CHALLENGES TO THE DEVELOPMENT OF ENERGY PERFORMANCE MEASUREMENT: A SYSTEMS THINKING APPROACH

University of Jyväskylä
School of Business and Economics

Master's thesis

2016

Mikko Asikainen
Corporate Environmental Management
Supervisor: Tiina Onkila

JYVÄSKYLÄN YLIOPISTO

ABSTRACT

Author Mikko Asikainen	
Title Challenges to the development of energy performance measurement: A systems thinking approach	
Subject Corporate Environmental Management	Type of work Master's thesis
Time (Month/Year) March/2016	Number of pages 92

Abstract

Growing global energy consumption and its consequent hindrance to sustainable development poses one of the greatest challenges of today. Improvement of the end-use energy efficiency is commonly regarded as one of the most basic and significant countermeasures for curbing the rising energy needs. However, it seems that the progress of end-use energy management is currently hindered due to the complexities involved in the measurement and management of energy efficiency. In essence, the lack of appropriate energy performance metrics constitute a gap between the current organizational needs and scientific literature.

Furthermore, the current scientific debate has questioned whether energy efficiency, as a current concept, is able to respond to the extant needs in business management. Thus, there exists a demand for a conceptual change that would enable organizations to simultaneously promote sustainable development and reach concrete results from energy management. For this reason, this thesis focuses on the concept of energy performance, which is able to encompass both operational and strategic dimensions of energy management.

In order to address the above-mentioned research gap, this thesis explores the barriers that hinder the development of energy performance measurement in the context of industrial companies, government entities, wholesale and retail companies and real estate companies. As the barriers and their interactions seem to constitute a complex problem situation, the research problem is approached from a systems thinking perspective, which enables the holistic examination of the barriers. The chosen approach departs from most previous research, which has typically studied barriers in isolation, neglecting the potential relationships between the barriers.

The main achievement of this study is to introduce a model for understanding the interactive nature of the barriers to the development of energy performance measurement. From the perspective of business management, the created model works as a tool for the management of change, as it increases the understanding of the paradoxal problem situation and enables rational discourse to take place. By doing so, the model aims to address the current needs of organizations in developing specific and quantitatively measurable performance indicators for energy.

Keywords
Energy management, energy performance, energy efficiency, performance measurement, barriers, sustainable development, rebound, systems thinking

Location
Jyväskylä University School of Business and Economics

FIGURES

TABLES

CONTENTS

1 INTRODUCTION

This thesis is a qualitative study which aims to create a holistic understanding of the barriers that hinder the development of energy performance measurement. This introductory chapter provides the reader with the essential background information, rationale for research, research objectives, and structure of the research. The background information is covered in three subchapters, which address the concepts of energy efficiency barriers, energy performance measurement and systems thinking. Systems thinking forms the general approach of this study, enabling the holistic examination of the research problem.

1.1 A short introduction to energy efficiency barriers

Growing global energy consumption and its consequent hindrance to sustainable development poses one of the greatest challenges of today. Depending on the utilized energy sources, various environmental and social impacts emerge as the rising energy demand is satisfied with an increasing energy supply. For this reason, energy conservation has a significant role from the perspective of environmental protection and sustainable development. (Dincer, 2003, 688-690.) Currently, improvement of the end-use energy efficiency is regarded as one of the most basic and significant countermeasures for curbing the rising energy needs (Tanaka, 2008, 2887; Viinikainen and Soimakallio, 2007, 5).

Although the level of energy efficiency has improved throughout the years, significant energy efficiency possibilities still remain unused (European commission, 2010; IPCC, 2014, 709). This misalignment between the actual and optimal level of energy efficiency is called the energy efficiency gap (Jaffe and Stavins, 1994, 804). Researchers have tried to address the energy efficiency gap by identifying barriers which impede the organizations' ability to adopt measures for energy efficiency improvement. Limited access to capital (Rohdin and Thollander, 2006, 1840), low priority of energy issues (Brown, 2001, 1202), lack of technical skills (Sardianou, 2008, 1417) and resistance to change (Nagesha and Balachandra, 2006, 1973) are examples of typical barriers identified in these studies. Despite the abundancy of research, the barriers to energy efficiency have persisted to this day (Chai and Yeo, 2012, 460-464).

Recently, the previous research on energy efficiency barriers has been criticized for treating the barriers in isolation, leaving the potential interactions between the barriers unremarked. The critics argue that the barriers to energy efficiency cannot be properly studied when their interconnected nature is neglected. It has been further argued that this inadequate consideration for interactions is the main reason for the persisted existence of the barriers. Sustainable improvement in energy efficiency is more likely to be achieved by adopting a more holistic approach to energy efficiency, i.e. considering the relationships between the relevant barriers. If improvement recommendations focus solely on single barriers or a group of barriers, the potential interactions among the barriers may render the improvement efforts ineffective. (Chai and Yeo, 2012, 460-464.)

1.2 Energy performance measurement and its development

Although energy efficiency measurement has been widely studied in technical literature, the topic has been suprisingly neglected in the management research (Virtanen et al., 2013, 401). The extant research (Sivill, 2011; Virtanen et al., 2013; Bunse et al., 2011; Chai and Yeo, 2012) emphasizes that in order to reach sustained efforts in energy management, organizations should develop specific and quantitatively measurable performance indicators for managing energy.

The current research has shown that the lack of appropriate performance indicators for energy has consequences in both strategic and operational levels. As savings from energy efficiency investments are often not visible, it can be challenging for the top management to be convinced about the benefits of energy efficiency improvements (Chai and Yeo, 2012, 465). According to Virtanen et al. (2013, 412), the effective use of management control systems may be hindered by the complexities associated with the measurement and management of energy efficiency. Consequently, inefficient use of management control systems may impair the motivation and capabilities of the employees in the operational level (Virtanen et al., 2013, 412).

In the context of the most advanced industrial sectors in energy management, Sivill (2011, 39) has argued that the development of energy performance measurement is one of the prerequisites for further progress in energy management. Energy performance, as defined by Sivill (2011, 30-32), differs from the concept of energy efficiency by including trade-offs between energy efficiency and other profitability factors. As the concept of energy efficiency is associated with the measurement of specific energy consumption and its derivatives, it is easily regarded entirely as an operational issue in business organizations. Energy performance, however, is much broader concept which is able to encompass both operational and strategic dimensions of energy management. (Sivill 2011, 30-38.)

However, there exists little knowledge on how energy performance is currently measured in practice, and how the concept is interpreted by organizational actors. Energy performance measurement, as such, still seems to be far from the actual practices of organizations. As with other energy efficiency measures, there exists certain barriers that inhibit its development (Sivill et al., 2013, 936). Interestingly, the developmental challenges of energy performance measurement can be interpreted to constitute a complex, ill-defined problem situation:

> *"Investing in the development of energy performance measurement is faced with a paradox: resources and commitment, which are still regarded as the most important barriers to energy management, are prerequisites for energy performance measurement being developed, whereas energy performance measurement influences the very same issues by enforcing changed behaviour" (Sivill et al., 2013, 948).*

Reflecting on the arguments presented by Chai and Yeo (2012, 460-464), the above finding suggests that there may exist an interaction between the identified barriers. In essence, this described paradox forms the observed problem situation of this study. Due to the complex nature of the problem situation, I argue that systems thinking offers a fertile ground for its holistic examination. I perceive this as an important research topic, taking into account the emphasized need to develop specific and quantitatively measurable performance indicators for energy (Sivill, 2011, 39; Virtanen et al., 2013, 412-413; Bunse et al., 2011, 676-677; Chai and Yeo, 2012, 469). Furthermore, Bunse et al. (2011, 676-677) have demonstrated that the lack of appropriate energy performance metrics constitutes a gap between industrial needs and scientific literature. This thesis aims to fill the above-mentioned gap by creating a deeper understanding of the barriers associated with the development of energy performance measurement.

1.3 Complexity, holism and systems thinking

In order to remain viable, organizations have to adapt to their ever-changing environment. Global competition, technological innovation, new regulations and other transformations in societies cause organizations to face an increasing level of complexity. For this reason, dealing with organizational intricacies is seen as an essential aspect of managerial work. Complexity emerges from the interconnected nature of problems. Problems seldomly exist in isolation, as it is inherent for them to be present in richly interconnected problem situations. In this kind of context, experience has shown that solutions lacking holism are likely to fail. (Jackson, 2004, 13-15.)

Reductionism is a traditional scientific method, which places emphasis on the parts that constitute a whole. Holism has challenged this conventional view by considering wholes being greater than the sum of their parts. In holism, the whole emerges from the multifaceted relationships between the parts. The emergent whole is something that gives a meaning to the constituting parts and their interconnected relationships. Holism has gained popularity among academic sciences due to reductionism's inability to deal with complexity and change. (Jackson, 2004, 3-4.)

In order to cope with complexity, both academics and practitioners have turned towards systems thinking (Jackson, 2004, 15). Systems thinking is a perspective, which has been considered to be successful in solving complex, interdisciplinary problems (Boulding, 1956, 199). It deals with the concept of a "system", which is a model of an entity as a whole (Checkland, 1981, 317). Systems thinking places explicit emphasis on the relationships and interactions between the system's elements and constituents, and addresses a problem situation in a holistic manner (Senge, 1993, 69). The approach emphasizes that the root causes of problems may emerge from the underlying structures of systems. Addressing these problems require a focus on internal system structures, shifting our attention towards circular causalities. (Chai and Yeo, 2012, 464; Senge, 1993, 73.)

A "system" is something that Barton and Haslett (2007, 143) define as a cognitive construct for making sense of complexity. System can be also defined as an organized whole, which is dependent on its parts and the interactions between the parts (Flood and Carson, 1990, 7). A diversity of different types of systems can be identified, such as physical, biological, human activity, designed, abstract and social systems (Jackson, 2004, 3). When a system model is applied to human activity, it is characterized by hierarchical structure, communication, control and emergent properties (Checkland, 1981, 317-318).

1.4 Research objectives

This thesis aims to create a holistic understanding of the barriers that hinder the development of energy performance measurement. The objective is to analyse how the barriers and their interactive relationships are formed. In order to do this, the principles of systems thinking are applied in the research process. The chosen approach departs from most previous research, which has typically studied barriers in isolation, neglecting the potential relationships between the barriers. This knowledge contributes to the previous research by creating a deeper understanding about the mechanisms that cause inertia in the progress of energy management. This information attempts to fill an existing gap between organizational needs and scientific literature, and potentially helps organizations, policymakers and other stakeholders to holistically address these barriers. Therefore, in order to reach the aim of this thesis, the following two questions are addressed:

- *What are the barriers that can be identified from the conducted interviews?*
- *How are the barriers and their interactive relationships formed from the perspective of systems thinking?*

As a methodology, this research applies Soft Systems Methodology (SSM), created by Peter Checkland. The aim of the chosen methodology is to create a holistic framework of the perceived problem situation. This framework is known as a conceptual model in the terms of systems thinking. In order to answer both research questions of this study, the research process combines both reductionist and holistic methods. The research is strongly interpretive by nature, which is characteristic to qualitative research. Due to the methodological choices, this research is neither descriptive nor normative, although it inherently involves elements of both.

The research material was collected in conjunction with a larger research project using semi-structured thematic interviews. Thematic analysis was performed in order to derive preliminary empirical results from the collected research material. Later, methods of SSM were applied to the preliminary empirical results in order to achieve a holistic view of the problem situation. Due to the chosen approach, this research applies abductive reasoning in the analysis of empirical findings. Therefore, the influence of theoretical framework is identifiable in the research results.

1.5 Structure of the research

The structure of this research is illustrated in figure 1. After the introduction, chapter 2 begins by presenting a theoretical definition for energy efficiency. The chapter continues with practical applications of energy efficiency measurement. Lastly, the chapter brings energy efficiency into the context of sustainable development, and concludes with presenting critique from the recent research. The general aim of this chapter is to introduce the current definition for energy efficiency, and present the possible need for a broader concept from the perspective of environmental protection and sustainable development.

Chapter 3 explores the scientific literature on performance measurement. The central aim of this chapter is to introduce the concept of energy performance measurement, which, as defined by Sivill (2011, 38), is a broader concept of energy efficiency in the context of business organizations. The chapter concludes with presenting critique towards performance measurement. Chapter 4 includes a literature review on energy efficiency barriers and their categorization, with academic discussion about the interactive nature of the barriers. The chapter concludes by presenting Sivill et al.'s (2013) recent research findings on the barriers inhibiting the development of energy performance measurement. This chapter aims to provide the necessary scientific background on energy efficiency barriers, and form the premise for conducting the empirical part of this research.

