the operation and follow-up phase meetings address topics like user practices. Introducing the passive house concept for renovation slightly changes the frequency and objectives of these meetings. Additionally, the type of collaboration (partnering) has also brought about new forms of interaction.

In the implementation phase, *traditional building site meetings,* building planning and building process meetings play an important role in finding technical and economic solutions for the implementation of the passive house concept. In Brogården, Skanska organized these meetings on a weekly basis; the participants often got homework to be solved for the next meeting. To find solutions for problems took on average two to three weeks. According to participating actors, energy efficiency issues occupied between 10-50% of the meeting time[21]. Among meetings organized in the spirit of the partnering framework contract[22], *start-up partnering meetings* and *Friday meetings*[23] are

[21] For example, finding solution for the building envelop was estimated to take 10-15%, while finding ventilation system solutions was estimated to take 50% of the meeting time. On an average, 92 person-hours were estimated to have been spent discussing energy efficiency issues in the frame of building planning and process meetings.

[22] Partnering is based on the principle that involved project partners work with a defined target and a common goal in mind; it thus requires meetings, active participation (direct ideas and solutions from the entrepreneurs), close collaboration between the different professions and teambuilding.

[23] Friday meetings take place every fifth Friday. So far approximately 45 meetings have taken place (February 2008 - January 2013).

the most important to highlight. Start-up meetings have been organized at each stage of the renovation process: the first meeting took a whole day, the second, a half day, the third, three hours, the fourth and the fifth two hours each[24]. These meetings also accommodate different guest lectures on topics such as energy efficiency and passive principles. On average, energy efficiency took up 25% of the meeting.

In the operation and follow-up phase, *individual move-in briefings*, regular *information meetings* and topical seminars were organized for tenants. At the individual move-in briefings, in comparison to traditional renovation, additional costs occurred in relation to providing information on passive house principles and practicalities as well as individual carpenter assistance to avoid problems like perforating the air tight layer. Alingsåshem spent an estimated 750 person-hours on the move-in assistance; this resource input would not have been necessary for a conventional renovation. Information meetings and topical seminars include a one-time public start-up meeting (April 2007), a scenario building workshop, and regular meetings often combined with topical seminars and guest lecturers (weekly, later monthly). These meetings were important in order to use the passive house system more efficiently, a concern not present in conventional renovation projects. Alingsåshem dedicated approximately 75 person-hours and the Tenants´ Association roughly 50 person-hours to these meetings.

4.3. New information channels: experience database and newsletter

Unlike conventional renovations, passive house renovations require new forms of written information channels, structures and storage; the *experience database* and the *Brogården newsletter*[25] are two good examples of these. In the operation and follow-up phase, Skanska set up a database with experience gathered from various partners involved in the renovation (i.e. performance evaluation). Experiences range from technical details through working process-oriented issues to new ideas for the future. The aim is to ensure continuity and to improve the (stages of the) renovation processes in the future. Another example of new information channels is the end-user involvement in the appropriate application of new technologies, which was also recognized early on in the Brogården project. The newsletter *Brogårdsbladet* has been one of the most important information tools for tenants to get acquainted with the details of the renovation process, passive house principles and measures. It has been issued and distributed to each apartment on an average 1.5 times per month since 2007. The newsletter is a common responsibility of Alingsåshem and the Tenants´ Association and takes one person-day per month for Alingsåshem (456 hours), 50% of the working time of one worker at the Tenants´ Association and one person-day per issue for Skanska (224 hours).

4.4. Potential for transaction cost reductions

The strategies and measures discussed above have provided a potential for knowledge development and learning in passive-house renovations. This, in turn has reduced construction and transaction costs. One indication of this is that the actual construction time was reduced from 12 months, as of the first renovation stage (demonstration project), to 7.5-10 months for the later renovation stages. The various strategic measures applied had an effect on the different sources of transaction costs.

Transaction costs of due diligence and the search for passive house technology solutions were reduced by study visits, demonstration projects, new forms of meetings and new forms of documentation. The searches for the form of collaboration and for assessment and monitoring methods were reduced by study visits, demonstration projects and new forms of meetings. Transaction costs of negotiations, such as project formulation and target setting were reduced by study visits, demonstration projects, new forms of meetings and new forms of documentation.