The three preceding chapters form the theoretical framework of this study. After the theoretical framework, the research continues with the empirical part of the study, which is formed by chapters 5 and 6. Chapter 5 describes the research approach, methodology and methods applied in this study. It also includes the necessary information about the research subjects and data collection procedures. In chapter 6, the results of this study are presented. The research concludes with chapter 7, which summarizes the findings, trustworthiness and limitations of this study. In addition, directions for future research are presented.

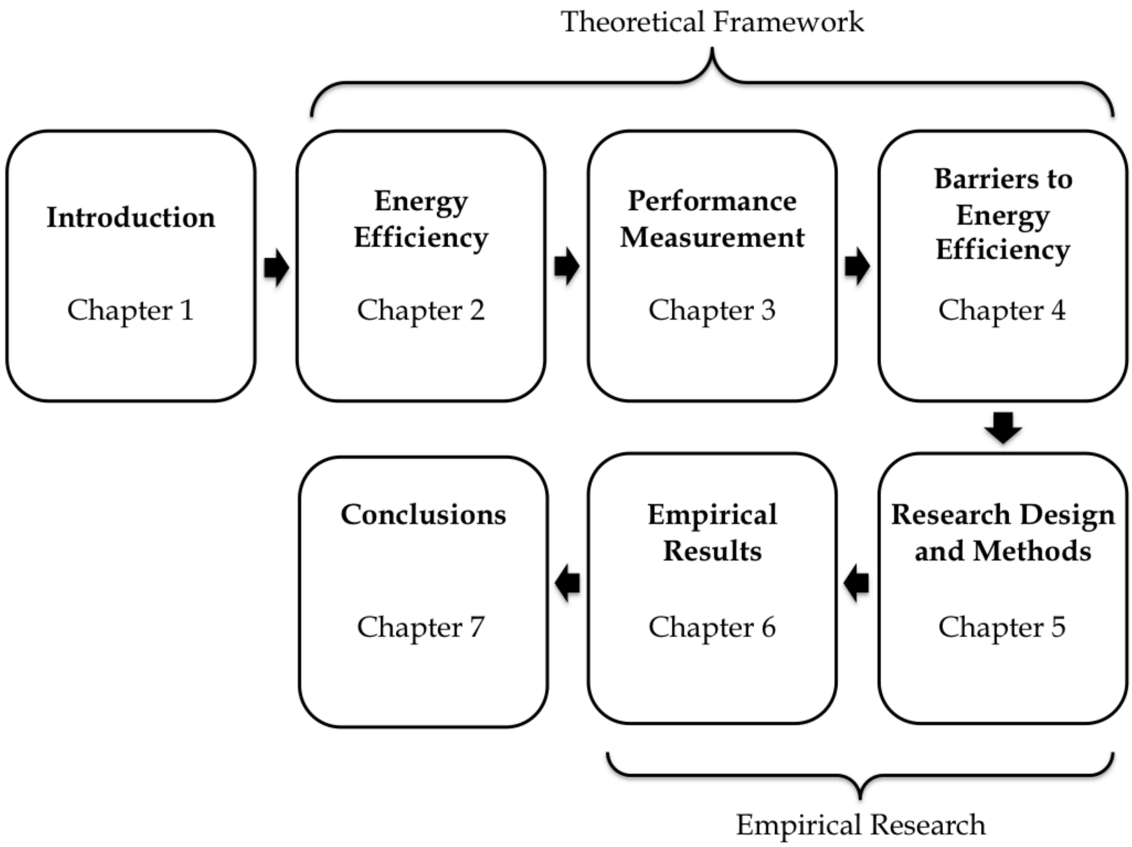

FIGURE 1 Structure of this research

2 ENERGY EFFICIENCY

2.1 Defining energy efficiency

The literature shows a number of slightly differing definitions for energy efficiency. In the second article of the Energy Efficiency Directive (EU, 2012) energy efficiency has been defined as "a ratio between an output of performance, service, goods or energy, and an input of energy". In the context of industrial sector, for example, this ratio might refer to the amount of energy required to produce a tonne of a certain product. In a general context, energy efficiency can be defined as the ratio of useful output of a process to energy input into a process at time t (equation 1). The time t can represent any duration of time. In this sense, energy efficiency is a static quantity, which reflects the circumstances at a certain period of time. (Patterson, 1996, 377; Viinikainen and Soimakallio, 2007, 15.)

$$\text{Energy efficiency at time } t = \frac{\text{The useful output of a process in time } t}{\text{The energy input into a process in time } t} \qquad (1)$$

Energy efficiency is an ambiguous, relative and generic term, which depends on the context and approach of measurement (Viinikainen and Soimakallio, 2007, 15). In practice, numerous methodological issues are present with the definition of the useful output and the energy input. As there exists no unequivocal quantitative measure for energy efficiency, various indicators are needed in order to comprehensively quantify changes in energy efficiency. (Patterson, 1996, 377.) Patterson (1996, 377–378) has categorized these indicators into four distinctive groups: thermodynamic, physical-thermodynamic, economic-thermodynamic and economic indicators. Thermodynamic indicators are founded on measurements derived from the science of thermodynamics. This means in practice that the useful output and the energy input of a process are both measured in terms of an energy unit, such as joule. Physical-thermodynamic indicators are hybrid indicators in which the energy input of a process is measured in units of energy, and the useful output is measured in physical units. The physical units can represent a variety of different measurable activities, depending on the context situation. Economic-thermodynamic indicators are also hybrid indicators, which express the useful output of a process in monetary terms. The market value of the output is compared to the energy input of a process, which is measured in units of energy. In economic indicators the energy input and the useful output of a process are both measured in monetary terms. (Patterson, 1996, 378–383; Viinikainen and Soimakallio, 2007, 26–29.)

Patterson (1996, 383) emphasises that value judgements are an integral part of any definition of energy efficiency, and therefore cannot be considered as objective measures. This observation is derived from the ratio presented above (equation 1). Value judgements are needed in defining what a useful energy output constitutes. From this perspective, ”unuseful” energy (for example waste heat) does not enter into the calculation of thermodynamic efficiency. Therefore, there is an implicit value judgement present in all definitions of thermodynamic energy efficiency. More value judgements are made when energy efficiency measures incorporate for example economic values, which change as peoples preferences change. In addition to value judgements, energy efficiency incorporates also other methodological issues. These include for example the problem of system boundaries, the problem of energy quality, and the problem of joint production. (Patterson, 1996, 383-386.)

The concepts of energy conservation and efficient use of energy are considered to partly overlap with the concept of energy efficiency. The first overlapping concept, energy conservation, can be defined as ”a decrease in energy consumption in absolute terms over some period of time”. Energy conservation can be achieved through decreased consumption of services or improvements in energy efficiency. The second overlapping concept, efficient use of energy, can be defined as ”the minimum possible energy used to produce some specified useful output through a process, product or service”. (Viinikainen and Soimakallio, 2007, 16.) Efficient use of energy, therefore, refers to an ideal situation where there are no losses in a specific process (Siitonen, 2010, 18).

2.1.1 Measurement of energy efficiency

In order to show improvements in energy efficiency, it has to be measured. Improvement of energy efficiency has been defined as ”an increase in energy efficiency as a result of technological, behavioral or economic changes” in the second article of the Energy Efficiency Directive (EU, 2012). A commonly used measure for energy efficiency is specific energy consumption (SEC), which is a physical-thermodynamic indicator (Phylipsen et al., 1997, 717). European Commission (2009, 18) has defined specific energy consumption in its simplest form as:

$$SEC = \frac{energy\ used}{products\ produced} = \frac{(energy\ imported - energy\ exported)}{production\ outputs\ produced} \qquad (2)$$

SEC therefore represents the ratio between energy input, which is measured in units of energy, and unit of output (European Commission, 2009, 18-19). In practice, SEC can be widely applied in various contexts. Firstly, the energy input can be defined in different ways, for example as net available energy, purchased energy, final energy or useful energy (Phylipsen et al., 1997, 717). Secondly, depending on the context, the unit of output can represent different physical quantities, such as mass (GJ/t) or surface-area (GJ/m^2), or other factors such as personnel (GJ/employee). In essence, SEC represents the amount of energy used for a given output at a certain period of time. Therefore, a single value of specific energy consumption without any reference data does not reflect the changes in energy efficiency. In order to monitor the progress of energy efficiency, a dimensionless energy efficiency index (EEI) can be derived from the SEC (Equation 3). (European Commission, 2009, 18-21.)

$$EEI = \frac{SEC_{ref}}{SEC} \tag{3}$$

EEI is calculated by dividing the reference value SEC_{ref} with the specific energy consumption of a certain process. The reference value SEC_{ref} may represent generally accepted industry benchmarks or certain past reference period of specific energy consumption, for example. (European Commission, 2009, 21.)

Energy efficiency indicators can be divided into descriptive and explanatory indicators (Patterson, 1996, 377), and a comprehensive measurement of energy efficiency often requires the use of several different measures and the support of other explanatory factors (Tuomaala et al., 2012, 15). These other explanatory factors vary strongly on context. Capacity utilization rate, for example, can be used as an explanatory factor in industrial processes. Similarly, space utilization rate may be a suitable explanatory factor in the context of buildings. (Tuomaala et al., 2012, 15.)

When energy efficiency of a certain process is measured, the boundaries that separate it from its environment have to be defined. The definition of the system boundaries is important from the perspective of measurement, as they affect the resulting outcome. System boundaries can be defined for small processes, such as for single machinery, or for larger entities, such as regional areas. Different system boundaries and sectors interact with each other, which makes the measurement of energy efficiency challenging. Individual energy efficiency targets may lead to suboptimization, resulting in an inefficient outcome from the holistic perspective. (Tuomaala et al., 2012, 26.) In the context of heat conservation investments, for example, Siitonen (2010, 36-37) observed that the realized CO_2 emission reductions can differ substantially on the mill site and on the national level: As the need for heating diminishes, CHP production may be decreased at the mill site, resulting in lower CO_2 emissions. Reduced CHP production may, however, simultaneously increase the demand for external electricity. As a result, the increased consumption of external electricity may increase the CO_2 emissions at the national level.

Madlener and Alcott (2009, 375) highlight that improvement of energy efficiency takes place if more output is achieved with the same input or if the same output is achieved with less input. This is important from the perspective of sustainability, as the former type of efficiency frees resources to be allocated to other tasks or population growth, and the latter occurs only if consumption stays constant or reproduction does not exceed the replacement rate. (Madlener and Alcott, 2009, 375.) This issue is relevant especially from the viewpoint of effective governmental policies on energy efficiency, which will be further considered in the next subchapter.

2.2 Can energy efficiency live up to its promise?

> *"It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth."*
> *~Jevons, W. Stanley (1906, 140)*

Energy efficiency is commonly referred as the fastest and most cost-efficient measure for reducing CO_2 emissions (IEA, 2007; Tanaka, 2008, 2887), and is currently seen as an important aspect of sustainability by governments worldwide (Hanley et al., 2009, 692). The European Union, for example, stresses energy efficiency as one of the key mitigation measures of climate change. However, recent research has pointed out that the aforementioned statement might actually be an oversimplification of reality (Siitonen, 2010, 36), and governmental programmes might be flawed as they lack a global perspective on energy efficiency (Madlener and Alcott, 2009, 374). In order to achieve productive results with the mitigation measures, it is advisable to critically examine the potential merits of energy efficiency policies (Hanley et al., 2009, 706). Building on this, this subchapter aims to explore energy efficiency from the holistic perspective, taking into account the different dimensions of sustainable development.

The Energy Efficiency Directive (EU, 2012, 1) states that reductions in primary energy consumption and greenhouse gas emissions can be achieved with further improvements to energy efficiency. With energy efficiency improvements, societies also aim to reduce other energy-supply derived environmental impacts, such as air pollution, ozone depletion and forest destruction (Dincer, 2003, 690). As Turner and Hanley (2011, 709) argue, the promotion of energy efficiency rests on the perception that the advancement of technological progress works as a mean to reduce the environmental burden of economic activity. However, empirical research has suggested that the factual impact of energy efficiency might potentially be contrary to this belief (Herring, 2006, 10; Brännlund, 2007, 15; Binswanger, 2001, 131). According to the IPCC (2014, 249) energy efficiency improvements have a direct effect on energy consumption, but simultaneously cause other changes in production, consumption and prices that may indirectly offset the gained energy savings. This counterintuitive outcome is caused by a phenomenon known as the rebound effect (Turner and Hanley, 2011, 709). From this view, improvements in energy efficiency promote economic growth and social welfare, and may backfire from the environmental perspective, leading potentially to an increased use of natural resources (Madlener and Alcott, 2009, 370). In order to understand this phenomenon, the concepts of IPAT-model and Environmental Kuznets Curve (EKC) are explored next.

2.2.1 IPAT-model and the Environmental Kuznets Curve

The IPAT-model is a simplified analysis tool used to assess the impact of human activity on the environment. The model places emphasis on how the state of population, affluence and technology contribute to the resulting environmental impact. The model was first introduced by Ehrlich and Holdren (1971, 1212), and is currently a central analysis tool for ecological economists. (Eriksson and Andersson, 2010, 9-18.) The model can be described with the following equation:

$$I = P \times A \times T \tag{4}$$

The equation illustrates the environmental impact (I), the size of the population (P), consumption per capita (A, as in affluence), and technology (T). The technology factor represents the ratio of resources used per unit of consumption. The model can be applied to various situations associated with the use of natural resources. In the context of energy consumption and energy efficiency, the environmental impact (I) could describe the total primary energy consumption. (Ehrlich and Holdren, 1971, 1212-1213; Eriksson and Andersson, 2010, 9-18.)

When governments are implementing new regulatory measures to promote energy efficiency, they are actively trying to affect the technology factor (T) in order to reduce the environmental impact (I). In other words, if energy efficiency is improved, it leads to the lower value of the technology factor (T), as the ratio of resources used per unit of consumption has diminished. Therefore, from the perspective of energy efficiency, the technology factor of the IPAT – model is of particular interest. (Alcott, 2008, 770.)

A relevant question to ask is how far the technology factor (T) can be reduced in the IPAT-model? Furthermore, is it possible to decouple economic growth (P x A) from the use of natural resources? (Eriksson and Andersson, 2010, 18; Bithas and Kalimeris, 2013, 78.) The EKC views this issue in an optimistic light, and conveys a message that economic growth does not have to be in conflict with environmental conservation (Turner and Hanley, 2011, 709). Originally, the EKC is a hypothetical model introduced by Grossman and Krueger (1995, 353-372). It is founded on the work of Simon Kuznets (1955, 1-27), who originally proposed a hypothesis that market forces first increase and later decrease the income inequality in a growing economy. Grossman and Krueger (1995, 353-372) adopted Kuznets' logic in the context of economic growth and environmental degradation.

The EKC model portrays economic growth as a necessity to offset environmental degradation. According to the hypothesis, the technology factor (T) increases in the early stages of economic growth, but starts to decline as the economy surpasses a certain level of growth. This relationship between the level of environmental degradation and economic growth can be perceived as an inverted U-shaped curve (figure 2). This progression is grounded on the assumption that technological development takes place when an industry reaches a certain level of maturity. (Kaika and Zervas, 2013, 1393; Eriksson and Andersson, 2010, 18.) As a result, further economic growth can be associated with falling levels of environmental pollution (Turner and Hanley, 2011, 709).

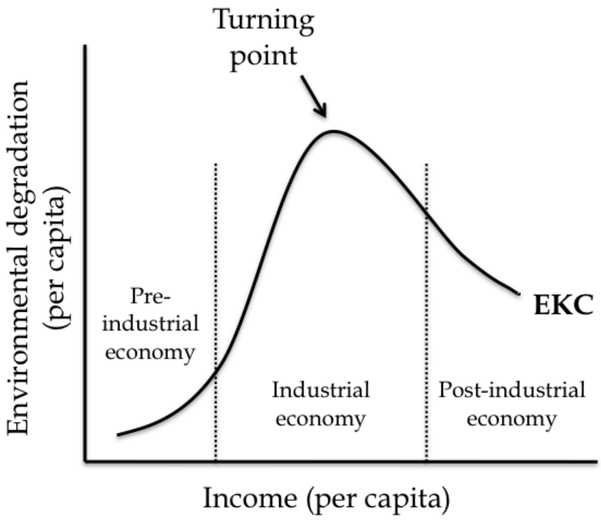

FIGURE 2 Environmental Kuznets Curve (Kaika and Zervas, 2013, 1394.)

There exists a large amount of theoretical and empirical studies of the EKC. However, these studies incorporate a considerable inconsistency among their results. (Kaika and Zervas, 2013, 1400.) For this reason, the validity of the theory has been questioned, especially in the context of carbon dioxide emissions (Wagner (2008, 403-404). Furthermore, Vollebergh et al. (2009, 27-28), Wagner (2008, 403-404) and Stern (2010, 2180-2182) have identified various fundamental econometric problems among the conducted empirical EKC literature. Considering these methodological shortcomings, Stern (2010, 2173) argues that the empirical evidence does not support the tenability of the EKC hypothesis. Interestingly, Turner and Hanley's study (2011, 709-710) highlights that in the context of technological change, it would be revealing to observe EKC in conjunction with the phenomenon of rebound effect. The rebound effect, also known as the Jevons Paradox, is a significant factor making the decoupling of economic growth from the use of energy a problematic issue (Eriksson and Andersson, 2010, 18).

2.2.2 The Jevons Paradox

Binswanger (2001, 130) argues that the perceived savings from energy efficiency measures are often overestimated because they tend to ignore the behavioral responses evoked by technological improvements. These behavioral responses lead to the realization of a rebound effect, which may partially or entirely offset the savings resulting from energy efficiency improvement measures. Madlener and Alcott (2009, 371) define the rebound effect as the additional energy consumption enabled by energy efficiency improvements. The magnitude of the rebound can be expressed as a percentage of the perceived savings from energy efficiency improvements (Berkhout et al., 2000, 426). If the magnitude of the rebound exceeds 100%, it results in a situation known as a backfire. Backfire occurs when realized energy efficiency improvements result in a greater energy consumption than it would be without the energy efficiency improvements. (Madlener and Alcott, 2009, 371.) The most commonly known example of a backfire is the situation when economist named W. Stanley Jevons (1906, 140) first identified the rebound effect in 1865. Jevons observed that the national consumption of coal escalated as the first coal-fired steam engine was introduced to markets. This new engine incorporated more efficient technology compared to the earlier engine designs. Jevons concluded that further efficiency improvements would eventually lead to an increased, rather than reduced, consumption of resources. (Jevons, 1906, 140-145.)

In more recent studies, three distinct types of rebund have been identified. The first type of a rebound is the direct rebound effect, which is the increased use of energy services caused by the reduction in their price due to efficiency improvements. In other words, increased energy efficiency results in an income effect. The second type of a rebound deals with the subtitution effect and allows the consumer to purchase more other goods and services due to reductions in the cost of energy services. This is known as the indirect rebound effect. The third type of rebound is the general equilibrium effect, which represents the countless adjustments of supply and demand in the economy caused by falling unit prices of energy. The total effect of a rebound consists of these three preceding types of rebound effects. (Greene et al. 1999, 2-28.)

Currently there exists a scientific consensus of the rebound effect as an empirically proven phenomenon (IPCC, 2014, 28; Saunders, 2000, 439; Berkhout et al., 2000, 431; Herring and Roy, 2007, 195). However, the magnitude of the effect is still under debate, with research literature showing controversial results (IPCC, 2014, 249; Herring and Sorrell, 2009, 241; Binswanger, 2001, 120-212). In the context of direct rebound, empirical research demonstrates that the effect will only likely partially offset the achieved energy savings. The magnitude of the direct rebound typically ranges from 0 to 30% (Sorrell et al., 2009, 1364; Berkhout et al., 2000, 431). However, it has been argued that focusing solely on the direct rebound is insufficient to describe the rebound as a phenomenon (Greene, 1999, 28; Binswanger, 2001, 120-212). A study conducted by Brännlund et al. (2007, 1), for example, indicated a 5 % increase in CO_2 emissions due to a 20% increase in energy efficiency when the indirect rebound effect was taken into account in addition to the direct rebound. Furthermore, Madlener and Alcott (2009, 374) and Hanley et al. (2009, 705) argue that in order to provide sufficient policy advice, the empirical research should aim to measure the total impact of direct, indirect and general equilibrium rebound effect, i.e. the total rebound. However, due to methodological challenges, the measurement of total rebound is not a straightforward task (Herring and Roy, 2007, 202). The results of conducted empirical studies on the total rebound vary, with some showing only a partial offset of energy savings, and some demonstrating a clear situation of a backfire (Hanley et al., 2009, 705; Madlener and Alcott, 2009, 371). The extent of total rebound is always situation-specific and dependent on consumers' preferences, and on the substitutability between goods and services. (Madlener and Alcott, 2009, 371-373.) As Saunders (2000, 446) argues, in order to fully understand the phenomenon, a great deal of empirical research still needs to be done.

2.2.3 Energy efficiency, sustainable development and IPAT-model revisited

As mentioned earlier, energy efficiency is commonly perceived as an important aspect of sustainability (Hanley et al., 2009, 692). Therefore, in this subchapter, energy efficiency is approached from the economic, social, and environmental dimensions of sustainable development. In addition, it is examined if the previously presented criticism towards energy efficiency could potentially alter it's perceived role from the perspective of these three dimensions.

The World Commission on Environment and Development (1987, 43) has defined the concept of sustainable development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable development is considered to cover the following three interdependent and mutually reinforcing dimensions: economic development, social development and environmental protection (United Nations, 2014, 6). As energy production incorporates a variety of environmental and social issues, there exists a close connection between energy conservation and sustainable development (Dincer, 2003, 690). In figure 3, Bunse et al. (2011, 668) have illustrated this connection in the context of industrial manufacturing. Through examples, this figure depicts how energy efficiency may contribute to the three aspects of sustainable development.

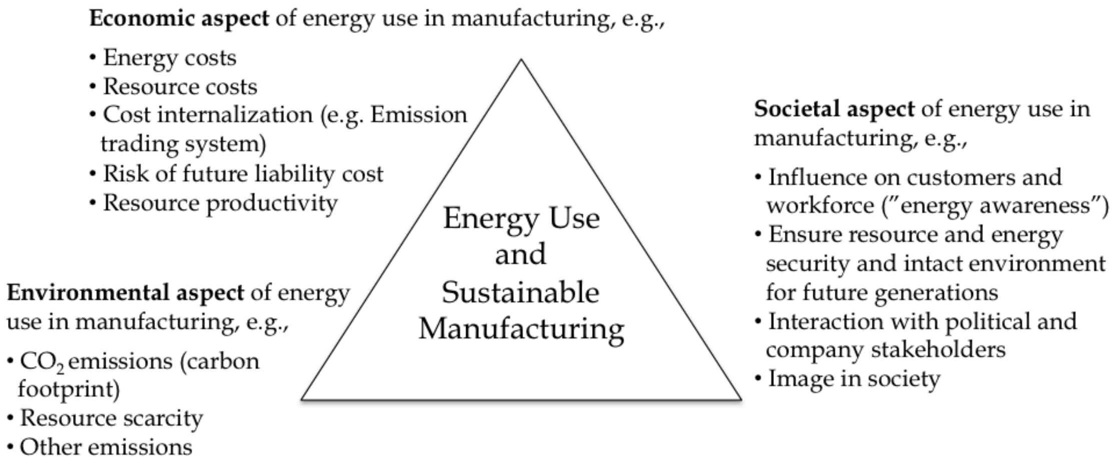

FIGURE 3 Energy efficiency and sustainable manufacturing. (Bunse et al., 2011, 668.)

However, reflecting on the issues brought out in the chapter 2.2.2, should the environmental aspect of this model be reconsidered? Considering the rebound effect, what role does energy efficiency have from the perspective of sustainable development? This question can be approached by observing the phenomenon from the perspective of IPAT-model.

When applied in the context of IPAT-model, the rebound effect suggests that increases in energy efficiency would lead to the diminution of the technology multiplier T and to the growth of affluence multiplier A. The resulting impact on total energy consumption (I) would therefore be dependent on the relative changes between these two factors:

$$I = P \times A\uparrow \times T\downarrow \quad (5)$$

Contemplating the IPAT-model from this perspective highlights an important issue brought up in the chapter 2.2.1. This issue is that governmental energy efficiency programmes do not take the growth of affluence multiplier A into account, since they implicitly assume that rebound equals zero (Madlener and Alcott, 2009, 374). This is an interesting issue, since the rebound effect is considered to be an empirically proven phenomenon (IPCC, 2014, 28; Saunders, 2000, 439; Berkhout et al., 2000, 431; Herring and Roy, 2007, 195).

As Brännlund et al. (2007, 15) argue, the rebound effect casts doubt on the validity of the hypothesis that energy efficiency reduces the environmental burden of economic activity. It is therefore important to recognize that energy efficiency may not always necessarily lead into energy conservation or decreased emission levels (Madlener and Alcott, 2009, 370). On the other hand, when we observe energy efficiency from the two remaining aspects of sustainable development (figure 3), the increasing levels of energy efficiency can be seen as a central part of vibrant economy and high quality of life. Therefore, although the extent of the environmental merits of energy efficiency can be questioned, energy efficiency should nevertheless be promoted on the economic and social welfare grounds.