[24] The first start-up meeting took place before the renovation started; all involved project participants (43 participants) attended a one-day meeting in Alingsås. The aim of this session was to present the vision, the goals and the targets of the renovation project. The passive house concept was delineated among actors by presentations (a 3.5 hours energy presentation, focusing on ventilation and outer walls) and team-games (a quiz competition).

[25] The newsletter is available at http://www.alingsashem.se/index.php?page=bobladet

Preparation for the main call can be reduced by new forms of meetings (see more details in Table 2). In addition, different ways to provide information provision to tenants (for example, the demonstration apartment, new forms of meetings and newsletters) seemed to contribute reducing transaction cost in relation with the operation and maintenance of passive house technology solutions. Monitoring activities also serve as a basis for learning from own experience and thus contributed to cost reductions in all phases of passive house renovation.

However, not all transaction costs could be reduced through learning. This study shows that transaction costs of due diligence, such as extended pre-study and the assessment of building developers and subcontractors have little room for reduction through learning. Similarly, transaction costs of negotiations, such as subcontracting and monitoring show very low or no reduction potential. This is because feasibility studies, building investigations and technical procurement requirements are highly building specific.

Table 3 Strategies for learning to reduce construction costs and specifically transaction costs in Brogården

		Strategies promoting learning		
Transaction costs		**Study visits & Demonstration projects**	**New forms of meetings**	**New channels of information**
Due diligence	Extended pre-study			
	Search for form of collaboration	√	√	
	Preparation of the call for building developer	√		
	Assessment of building developers´ application			
	Assessment of subcontractors			
	Search for passive house technologies	√	√	√
	Search for assessment methods	√	√	
Negotiation	Project formulation	√	√	√
	Target setting	√	√	√
	Preparation for the main call		√	
	Subcontracting under partnering			
Monitoring	Monitoring			

5. Concluding remarks

To overcome barriers to energy efficient renovations and to make passive house renovations more financially attractive, transaction costs related to the introduction and implementation of passive house technologies must be better understood and ultimately reduced. This study has identified three natures of transaction costs arising during the application of the passive house concept: due diligence, negotiations and monitoring. Due diligence costs arise in relation to extended pre-study, search for the form of collaboration, passive house technology solutions and monitoring methods, preparation of the call for building developers, and assessment of the applications of building developers and subcontractors. Negotiation costs occur in relation to project formulation, target setting, preparation for the call for building developers and subcontracting under partnering. Transaction costs of monitoring arose in relation to monitoring of energy and cost savings, energy efficient equipment and maintenance of passive house technologies. It was found that certain sources of transaction costs, for example due diligence and negotiation, can arise throughout the life-cycle of the passive house renovation project; while monitoring is more typical in the operation phase.

Findings strongly suggest that transaction costs of passive house renovations are higher than transaction costs associated to conventional renovations. Out of these, most of the costs occur in the planning and implementation phases. Interestingly, our study revealed that a high proportion of these costs can be reduced through learning. In fact, it was found that certain strategies have already been introduced and applied to varying extents in the Brogården project to promote learning and resulting cost reductions. These are actors´ strategies such as study visits, demonstration projects, new forms of meetings and written information to open up new information channels. These strategies have been applied, for instance, to reduce additional costs related to project formulation, target setting and the search for passive house technologies, which seems to be the highest transaction costs in the Brogården project. This is surprising, considering that even if stakeholders are sometimes fully aware of the existence of transaction costs, they do not keep track of them and/or implement strategies to reduce them.

References

Audenaert, A., De Cleyn, S. H., & Vankerckhove, B. (2008). Economic analysis of passive houses and low-energy houses compared with standard houses. *Energy Policy*, *36*(1), 47–55.

Berggren, B., Janson, U., & Sundqvist, H. (2009). *Energieffektivisering vid renovering av rekordårens flerbostadshus [Energy efficiency of multifamily dwellings]* (No. EBD-R-08/22). Lund: Energy and Building Design, Lund University.

Björkqvist, O., & Wene, C. (1993). A study of transaction costs for energy investments in the residential sector. Presented at the 1993 Summer Study, The European Council for an Energy Efficient Economy.

Bleyl-Androschin, J. W., Seefeldt, F., & Eikmeier, B. (2009). Energy contracting: how much can it contribute to energy efficiency in the residential sector? Presented at the eceee 2009 Summer Study: Act! Innovate! Deliver! Reducing energy demand sustainably.

Blomsterberg, Å. (2009). *Lågenergihus - En studie av olika koncept [Low-energy houses - A study of different concepts]* (No. EBD-R--09/28). Lund: Lund University.

BPIE. (2011). *Europe's buildings under the microscope - A country-by-country review of the energy performance of buildings*. Brussels: Building Performance Institute Europe. Retrieved from http://www.bpie.eu/documents/BPIE/HR_%20CbC_study.pdf

CarbonTrust. (2005). *The UK Climate Change Programme: Potential Evolution for Business and the Public Sector*. London, UK: Carbon Trust.

Coase, R. H. (1937). The Nature of the Firm. *Economica*, *4*(16), 386–405.

Coase, R. H. (1960). The Problem of Social Cost. *Journal of Law & Economics*, *3*.

Commons, J. R. (1931). Institutional Economics. *American Economic Review*, *21*, 648–657.

Douglass, C. N. (1990). Institutions and a transaction cost theory of exchange. In J. E. Alt & K. A. Shepsle (Eds.), *Perspectives on positive political economy* (pp. 182–194). Cambridge, UK: Cambridge University Press.

EastonConsulting. (1999). *Energy Service Companies. A Market Research Study* (No. 64). Prepared for Energy Center of Wisconsin:64.

Enseling, A., & Hinz, E. (2009). *Energiebilanz- und Wirtschaftlichkeitsberechnungen für ein vermietetes Mehrfamilienhaus im Bestand [Energy balance and efficiency calculations for a rented multifamily-dwelling]*. Darmstadt: Institut Wohnen und Umwelt GmbH.

Feist, W. (2006). Factor 10 is a reality. Presented at the 15th Anniversary of the Darmstadt - Kranichstein Passive House.

Feist, W., Schneiders, J., Dorer, V., & Haas, A. (2005). Re-inventing air heating; Convenient and comfortable within the frame of Passive House concept. *Energy and Buildings*, *37*, 1186–1203.

Harvey, L. D. D. (2009). Reducing energy use in the buildings sector: measures, costs, and examples. *Energy Efficiency (special issue): How Far Does it Get Us in Controlling Climate Change?*, *2*(2), 139–163.

Hastings, R. (2004). Breaking the heating barrier. Learning from the first houses without conventional heating. *Energy and Buildings*, *36*, 373–380.

HausderZukunft. (2007). Passive house renovation, Makartstrasse, Linz. Retrieved January 1, 1930, from www.hausderzukunft.at/results.html/id3951

Hein, L., & Blok, K. (1995). Transaction costs of energy efficiency improvement. Presented at the eceee Summer Study: Sustainability and the reinvention of the government - A challenge for energy efficiency.

Hellberg, H. (2012). Eknomi vid ombyggnad med energisatsning [The economy of energy efficient renovations]. *Bygginfo PM*, *3*, 80–82.

Hermelink, A., & Hübner, H. (2003). Is one litre enough? – tenants' satisfaction in passive houses. In S. Attali, E. Métreau, M. Prône, & K. Tillerson (Eds.), . Presented at the eceee 2003 Summer Study: Time to Turn Down Energy Demand.

IBB. (2010). *Wirtschaftlichkeit energetischer Sanierungen im Berliner Mietwohnungsbestand [Energy efficient renovation of the housing stock in Berlin]*. Berlin: Investitionsbank Berlin.

IPHA. (2012). Passive houses worldwide. Retrieved January 1, 2001, from http://www.passivehouse-international.org/index.php?page_id=65

Janson, U. (2010). *Passive houses in Sweden - From design to evaluation of four demonstration projects*. Lund University, Faculty of Engineering LTH, Lund.

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.

Kadefors, A. (2011). Organizing Collaboration in Construction Projects - Formal Models Metting Practitioner Perspectives. Presented at the Management and Innovation for a Sustainable Built Environment.

Lee, W. L., & Yik, F. W. H. (2002). Regulatory and voluntary approaches for enhancing energy efficiencies of buildings in Hong Kong. *Applied Energy*, *71*, 251–274.

Levine, M., Ürge-Vorsatz, D., Blok, K., Geng, L., Harvey, D., Lang, S., … Yoshino, H. (2007). Residential and commercial buildings. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Matthews, R. C. O. (1986). The Economics of Institutionsand the Sources of Growth. *The Economic Journal*, *96*(384), 903–918.

Ménard, C. (2004). *Transaction costs and property rights* (First., Vol. 2). Cheltenham UK and Northampton MA: Elgar Reference Collection.