As stated, the current scientific evidence leaves the environmental outcomes of energy efficiency more or less unanswered. In order to address the negative impact of the rebound effect, researchers in the field of social sciences have advocated that energy efficiency should be combined with the concept of sufficiency (Herring and Sorrell, 2009, 241). Sufficiency, from behavioral and ethical aspect, refers to the individuals' abilities to be sensitive to critical environmental risks, and to the needs of management and self-management in situations where voluntary restrained consumption is needed to avert such risks (Princen, 2005, 19). From the perspective of the IPAT-model, this activity would decrease the affluence factor (A) of the model (Alcott, 2008, 770). However, despite its importance from the perspective of consumer behaviour, it can be argued that sufficiency is largely incommensurable with contemporary economic activities, such as the profit maximization goal of business organizations. Although organizations may prioritize also other than purely economic goals (Kolk and Tulder, 2010, 119-120), sufficiency as a form of doing business would arguably demand fundamental changes in the economic code of practice.

From a more technical perspective, the rebound phenomenon emphasizes the importance of what energy sources we utilize in our energy production. As Herring (2006, 19) argues, a sustained energy growth with lower CO_2 emissions could be achieved by shifting to less carbon intensive fuels. The aforementioned argument by Herring provokes a thought whether we should adopt a broader view on energy efficiency, i.e. a view that would also take the utilized energy sources into account. Sivill (2011, 38), who approaches the issue from the perspective of business management, argues that this would be advisable in the context of industrial energy management. This issue, and performance measurement in general, will be discussed more in-depth during the next chapter.

3 PERFORMANCE MEASUREMENT

3.1 Defining performance measurement

Performance measurement has been largely studied across different fields of research, and depending on the research field, the literature shows varying definitions for the concept (Franco-Santos et al., 2007, 785). Neely et al.'s. (2002, 13) "the process of quantifying the efficiency and effectiveness of past actions" is the most commonly quoted definition for performance measurement. Although this definition captures the essence of performance measurement from the operational aspect, it perceives the concept from a rather narrow viewpoint, neglecting which organizational issues should be quantified, and why should they be quantified (Moullin, 2007, 181). Moullin (2002, 188) has attempted to broaden the concept by proposing the following definition for performance measurement: "evaluating how well organizations are managed and the value they deliver for customers and other stakeholders". This latter definition succeeds to imply why and how performance measurement should take place in an organization, and takes into account the strategic dimension of the concept (Moullin, 2007, 181). According to Gates (1999, 4), performance measurement can be viewed as a measure for translating business strategies into deliverable results. Furthermore, Ittner et al. (2003, 715) argue that performance measurement provides organization with information that allows the critical evaluation of a chosen strategy. Thus, performance measurement can be perceived from both operational and strategic perspectives. In essence, as Sivill (2011, 17) points out, performance measurement can be defined as continuous improvement in operational management, and translating vision into action in strategic management. Therefore, a performance measurement system may incorporate both operational and strategic dimensions at the same time (Sivill, 2011, 17).

A performance measurement system is the outcome of performance measurement, where single measures of performance interactively form a larger entity (Kankkunen et al., 2005, 17-18). In addition to these measures, a supporting infrastructure is seen as crucial feature of a performance measurement system. A supporting infrastructure can refer to simplistic manual methods of collecting data or to more sophisticated information systems that enable data to be acquired, collated, sorted, analysed, interpreted and disseminated. As the common purpose of performance measurement systems is to reach certain organizational goals, organizational objectives can also be seen as a central feature of these systems. However, this is not always the case, as some performance reports, such as financial accounts, do not necessarily incorporate any specific performance objectives. (Franco-Santos et al., 2007, 796-797.)

Performance measurement systems, in turn, can be seen as a crucial component of management control systems, which direct and influence organizational activities (Merchant and Stede, 2012, 33). Therefore, performance measurement can be perceived to incorporate a directive role in an organization (Kankkunen et al., 2005, 237). According to Epstein (2008, 128), a performance measurement system allows organizations to communicate and harmonize their strategy throughout the organization. In addition, a measurement system gives feedback about the effectiveness of the chosen strategies. (Epstein, 2008, 128.) From this perspective, performance measurement has a central role in motivating employees and supporting decision-making towards organizational goals. (Kankkunen et al., 2005, 237.) Moreover, Franco-Santos et al. (2007, 797) argue that organizational learning can be seen as the paramount for successfully designing, maintaining and using a performance measurement system. Therefore, performance measurement also has a central role from the learning perspective in an organization.

Past research (Ittner er al, 2003, 715; Otley, 1999, 363) has identified several different processes in the design, maintenance and use of performance measurement systems. Franco-Santos et al. (2007, 797-798) have grouped these processes into five distinct categories: design and selection of measures, acquisition and manipulation of data, information management, evaluation of performance and rewarding, and review procedures that provide a feedback loop within the system. Each of these processes can happen at individual, team, or organizational levels. (Franco-Santos et al., 2007, 797-798.)

3.1.1 Measures of performance

In practice, performance measurement focuses on the performance of organizational entities or employees (Merchant and Stede, 2012, 33). Organizations use many different types of measures to assess their performance, and these measures can be classified from various perspectives (Kankkunen et al., 2005, 135). One common way to classify performance measures is to divide them into objective and subjective measures. Objective measures include financial measures, such as earnings per share and return on assets, and non-financial measures, such as market share and customer satisfaction. (Merchant and Stede, 2012, 33-34.) Subjective measures are typically used to complement the objective measures. These measures rely on the availability of information, and are based on the subjective judgements of the evaluator. (Epstein, 2008, 129-130.) The acquisition and treatment of information is typically more straightforward with objective measures than with subjective measures. On the other hand, subjective measures may reveal organizational problems sooner than objective measures. Subjective measures may also help organizations to identify the underlying reasons for these problems. A balanced mix of objective and subjective measures is perceived as the prequisite for successful performance evaluation (see e.g. Kaplan and Norton, 1996). The eligible balance between the measures is dependent on context, and is directed by the chosen organizational strategies. (Kankkunen et al., 2005, 135-137.)

The measures of performance can also be classified as strategic or operational measures (Kankkunen et al., 2005, 21). Strategic and operational measures are often founded on differing premises. Whereas strategic performance measures are directly derived from the strategy of an organization, operational performance measures may be used to provide control over operational activities at a local level. (Kankkunen et al., 2005, 170; Merchant and Stede, 2012, 34.) To some extent, it is possible to derive operational performance measures from strategic performance measures. These measures aim to direct operational activities in alignment with chosen organizational strategies. However, many operational measures do not represent any actual strategic characteristics and are solely focused on directing operational processes. (Kankkunen et al., 2005, 21.)

In general, the performance measures vary across different organizational levels (Merchant and Stede, 2012, 34). The performance measures used by top management typically focus more on strategic and financial perspectives rather than on operational and non-financial perspectives. Respectively, the operational perspective is more emphasised in the performance measurement of lower organizational levels. (Kankkunen et al., 2005, 167.)

Epstein (2008, 131) emphasises that organizations should include environmental and social indicators in their performance measurement systems. This way the performance measurement acts as an effective instrument to promote sustainability in a business context. By including environmental and social indicators in the performance evaluation, sustainability objectives can be aligned with the overall strategy of the company. (Epstein, 2008, 131-132.)

According to Merchant and Stede (2012, 36-39), the performance measurement system should express the seven following characteristics:

1. The measures of performance should be congruent with the objectives of the organization. Incongruent measures may motivate employees towards unwanted behaviour.
2. The used measures should adhere to the principle of controllability. The controllability principle implies that measures are useful only to the extent that they provide information about the excecuted actions. Performance measurement might be rendered ineffective if uncontrollable factors affect the results of the measurement.
3. The measures should meet a satisfactory degree of precision, as lack of precision is an undesirable quality of a performance measure. However, all measures inherently contain some level of systematic or random error. Some subjective aspects, such as social responsibility, might even be impossible to measure in a precise manner.
4. The measures should not reflect personal interpretations. In other words, the measures should be as unbiased as possible. In order to increase the objectivity, external auditors can be used to verify the measurements.
5. The results of the measurement should be available in a timely manner. Timely measurement helps organizations to identify and intervene problem situations. Also the motivational impact of measurement could be impaired if the results of measurement are significantly delayed.
6. It is important that the used performance measures are understandable by nature. The employees need to understand how to influence the measures which they are being held accountable for.
7. The benefits of the measurement should exceed the incurred costs. Even a decent performance measure may be rendered unusable if it is too expensive to maintain or develop.

In practice, there exists various tradeoffs between the characteristics presented above. Due to these tradeoffs, all performance measures incorporate certain advantages and disadvantages. This leads to the fact that performance measures cannot be simply classified as effective or ineffective. (Merchant and Stede, 2012, 39.) As Meyer (2003, 53-54) argues, perfect measures of performance do not exist, and finding the best of the imperfect measures is a central challenge for performance measurement.

Gray et al. (2015, 15) highlight that as a performance measurement system aims to assess an organization as a whole, the robustness of performance measures should be assessed both individually and collectively. The effectiveness of a performance measurement system is dependent on what kind of entity the system forms and how this entity serves a particular context situation (Kankkunen et al., 2005, 133-137). In essence, performance measurement needs to be considered as a part of a wider whole, working in conjunction with other organizational processes, such as routines, rituals, training programmes and reward systems (Micheli and Manzioni, 2010, 473).

3.2 Energy performance measurement

Energy performance measurement can be seen as an application of business performance measurement (Sivill et al., 2013, 938). This subchapter examines the concept of energy performance measurement from the perspective of energy end-use management.

Energy performance is a context-dependent concept, with varying definitions in the literature. The term is quite often used as a synonym for energy efficiency (e.g. Tanaka, 2008, 2887-2888; O'driscoll et al., 2013, 2205), whereas other sources expand the concept by considering other important performance areas (such as cost, flexibility, delivery time and quality) concurrently with energy efficiency (Bunse et al., 2011, 668). However, all different definitions share the fact that energy performance is founded on the first and second laws of thermodynamics (Sivill et al., 2013, 939). Energy performance is also typically seen as an integral component of energy management (O'driscoll et al., 2013, 2207; International Organization for Standardization, 2011, 1-25). For this reason, the definition of energy performance is dependent on how energy management is defined in a particular context. (Sivill et al., 2013, 937.) O'Callaghan and Probert (1977, 128) have given the following definition for energy management:

> *"Energy management applies to resources as well as to the supply, conversion and utilization of energy. Essentially it involves monitoring, measuring, recording, analyzing, critically examining, controlling and redirecting energy and material flows through systems so that least power is expended to achieve worthwhile aims" (O'Callaghan and Probert, 1977, 128.)*

More recently, Capehart et al. (2012, 1) have proposed a definition for energy management that explicitly states what these ”worthwhile aims” are:

> *”The efficient and effective use of energy to maximize profits (minimize costs) and enhance competitive positions” (Capehart et al., 2012, 1.)*

From these perspectives, energy management is seen as a functional part of operational management, separated from other management functions. However, in practice, energy management not only affects energy demand and costs, but also other energy-related environmental and social aspects. (Sivill et al., 2013, 937.) These aspects may have an impact on customers’ loyalty (Du et al., 2007, 237), customers’ willingness to pay (Creyer, 1996, 173), shareholders’ willingness to invest (Petersen and Vredenburg, 2009, 617-619), and on the risk to be blamed by stakeholders in a crisis setting (Klein and Dawar, 2004, 216). Respectively, all other management functions have a direct or indirect effect on energy performance. Therefore, from a broader perspective, energy management can be seen as a part of sustainability management, which aims to integrate the management of economic, environmental and social factors. In addition, this latter perspective encompasses operational and strategic dimensions, whereas the former, as presented by O’Callaghan and Probert (1977, 128) and Capehart et al. (2012, 1), focuses solely on the operational level. (Sivill et al., 2013, 937-939.) This thesis applies the concept of energy performance which follows the presented broad perspective on energy management, as defined by Sivill:

> *”Energy end-use performance in business management is related to activities which influence: 1) the efficiency of energy production and consumption; 2) the sources of energy used for manufacturing products, and 3) the value added in the activities related to the previous two. The goal of energy performance is to increase the margin of profit or the growth of revenue.” (Sivill, 2011, 31.)*

Importantly, Sivill’s concept of energy performance differs from the concept of energy efficiency as it considers compromises between energy efficiency and other profitability factors. In this context, the other profitability factors may include direct factors, such as market prices for energy, or indirect factors, such as stakeholders’ environmental and social concerns. Technically, energy efficiency can be improved through improving operations, investing in more efficient technology, or by improving process integration. The value of these improvements are determined by the other profitability factors. (Sivill, 2011, 31-32.) In practice, the estimation of this monetary value is not a straightforward task, as there is no consistent way to estimate the monetary value for the direct profitability factors (Siitonen and Holmberg, 2012, 324). Furthermore, the value of indirect profitability factors are strongly dependent on interpretation, which poses further challenges for value estimation (Peloza and Shang, 2011, 117-119; Bateman and Willis, 1999, 17-20). In essence, the comprehensive literature review of Peloza and Shang (2011, 127) showed that in the context of corporate responsibility activities, the created stakeholder value is implicitly assumed but not actually explicitly measured.

In energy performance measurement, the measurement process is realized through energy performance indicators. Like energy efficiency indicators, also the energy performance indicators can be divided into descriptive and explanatory indicators (Patterson, 1996, 377; Sivill et al., 2013, 939). Energy performance indicators also share the same methodological issues as energy efficiency indicators (see chapter 2.1). As figure 4 shows, energy performance indicators need to be designed in temporal, organizational and systemic dimensions. From the organizational perspective, it is important to consider for whom the measure is targeted at, as actors at different organizational levels have differing needs of information (Kankkunen et al., 2005, 170; Merchant and Stede, 2012, 34). As an example, the operational level may find physical-thermodynamic indicators most useful, whereas actors at managerial level may also be interested in economic-thermodynamic indicators (Patterson, 1996, 380-384). From the temporal perspective, the energy performance indicator needs to be defined if it's meant to monitor value changes over time, predict future potential, or desired to enable a fast reaction to fault situations. Data can also be collected at different aggregation levels, from a single equipment or a sub-system to company or supply chain levels. As different system levels represent different entities, system boundaries have to be defined for energy performance indicators. (Sivill et al., 2013, 939; Sivill, 2011, 30-31.)

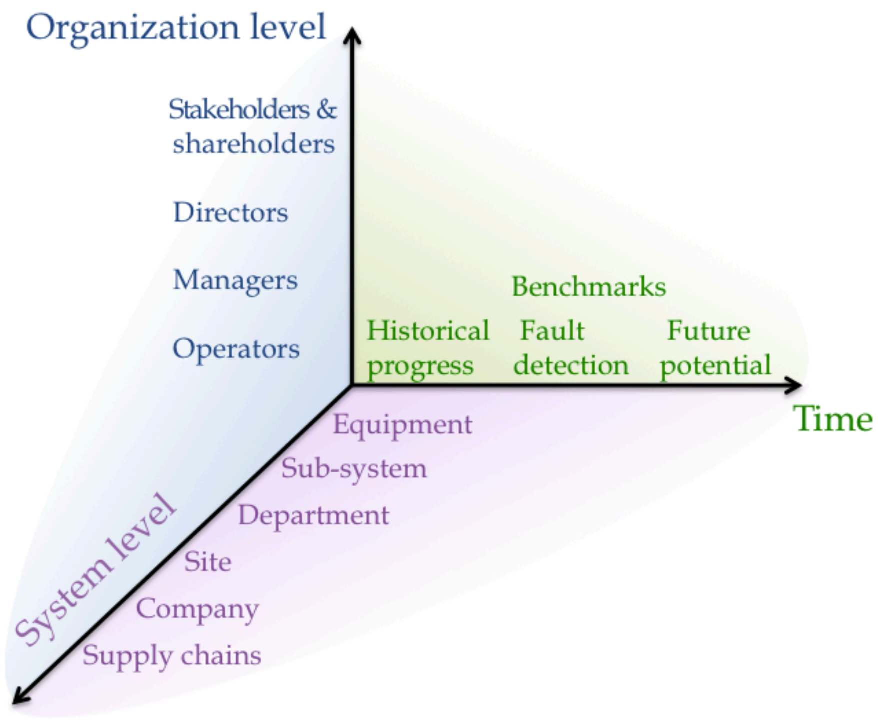

FIGURE 4 Dimensions of energy performance measurement. (Sivill, 2011, 31.)

In summary, it is important to acknowledge the characteristics that differentiate the concept of energy performance from the concept of energy efficiency. From the environmental and social perspective, energy performance extends the concept of energy efficiency by taking into account the utilized energy sources. By doing so, it may potentially address the increased CO_2 emission levels caused by the rebound effect, as expressed in chapter 2.2.3. The selection of an energy source is directed by the direct profitability factors (e.g. market prices) and indirect profitability factors (e.g. stakeholders' environmental concerns). Essentially, the concept of energy performance is also able to capture both strategic and operational dimensions of business management. (Sivill, 2011, 38.) This conceptual transition is consistent with the recent trends in management, as boundaries between various management functions are becoming increasingly integrated, and sustainable development is becoming a central factor in business strategies (Sivill, 2011, 38; Schönsleben et al., 2010, 477; Gond et al., 2012, 205-206; Virtanen et al., 2013, 412-413; Wagner, 2007, 621-622; Zeng et al., 2007, 1766).

Still, from a holistic management perspective there still exists no definition or a framework for energy performance measurement. Little is also known how organizational actors in strategic and operational level interpret energy performance measurement and how it is currently measured in organizations. As the concept of energy performance has not yet reached an institutionalised position, it continues to evolve in the interaction of performance measurement, environmental responsibility, and sustainable development. (Sivill, 2011, 22-39.)

3.3 Critique towards performance measurement

In essence, performance measurement is typically used to provide rational discourse within an organization. This rational discourse often aims to bring clarity to complex and confusing situations. However, this is not always the case as performance measurement has the potential to turn out to be dysfunctional for organizations. (Micheli and Manzioni, 2010, 472.) In fact, there exists only a limited amount of empirical research examining the role of performance measurement in organizational effectiveness. The current evidence about the usefulness of performance measurement still remain inconclusive. (Tung et al., 2011, 1288; Upadhaya et al., 2014, 855; Propper, 2003, 264.) A typical example of the unintended consequences of performance measurement is when the total number of performance measures grows large. Increasing amounts of measurement information may allow more precise analysis and verifiability, but may also become too complex to follow. This may lead to the inhibition of effective decision-making. (Niemelä et al., 2008, 105; Delmas et al., 2013, 262.) From another perspective, organizational actors have the ability to steer the rational discourse by deciding what is measured and how it is measured. This may lead to the promotion of certain interests within an organization, without any actual aim to measure the genuine performance of the organization. (Micheli and Manzioni, 2010, 472; Delmas et al., 2013, 263.)

As stated, performance measurement has been widely criticized for its ability to turn out to be dysfunctional for organizations. Unpredicted consequences of performance measurement may include encouragement of dysfunctional behaviour, repressment of innovation, suppression of learning, and inability to make an impact on decision-making. (Micheli and Manzioni, 2010, 465.) This dysfunctional behaviour may take many forms, including gaming, tunnel vision, myopia, measure fixation, sub-optimization, misrepresentation and misinterpretation (Smith, 1995; Goddard et al., 2000, 103-105). In their research, Goddard et al. (2000, 95) showed that these unintended behaviours can be derived from the theoretical principal-agent model. They further argue that all these different forms of behaviour can be explained by the asymmetric aims between the agent and the principal. As the principal implements performance measurement in order to get higher effort from the agent, the outcome may be better services, but also other less desired behaviour (Propper, 2003, 252).

In addition to the presented behavior-related issues with performance measurement, it is interesting to contemplate how accurately these measures are able to describe the reality. Based on her research findings, Chwastiak (2006, 51) has argued that the rational discourse produced by performance measurement can never capture and regulate the diversity of all human endeavors. This finding is in line with Merchant and Stede's (2012, 39) argument that all measures of performance incorporate certain advantages and disadvantages. In the absence of so-called perfect measures, Gray et al. (2015, 19) argue that organizations are dependent on ”proxies” in their attempt to represent their true performance. Using proxies to estimate performance may cause problems if these measures are regarded to actually depict the true performance of an organization. In other words, if these measures are considered to represent the reality, organizational actors may be drifted to act based on these indicators. If means become ends, counterproductive effects may emerge and lead to the undermining of the true performance. (Gray et al., 2015, 19.)

In addition to the critique presented above, performance measurement has also been criticized for its ability to construct subjective reality. As performance measurement provides a rational discourse within an organization, it can be used as a medium to promote a variety of interests. (Delmas et al., 2013, 263.) From the perspective of social construction, we simultaneously represent and construct the world through language. Reality enters human practices by how people constitute the world in their speech, writing and arguing. As representations are formed by human practices, it is possible to construct different realities. (Potter, 1996, 97-98.) These representations form our understanding of the world, and they can also be used as a political act to guide our subjective perspectives (Hall, 1988, 149-154).

From this perspective, performance measurement may be a conscious attempt to construct a certain reality. Attempts to create reality can be found in the context of sustainability measurement, for example. Everett and Neu (2000, 23-24) and Gray (2010, 52) argue that the efforts to measure sustainability often aim to communicate a certain state, or a reality, of the organizations' sustainability. Through this communication, the organizations are simultaneously constructing the concept of sustainability. But can performance measurement capture the whole essence of the concept? Social and environmental performance, after all, is essentially an artificial construct that can be evaluated and interpreted in many ways. Some issues are inevitably prioritized over others when data is selected and aggregated into a performance measure. If emphasis is placed on greenhouse gas emissions, for example, it only touches the surface of the many ways human activity can affect the natural environment. (Delmas et al., 2013, 256.)

Furthermore, Micheli and Manzioni (2010, 472) found out that performance measures are often used solely for symbolic purposes, without any meaningful intention to reach substantial results. Performance measurement might be utilized in order to increase the relative power of a department within an organization, or to acquire a greater legitimacy by satisfying the demands of external stakeholders. Palme and Tillman (2008, 1346) have made a similar observation in practice: although the sustainability indicators are frequently used in stakeholder communication, the actual contribution to sustainable development remain slim, as the indicators have no considerable role in the decision making process of an organization. ”There is very little evidence of anyone actually walking the talk” as Laine (2005, 395) summarises his research. These observations are in line with the study conducted by Delmas et al. (2013, 263) where researchers found out that organizations may excel at governing, reporting and utilizing environmental performance systems, and still produce pollution to a large extent.

4 BARRIERS TO ENERGY EFFICIENCY

4.1 Barriers and their categorization

Although the level of energy efficiency has improved throughout the years (European commission, 2010), a significant energy saving potential still remain untapped (IPCC, 2014, 709). This misalignment between the actual and optimal level of energy efficiency is called the energy efficiency gap (Jaffe and Stavins, 1994, 804). Researchers have tried to address the energy efficiency gap by identifying barriers which impede the organizations' ability to adopt measures for energy efficiency improvement. This so-called barrier theory is a generally accepted model for explaining the persisting existence of the energy efficiency gap (IPCC, 2014, 709; Thollander, 2013, 637). The accumulated literature on the topic is extensive, as the topic has been studied since the late 70's (Trianni et al., 2013, 162). Energy efficiency and it's associated barriers constitute a multi-discplinary issue, and it has been studied in many different fields of research, ranging from economics to ecology and psychology. (Chai and Yeo, 2012, 460; Stern, 1992, 1224.)

Barriers are strongly context-dependent as different nations, regions and organizations incorporate varying social obstacles and market imperfections. Also different stakeholder groups, cultures, technology utilized and the type or phase of energy consumption affect the level of the barriers. (IPCC, 2014, 709; Viinikainen and Soimakallio, 2007, 23.) Industrial manufacturing is well represented in the research literature, incorporating both theoretical and empirical studies, with theoretical studies being relatively more abundant. (Trianni et al., 2013, 163.) Typically researchers have attempted to identify different barriers to energy efficiency adoption, and have assigned these barriers to distinct barrier groups or categories. Common barrier groups identified in the literature include economic market failures (e.g. split incentives and insufficient or inaccurate information), economic non-market failures (e.g. cost of production disruption and low priority on energy issues), behavioral barriers (e.g. resistance to change), organizational barriers (e.g. energy manager lacks influence and lack of environmental policies within company), institutional barriers (e.g. lack of government incentives and weak legislation) and physical constraints (e.g. inappropriate technology and technical dependency). (Brown, 2001; Sorrel et al., 2000; Weber, 1997; Thollander and Ottosson, 2008; UNEP, 2006; Nagesha and Balachandra, 2006; Sardianou, 2008; Zilahy, 2004.)

Table 1 reviews the typical barriers and barrier categories identified in the current scientific literature. The table is adapted from Chai and Yeo (2012, 463) and was supplemented with relevant literature (Sleich, 2009; Trianni et al., 2013; Hasanbeigi et al., 2010; Zilahy, 2004; Viinikainen and Soimakallio, 2007; Kostka et al., 2013; Soroye and Nilsson, 2010; Sola and Xavier, 2007).