Mundaca, L. (2007). Transaction costs of Tradable White Certificate schemes: The Energy Efficiency Commitment as a case study. *Energy Policy*, *35*, 4340–4354.

Mundaca, L., Mansoz, M., Neij, L., & Timilsina, G. (2013). Transaction costs analysis of low-carbon technologies. *Climate Policy*, *(forthcoming)*.

Mundaca, L., & Neij, L. (2006). *Transaction Costs of Energy Efficiency Projects: A Review of Quantitative Estimations* (No. Report prepared under Work Package 3 of the EuroWhiteCert project).

Mundaca, L., & Neij, L. (2007). *Exploring transaction costs under the "Free-of-Charge Energy Audit" programme in Denmark* (Task report work package 4. EuroWhiteCert Project). Lund: International Institute for Industrial Environmental Economics.

North, D. C. (1990). *Institutions, institutional change and economic performance*. Cambridge, UK: Cambridge University Press.

Ostertag, K. (1999). Transaction Costs of Raising Energy Efficiency. Presented at the The IEA International Workshop on Technologies to Reduce Greenhouse Gas Emissions: Engineering Economic Analyses of Conserved Energy and Carbon.

Passive-On. (2007). Passive-On Project: Passive House or Passivhaus? Retrieved January 1, 2011, from http://www.passive-on.org/CD/5.%20Long%20Description/Passive-On%20-%20Long%20Description%20-%20English.pdf

PHI. (2012). Are passive houses cost-effective? Retrieved January 1, 2011, from http://passipedia.passiv.de/passipedia_en/basics/affordability/investing_in_energy_efficiency/are_passive_houses_cost-effective

Qian, Q. K., Chan, E. H. W., & Choy, L. H. T. (2013). How transaction costs affect real estate developers entering into the building energy efficiency (BEE) market? *Habitat International*, *37*, 138–147.

Sanstad, A. H., & Howarth, R. B. (1994). "Normal" markets, market imperfections and energy efficiency. *Energy Policy*, *22*(10), 811–819.

Sathaye, J., & Murtishaw, S. (2004). *Market Failures, Consumer Preferences and Transaction Costs in Energy Efficiency Purchase Decisions*. Berkeley, USA: International Energy Studies. Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory.

SCB. (2010). *Bostads- och byggnadsstatistik Årsbok 2010 [Yearbook of Housing and Building Statistics 2010]*. Stockholm: Statistics Sweden. Retrieved from http://www.scb.se/statistik/_publikationer/BO0801_2010A01_BR_BO01BR1001.pdf

Schnieders, J. (2003). CEPHEUS - measurement result from more than 100 dwelling units in passive houses. In E. M. Sophie Attali (Ed.), (pp. 341–351). Presented at the eceee Summer Study: Time to turn down energy demand.

Schnieders, Jürgen, & Hermelink, A. (2006). CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building. *Energy Policy*, *34*(2), 151–171.

Selten, R. (1990). Bounded rationality. *Journal of Institutional and Theoretical Economics*, *146*(4), 649–658.

Sioshansi, F. P. (1991). The myths and facts of energy efficiency: Survey of implementation issues. *Energy Policy*, *19*(3), 231–244.

Skanska. (2012). *Praktiska tillämpningar av högpresterande värmeisolering i ombyggnadsprojekt [The practical applications of high performance building insulations in renovation projects]* (No. SBUF projektnummer 12455). Gothenburg, Sweden: Skanska Sverige AB.

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

WBCSD, W. B. C. for S. D. (2009). *Energy efficiency in buildings - Transforming the Market*. France: WBCSD.

Williamson, O. (1993). Transaction cost economics and organisation theory. *Industrial and Corporate Change*, *2*(2), 107–156.

Williamson, O. (1996). *The Mechanisms of Governance*. New York: Oxford University Press.

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 and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria: Cambridge University Press.

Ürge-Vorsatz, D., Harvey, L. D. D., Mirasgedis, S., & Levine, M. D. (2007). Mitigating CO2 emissions from energy use in the world's buildings. *Building Research and Information*, *35*(4), 379–398.

Ürge-Vorsatz, D., Koeppel, S., & Mirasgedis, S. (2007). An appraisal of policy instruments for reducing buildings' CO2 emissions. *Building Research and Information*, *35*(4), 458 – 477.