Category	Typical Barriers	References
Economic non-market failure or market barriers (Sorrel et al., 2000; Brown, 2001)	Low priority of energy issues	Brown (2001), Sleich (2009), Trianni et al. (2013), Hasanbeigi et al. (2010), Zilahy (2004), Viinikainen and Soimakallio (2007)
	Cost of production disruption	Rohdin and Thollander (2006), Thollander and Ottosson (2008), Thollander and Dotzauer (2010), Trianni et al. (2013), Hasanbeigi et al. (2010)
	Other priorities for capital investments	Rohdin and Thollander (2006), Thollander and Dotzauer (2010), Sardianou (2008), Trianni et al. (2013), Viinikainen and Soimakallio (2007)
	Lack of time/other priorities	Rohdin and Thollander (2006), Nagesha and Balachandra (2006), Thollander and Dotzauer (2010), Sleich (2009), Kostka et al. (2013), Trianni et al. (2013), Hasanbeigi et al. (2010)
	Reluctant to invest because of high risk	Wang et al. (2008), Soroye and Nilsson (2010), Trianni et al. (2013)
	Technical risk such as risk of production disruptions	Thollander and Ottosson (2008), Trianni et al. (2013)
	Competition from other projects	Ren (2009)
	Lack of management support	UNEP (2006), Sola and Xavier (2007), Hasanbeigi et al. (2010)
	Limited access to capital	Rohdin and Thollander (2006), UNEP (2006), Thollander and Dotzauer (2010), Sardianou (2008), Trianni et al. (2013)
	Capital market barriers	Brown (2001)
	Lack of investment capability	Nagesha and Balachandra (2006)
	Lack of funding/financing capabilities	Wang et al. (2008), Kostka et al. (2013), Hasanbeigi et al. (2010), Zilahy (2004), Viinikainen and Soimakallio (2007)
	Uncertainty about future energy price	Thollander and Dotzauer (2010), Sardianou (2008), Viinikainen and Soimakallio (2007)
	Increased perceived cost of energy conservation measures	Sardianou (2008), Hasanbeigi et al. (2010), Zilahy (2004)
	Cost of identifying opportunities, analyzing cost effectiveness and tendering	Thollander and Ottosson (2008), Thollander and Dotzauer (2010), Rohdin and Thollander (2006), Trianni et al. (2013)
	Uncertainty regarding the company's future	Trianni et al. (2013)
	Perception that technology will become cheaper	Hasanbeigi et al. (2010)
	Annual budgeting format	Viinikainen and Soimakallio (2007)
	Separated budgets for investments and for operation and maintenance	Viinikainen and Soimakallio (2007)
	Cost of staff replacement/retirement/ retraining	Trianni et al. (2013)
Economic market failure (Sorrell et al., 2000; Brown, 2001)	Split incentives	Brown (2001), Sleich (2009), Trianni et al. (2013), Zilahy (2004), Viinikainen and Soimakallio (2007)
	Un-priced cost and benefits	Brown (2001), Viinikainen and Soimakallio (2007)
	Insufficient and inaccurate information	Brown (2001), Wang et al. (2008), Ren (2009), UNEP (2006), Nagesha and Balachandra (2006), Thollander and Ottosson (2008), Soroye and Nilsson (2010), Sola and Xavier (2007), Zilahy (2004), Trianni et al. (2013)
	Lack of experience in technology and management	Wang et al. (2008), Ren (2009)
	Difficulties in obtaining information about the energy consumption of purchased equipment	Thollander and Dotzauer (2010), Sleich (2009), Trianni et al. (2013)
	Lack of technical skills	Thollander and Dotzauer (2010), Sardianou (2008), Trianni et al. (2013), Sola and Xavier (2007), Viinikainen and Soimakallio (2007)

	Lack of trained manpower	Wang et al. (2008), Thollander and Dotzauer (2010), Thollander and Ottosson (2008), Rohdin and Thollander (2006), Sardianou (2008), Kostka et al. (2013), Zilahy (2004), Viinikainen and Soimakallio (2007)
	Lack of information on profitability of energy saving measures	Sardianou (2008), Wang et al. (2008), Kostka et al. (2013), Viinikainen and Soimakallio (2007)
	Lack of information with respect to energy conservation opportunities	Sardianou (2008), Sleich (2009), Trianni et al. (2013), Hasanbeigi et al. (2010), Viinikainen and Soimakallio (2007)
Behavioral (Sorrell et al., 2000)	Resistance to change	Nagesha and Balachandra (2006)
	Desire for comfort	Viinikainen and Soimakallio (2007)
	Current situation is perceived as sufficiently efficient	Hasanbeigi et al. (2010)
Institutional (Weber, 1997)	Weak legislations and/or enforcement	UNEP (2006), Nagesha and Balachandra (2006), Kostka et al. (2013), Hasanbeigi et al. (2010)
	Lack of government incentives	UNEP (2006), Kostka et al. (2013), Hasanbeigi et al. (2010), Viinikainen and Soimakallio (2007)
	Lack of coordination between external organizations	Hasanbeigi et al. (2010), Sola and Xavier (2007)
	Uncertainty that new technologies will not satisfy future standards	Hasanbeigi et al. (2010)
Organizational (Sorrell et al., 2000; Weber, 1997)	Lack of sense of corporate social responsibility or environmental values	Rohdin and Thollander (2006), Zilahy (2004)
	Lack of environmental policies within company	UNEP (2006)
	Energy manager lacks influence	Sardianou (2008), Trianni et al. (2013)
	Lack of sub-metering	Thollander and Dotzauer (2010), Thollander and Ottosson (2008), Trianni et al. (2013)
	Improper company structure	Zilahy (2004), Kostka et al. (2013), Trianni et al. (2013), Hasanbeigi et al. (2010)
	Poor communication	Zilahy (2004)
	Staff not accountable for energy issues	Trianni et al. (2013)
	Short-term planning	Zilahy (2004), Sola and Xavier (2007), Viinikainen and Soimakallio (2007)
Physical constraints	Inappropriate technology at site	Thollander and Dotzauer (2010), Wang et al. (2008), Trianni et al. (2013)
	Inappropriate industrial framework	Wang et al. (2008)
	Technical dependency	Zilahy (2004)

TABLE 1 Identifying barriers to energy efficiency from the reviewed literature. Adapted from Chai and Yeo (2012, 463) and supplemented with relevant literature.

As can be seen from Table 1, many of the barriers identified in the literature are essentially similiar to each other. The overlaps between the barriers constitute a central problem, as they may cause inaccurate and misleading categorization. This, in turn, may cause further problems when the barriers are studied empirically. Therefore, there is a need to reduce the barriers to the minimum in order to prevent overlaps. (Cagno et al., 2013, 306.) In their literature review, Chai and Yeo (2012, 463) attempted to reduce the barriers into the following 13 key barriers:

- Fear of technical risk / cost of production loss
- Perceived high cost of energy investment
- Other capital investments are more important
- Uncertainty about future energy price
- Lack of experience in technology
- Lack of information in energy efficiency and savings technology
- Lack of trained manpower/staff

- Lack of energy metering
- Lack of access to capital/ budget
- Lack of government incentives
- Weak policies and legislations
- Resistance to change
- Legacy system

The integration and reduction of the barriers into specific key barriers is argued to support the data collection and discussion in the future research (Chai and Yeo, 2012, 462). In their recent study, Cagno et al. (2013, 306) have also proposed a new sophisticated taxonomy that aims to reduce the number of energy efficiency barriers to an adequate level.

In addition to the efforts to identify and classify the barriers to energy efficiency adoption, the researchers have also attempted to recognize the most significant barriers and barrier groups. Interestingly, despite the extensive scientific literature on the subject, there exists no general agreement on which barriers are the most important. As mentioned before, the significance of different barriers and barrier groups is heavily dependent on the context of the research. As an example, some researchers have stressed the significance of imperfect markets to the adoption of energy efficiency measures (Brown, 2001, 1197), while others may highlight financial and economic barriers (Nagesha and Balachandra, 2006, 1978-1979), information barriers (Schleich, 2009, 2150), organizational barriers (Zilahy, 2004, 311; Sola and Xavier, 2007, 5784) or behavioral barriers (Nagesha and Balachandra, 2006, 1978-1979). Furthermore, as Chai and Yeo (2012, 460-461) argue, although the attempt to classify barriers into categories is interesting, it does not uncover any new information regarding the nature of the barriers. In order to further the scientific knowledge on the subject, the adoption of a novel approach may be required. Understanding the interactions between the barriers might potentially offer this kind of approach.

4.2 Interactive nature of the barriers

An essential, but largely overlooked, characteristic of energy efficiency barriers is their ability to influence each other. Current literature on energy efficiency barriers has focused to analyze single barriers or barrier groups in isolation, leaving the barrier-barrier interactions without consideration. As a matter of fact, the research on the interactions of energy efficiency barriers has only taken its first steps through studies conducted by Wang et al., (2008), Chai and Yeo (2012) and Cagno et al. (2013). In other words, there currently exists a lack of scientific knowledge in the holistic understanding of energy efficiency barriers. (Wang et al., 2008, 1879-1880; Chai and Yeo, 2012, 460.) According to the Viinikainen and Soimakallio (2007, 25), the comprehensive removal of barriers has proven to be challenging in practice, as the removal of a single barrier may intensify another barrier or produce a new one. Another central factor that has sparked the interest in investigating the possible relationships among the barriers is their common simultaneous precence in organizations (Cagno, 2013, 303). Chai and Yeo (2012, 464) argue that these interactions are the fundamental reason for the persisted existence of energy efficiency barriers. Understanding the mutual relationships among the barriers would provide valuable information for top management and governmental decision makers in order to successfully further promote energy efficiency (Wang et al., 2008, 1880).

As mentioned, the research conducted by Wang et al. (2008), Chai and Yeo (2012) and Cagno et al. (2013) have contributed to the scientific understanding of the interrelated nature of energy efficiency barriers. Wang et al. (2008, 1888-1889) observed that some of the identified barriers work as a root cause for other barriers (called driving barriers), and some barriers were strongly influenced by other barriers (called driven barriers). In the context of their study, they identified that lack of awareness, limited policy framework, lack of incentive support, lack of funding/financing capabilities, lack of trained manpower, and insufficient/inaccurate information worked as powerful drivers, having a strong influence on other barriers. Respectively, barriers such as lack of experience in technology and management, lack of appropriate production technologies, lack of public participation, objections from interest groups, reluctance to invest because of high investment risk, inappropriate industrial framework and lack of strategic planning were most influenced by the driving barriers. They also observed that some of the driving barriers (lack of awareness, limited policy framework and lack of incentive support) had relatively higher driving power, and should therefore be treated as strategic issues in energy saving practices. The three remaining driving barriers (insufficient/inaccurate information, lack of funding/financing capabilities, lack of trained manpower) had a high driving power, but were less dependent on other barriers. (Wang et al., 2008, 1888-1889.)

Another interesting finding was made by Cagno et al. (2013, 303) when they identified three different types of interaction between the barriers. The researchers named these interactions as causal relationship, composite effect and hidden effect: Firstly, a causal relationship takes place between two barriers (A and B) when an increase in barrier B is due to barrier A. In this context, barrier A can generate barrier B, or if barrier B already exists, barrier A can modify barrier B. The causal relationship may not necessarily appear simultaneously with barrier A, in the sense that the effect can be delayed. This implies that barrier B may exist autonomously even if barrier A disappears. (Cagno et al., 2013, 303.)

Secondly, the composite effect refers to a situation where a barrier can inhibit the implementation of an energy efficiency measure only in combination with other barriers. For example, a composite effect of hidden costs, high initial costs and resources for higher priority investments can make low capital availability a barrier (see figure 5). (Cagno et al., 2013, 304.)

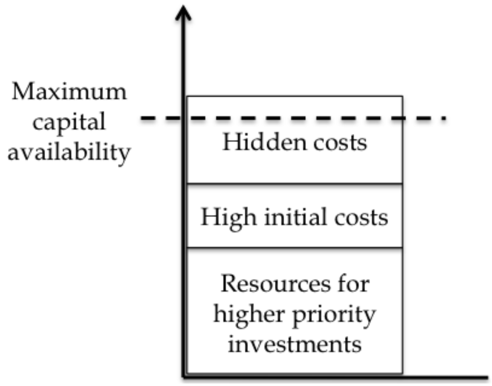

FIGURE 5 The composite effect. (Cagno et al., 2013, 305.)

Lastly, a hidden effect exists when an organizational actor is not aware of an existing barrier A, and has the conception of being affected by another barrier B. The actor confuses barrier A with barrier B since the presence of barrier A influences the perception of barrier B. Therefore the actor's attempts to address barrier B are rendered ineffective, as the real barrier in question is barrier A. As an example, the actor may consider technology as inadequate due to insufficient or inaccurate information. As a result, some barriers may be overestimated due to a distorted perception of performance. (Cagno et al., 2013, 305.)

In addition, Cagno et al. (2013, 300) highlight that all barriers are always associated with the subjective perceptions of the barriers. Furthermore, organizational actors assign values to these subjective perceptions. Therefore, it is possible to distinguish a real value and a perceived subjective value of a barrier. In their study, the researchers identified that the decision-making of the actors is affected indirectly by the real values and directly by the perceived values of barriers (figure 6). Therefore, in order to distinguish the real barriers from the perceived barriers, it is important to evaluate the real and perceived values of each barrier. (Cagno et al., 2013, 300.)

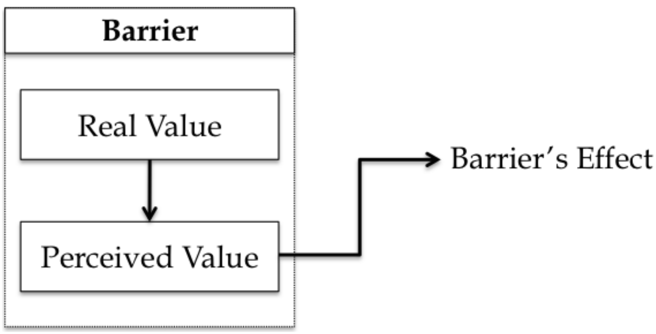

FIGURE 6 The real and perceived values of a barrier. (Cagno et al., 2013, 300.)

4.2.1 Contribution of systems thinking to the barrier research

Using systems thinking, Chai and Yeo (2012) attempted to identify the underlying structure that would explain the behavioral patterns behind the barriers to the adoption of energy efficiency measures. As a result of their research, they proposed a conceptual model known as the MCIR framework. The framework consists of four sequential stages: Motivation, Capability, Implementation and Results. Their model also incorporates a feedback loop from ”Results”-stage to the ”Motivation”-stage. This generic framework offers a novel perspective to energy efficiency barriers, and provides evidently the first systematic method for analyzing shortcomings in energy efficiency policy. The researchers reported that they were also able to demonstrate through a case study that the proposed framework will lead to positive feedback for future energy efficiency implementations. (Chai and Yeo, 2012, 471.) The framework is depicted in figure 7.

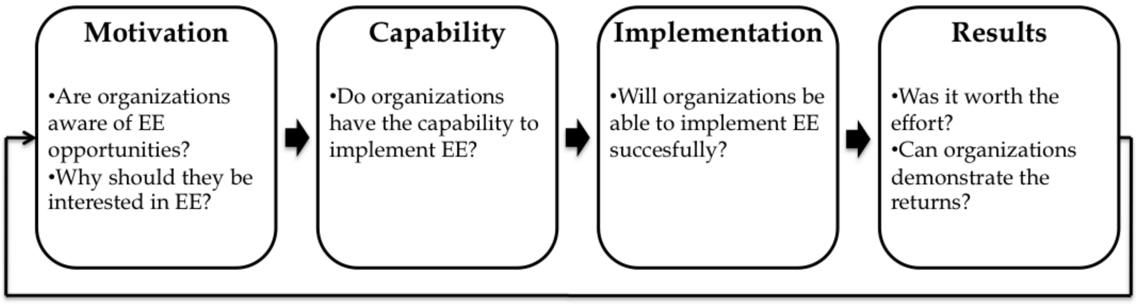

FIGURE 7 Motivation-Capability-Implementation-Results (MCIR) framework. (Chai and Yeo, 2012, 468.)

The MCIR framework was constructed according to the principles of systems thinking, and it portrays typical characteristics of a conceptual model, including interactions, relationships, delays and feedbacks. For each stage of the model, Chai and Yeo (2012, 468-469) included questions that reflect the interests of different stakeholders, and capture central factors that affect the adoption of energy efficiency measures. The main concern in the first stage of the model is organizations’ awareness of energy efficiency opportunities, and the interests they have in seeking improvements in energy efficiency. Once organizations are aware of the opportunities, the model continues to the second stage, ”Capability”, where organizations are concerned with their abilities to implement energy efficiency improvements. In the third stage, organizations implement energy efficiency measures in reality. In this stage, the major concern is if the developed capabilities are sufficient enough to result in a successful project. The final stage of energy efficiency adoption, ”Results”, refers to the actual outcomes of the implemented project. In this stage, the top management is likely to be interested in the quantitative demonstration of the results, and returns, of the project. This final stage also results in the feedback to the first stage of the model. In other words, convincing and positive financial results from the conducted projects generate a positive feedback –effect, which motivates the top management to further invest in energy efficiency. (Chai and Yeo, 2012, 468-469.)

In the second phase of their research, Chai and Yeo (2012, 469-470) mapped the barriers identified in the conducted interviews and reviewed literature into the MCIR framework. Each stage of the model incorporates a certain set of these barriers. By presenting the barriers in a sequential manner, the model can identify potential chokepoints of energy efficiency. The MCIR framework with mapped barriers is depicted in figure 8.

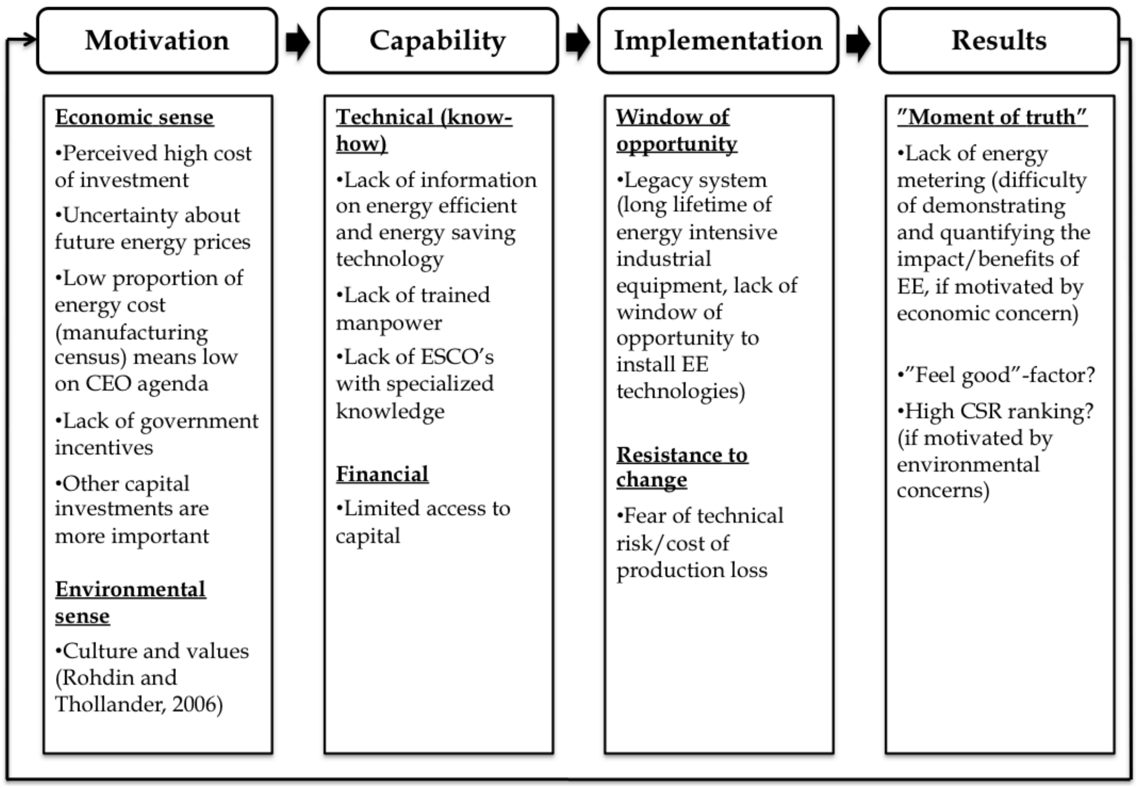

FIGURE 8 Mapping barriers into the MCIR framework. (Chai and Yeo, 2012, 469.)

The ”Motivation” –stage embodies barriers that tend to decrease management's motivation or interest to pursuit energy efficiency. These barriers may include split incentives, lack of awareness of energy efficiency opportunities, or lack of financial incentives, for example. Barriers in the ”Capability” –stage can be classified as financial or technical barriers. These barriers may include lack of financial resources, lack of trained manpower, or lack of information on energy efficiency technologies, for example. The ”Implementation” –stage features barriers that may inhibit the implementation of energy efficiency measures. Resistance to change and short window of opportunity are common examples of these kind of barriers. In this context, short window of opportunity may refer to the fear of disrupting production in manufacturing processes which run on a continuous basis. The ”Results” –stage barriers are commonly reported by organizations, with lack of positive results from energy efficiency investments as the most essential barrier. The positive results from energy efficiency investments may refer to financial gains, for example. (Chai and Yeo, 2012, 469-470.) Chai and Yeo (2012, 469-470) argue that the presented framework provides a sound reasoning for energy efficiency adoption in organizations, and can potentially lead to a positive feedback of energy efficiency improvement. Furthermore, they conclude that the level of energy efficiency adoption is only as strong as the weakest link.

Chai and Yeo's model (figure 7) can be found particularly interesting from the perspective of energy performance measurement. As energy performance measurement is used for evaluating performance, raising awareness, setting targets and offering decision support in energy management (Sivill, 2011, 3), it may address a central barrier in the "Results" –stage of the model, namely the difficulty of demonstrating and quantifying the impact and benefits of energy efficiency (figure 8). From this perspective, energy performance measurement may play a central role in enabling the formation of a positive feedback from the final stage of the model in to the first stage of the model. As mentioned before, this feedback-effect could motivate the top management to further invest in energy efficiency (Chai and Yeo, 2012, 468-469.) Building on this, the following subchapter will explore the associated barriers with the development of energy performance measurement.

4.3 Barriers for energy performance measurement

In a study conducted by Sivill et al. (2013, 936), the researchers aimed to identify the barriers inhibiting the development of energy performance measurement. The findings included barriers related to design and technology (information overload, information deficiency, lack of examples, issues related to the development of indicators), organizational and behavioral barriers (commitment issues, lack of skills, issues with information delivery, lack of resources) and other external factors/barriers (business environment and national differences). These barriers are largely consistent with the current findings in the literature on energy efficiency barriers (table 1). Furthermore, the researchers made an interesting observation as they were working to find out the development priority of energy performance measurement:

> *"Investing in the development of energy performance measurement is faced with a paradox: resources and commitment, which are still regarded as the most important barriers to energy management, are prerequisites for energy performance measurement being developed, whereas energy performance measurement influences the very same issues by enforcing changed behavior" (Sivill et al., 2013, 948).*

Reflecting on the issues presented in the previous subchapter, namely the interactive nature of energy efficiency barriers, this finding suggests that there may exist an interaction between the identified barriers. Lack of commitment and resources are seen as the primary barriers for the development of energy performance measurement. Simultaneously, the difficulties in demonstrating and quantifying the impact of energy efficiency inhibit the formation of commitment and necessary resources. To my view, this problem situation indicates a similar sequential and closed-loop process as Chai and Yeo (2012) have presented in figure 7. Therefore, I argue that systems thinking offers a fertile ground for the holistic examination of this problem situation, and may potentially offer some insight in overcoming the barriers to the development of energy performance measurement. I perceive this as an important research topic, taking into account that the recent literature emphasizes the need to develop specific and quantitatively measurable performance indicators for managing energy efficiency (Sivill, 2011, 39; Virtanen et al., 2013, 412-413; Bunse et al., 2011, 676-677; Chai and Yeo, 2012, 469).

5 RESEARCH DESIGN AND METHODS

5.1 Research approach

"The systems approach is not a bad idea." ~C. West Churchman (1968, 231)

This study approaches the research problem from a systems perspective. On a general level, there are two types of systems approaches, which are the hard and soft systems approach (Checkland, 1981, 189-191). Methodologically, these two approaches incorporate substantial differences. For this reason, the choice of exact approach has to be considered from the perspective of the perceived problem situation, and it's associated research questions.

The hard systems approach is founded on the premise that the performance of a perceived system can be optimized to an optimum state. This optimization is realized by following certain systematic procedures, which involve establishing clear objectives and formation of generalizable models. Mathematical modelling is also seen as a crucial component in the process. The approach represents functionalism, and is objectivist by orientation. (Jackson, 2004, 25-185.) The hard systems approach has typically been applied in well-defined technical problems (Checkland and Scholes, 1999, 10). However, it has turned out to be inadequate in addressing organizational problem situations, which often include human factors and are ill-defined by nature (Flood and Carson, 1990, 116).

As the hard systems approach has been unable to deal with increasing pluralism, soft systems approach was developed. (Jackson, 2004, 25-185.) The fundamental difference between hard and soft systems approaches lie in their differing definitions of a "system". In hard systems approach, a system is considered as a model that aims to describe a real world situation. In contrast, a system in soft systems approach represents a mental model that constructs our understanding of the complexities of a real world. (Checkland and Scholes, 1999, 10-11.) Soft systems approach advocates the importance of subjectivity, and is founded on a paradigm of learning. The approach is interpretive in character, and aims to integrate the differing values, beliefs, philosophies and interests of various stakeholders. (Jackson, 2004, 135.) Unlike hard systems approach, the soft systems approach does not presume the systems to be founded on easily identifiable, agreed-on goals. Instead, the soft systems approach leaves room for conflicting world views, making subjectivity a central feature in the methodological process. (Jackson, 2004, 22.)

Considering the context of the research problem, the soft systems approach is seen as a suitable approach for this research. Although the chosen approach emphasizes subjectivity, it has to be remembered that a researcher is expected to adhere to methodological and linguistic objectivity. For this reason, the question of subjectivity and objectivity is not a simple one. Although the researcher adheres to an objective research process, his intellectual perspectives are always inherently included in the formulation of the research problem and in the interpretation of the research results. (Hirsjärvi et al., 2009, 309-310.)

Furthermore, due to the soft systems approach, the resulting outcomes of this research are formed in an abductive process. In abductive reasoning, the units of analysis are derived from research material, and the process of analysis is guided by a theoretical framework. Explanations or confirmations are sought from the theoretical framework to support the empirical findings. Therefore, the influence of prior knowledge is identifiable in the results. In this context, the meaning of prior knowledge is not to test a certain theory, but to promote new ideas. (Tuomi and Sarajärvi, 2009, 96–97.) Thus, the process of abductive reasoning results in the formation of a hypothesis that aims to explain a certain problematic phenomenon (Paavola and Hakkarainen, 2006, 269-272).

5.2 Research methodology

As a methodology, this research applies the Soft Systems Methodology (SSM), created by Peter Checkland (1981, 149-180). SSM is known to be effective in the context of ill-defined and complex problem situations. It seeks to improve perceived problem situations by facilitating a systemic process of learning. The methodology is interpretive by nature, and is consonant with the phenomenology of Husserl and Schutz, and interpretive sociology of Weber. (Jackson, 2004, 185.) By adopting SSM, this research is able to holistically address the associated complex problem situation.

Checkland has originally defined SSM as a 7-stage process, although he also emphasized that even though the methodology has been described as a chronological sequence, it should be used flexibly and iteratively. The process can, in principle, start at any part of the described process. Furthermore, SSM is fundamentally a cyclic methodology. Therefore strict adherence to the 7-stage process can be a limiting factor, which may inhibit effective use of the methodology. In practice, a systems researcher will work simultaneously on several stages, at different levels of detail. (Checkland, 1981, 162-163; Checkland and Scholes, 1999, 23.) The seven stages of the process are:

1. The problem situation: unstructured.
2. The problem situation: expressed.
3. Formulating root definitions of relevant systems.
4. Building conceptual models.
5. Comparing the models with the real world.
6. Defining changes that are desirable and feasible.
7. Taking action to improve the problem situation.

The methodology can also be divided into two distinct phases, known as the real-world and systems thinking –phases. Stages 1, 2, 5, 6 and 7 are associated with the real-world phase, whereas stages 3 and 4 are associated with the systems thinking -phase. The real world –phase addresses the individuals and the situation in which there is perceived to be a problem. The systems thinking –phase addresses the conceptual world, in which the complexities of the real world are unravelled, translated and understood as the meta-language of the systems. This phase results in the formation of conceptual models. In essence, these models are not supposed to be manifestations of the real world. Instead, these models are meant to structure our thinking about the complexities of the real world. Therefore, although the system models are related to experience, they are not descriptive or normative by nature. However, the models are seen as practical, since they contain only components that are crucial to the existence of the perceived problem. (Checkland, 1981, 163–173.)

The application of SSM can be seen as a participative process, as it aims to concretely improve the perceived problem situation (Jackson, 2004, 190). Unfortunately, in the context of this research, the participatory nature of the methodology is fairly limited. This is mainly due to the time and scope restrictions of a Master's research. In practice, this means that the stages 5, 6 and 7 of the methodology are left outside the scope of this study. Despite these limitations, the application of soft systems methodology is seen as an effective way to fulfil the purpose of this research.

Based on the research questions, the theoretical framework and the principles of SSM, a specific methodology for this study was created. This methodology took the form shown in figure 9.

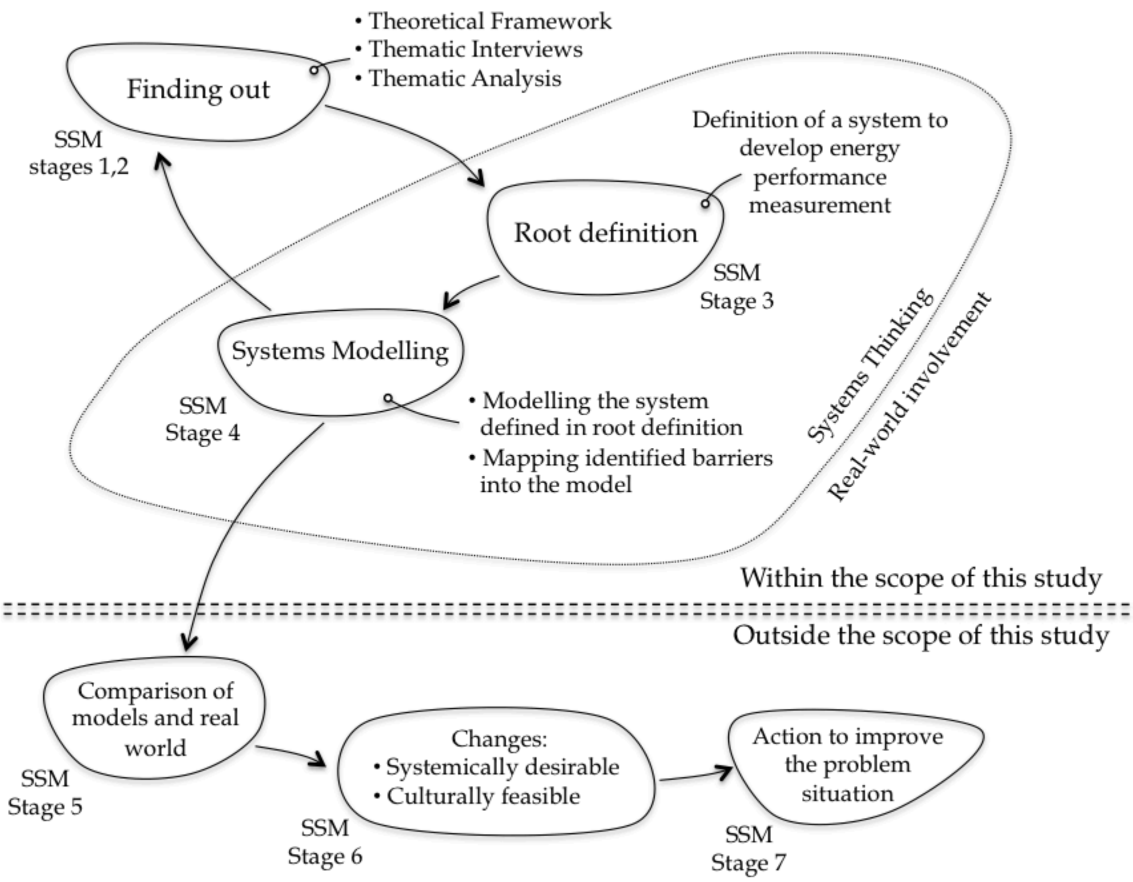

FIGURE 9 The methodology of this study

The figure 9 illustrates the main sections within this study (i.e. finding out, root definition and systems modelling), along with explanations about the central contents of these sections. Also the corresponding stages of SSM are depicted in the illustration.

The first section, ”Finding out”, aims to gain a better understanding of the problem situation. This is achieved through getting acquainted with the relevant scientific literature, performing interviews, and carrying out a thematic analysis. The thematic analysis aims at identifying the relevant barriers to the implementation of energy efficiency measures. The results of this section enable the answering of the first research question of the study. At this point, it is worth mentioning that thematic analysis is a reductionist research method. Although SSM emphasizes the use of holistic research methods, the use of thematic analysis is highly justifiable in the context of this study, as will be explained in chapter 5.4.1.

The second section, ”Root definition” aims at defining a suitable root definition for a system to develop energy performance measurement. In SSM, a root definition expresses the core purpose of a system to be modelled, and forms an integral part of successful modelling (Checkland and Scholes, 1999, 33). There are certain established practices, or methods, for formulating root definitions, which will be explored in more detail during the chapter 5.4.2.

In the last section, within the scope of this study, a conceptual model is created based on the system described in the formulated root definition. The modelling process may also be influenced by other systems thinking present in the existing literature. (Checkland, 1981, 163.) Importantly, the initial conceptual model focuses solely on the process of developing energy performance measurement. In essence, this model will not explicitly display the previously identified barriers, as they are concerned to be implicit environmental constraints at this stage. This is due to the established methods of conceptual model building, as will be explained during the chapter 5.4.2. In order to answer the second research question of this study, the identified barriers are mapped into the created conceptual model, making the environmental constraints explicit. Chai and Yeo (2012, 469) have previously used this technique to describe the possible interactions of the barriers. As a result, the analysis will create a framework for understanding and potentially improving the perceived problem situation. The increased understanding of the problem situation is depicted as a feedback-effect into the ”finding out”-section in figure 9. In essence, this framework is trying to shed some light to the previously expressed paradox of Sivill et al. (2013, 948).

As mentioned earlier, the stages 5, 6 and 7 of the SSM are left outside the scope of this study. Still, they are depicted in figure 9 in order to illustrate how this research could have been carried out if all the stages of SSM would have been applied. In essence, it shows the possibilities of future research in the context of this study.

5.3 Research subjects and data collection

The research material for this study was collected in conjunction with a larger research project, which aim was to analyse and describe the current state of energy management in Finland. Two separate Masters' theses, including this one, were based on the material collected in this larger research project. The data collection was conducted by using semi-structured thematic interviews. The content of the interviews revolved around issues related to energy efficiency and energy management (Appendix 1). A central objective of the interviews was to provide enough information for the execution of all these three separate studies. For this reason, it was beneficial to conduct numerous interviews, and to structure the interview form in a way that it could encompass the diversity of energy management as well as possible. From the perspective of this research, this was seen as a window of opportunity for performing a study with systems thinking approach.

The selection of the interviewed organizations and personnel was influenced by the needs of the three distinct studies. As it was necessary that the interviewees understood the specifics of energy management, the general aim was to interview organizations that practice energy management to some extent. From the perspective of this study, it was seen as crucial to collect data from different organizational types to create a comprehensive picture about the problem situation. Altogether 32 organizations were interviewed in different locations in Finland. However, as SSM advocates a system researcher to concretely participate in the research situation, only the interviews which I myself conducted were included as research material in this study. Therefore, this research includes the interviews of 18 persons from 15 different organizations. These interviewed organizations included industrial companies (7), different government entities (5), wholesale and retail companies (2) and real estate companies (1). The interviewees consisted of managers and personnel responsible for energy and environment related issues. A short description of the persons interviewed can be found in table 2. All interviews were carried out in person, and the duration of each interview ranged from 1 to 2 hours. During all interviews, notes were written down and the discussions were recorded with a voice recorder. The voice recordings were transcribed along with backup notes.

Organization	Person(s) interviewed
A	• Real Estate Manager
B	• Technical Manager • Technical Specialist
C	• Senior Energy Expert
D	• Energy Engineer
E	• EHSQ Manager
F	• Factory Service Manager
G	• Sustainability Specialist
H	• Real Estate Manager • Maintenance Engineer
I	• HVAC Engineer
J	• Electrical Engineer
K	• Maintenance Engineer • Automation Engineer
L	• Real Estate Manager
M	• Performance Manager
N	• Energy Specialist
O	• EHSQ Specialist

TABLE 2 Organizations and personnel interviewed in this study.

It needs to be aknowledged that the majority of the previous research on energy efficiency barriers has been conducted in the context of industrial companies, whereas the observed organizations in this research represented industrial companies, real estate companies, wholesale and retail companies and different government entities. These organizations have differing needs, drivers and barriers regarding their energy management. Due to these facts, the results of this research will be more general by nature. This can be seen simultaneously as an opportunity and as a limiting factor. I myself perceive that this serves the purpose of systems thinking, as novel information may emerge by observing a variety of organizations.

5.4 Research methods

In order to successfully derive research results from the empirical observations, clear and appropriate research methods are needed. Methods consist of certain practices and operations that allow the researcher to produce findings from the research material. In addition, methods consist of certain rules which allow the further interpretation of these findings. The selected research methods must be consistent with the theoretical framework. (Alasuutari, 2011, 82-83.)

In order to answer the first research question of this study, the selected research method has to be able to reduce the collected research material into adequate parts. The second research question, on the other hand, can be answered when these parts are perceived from a holistic perspective. For this reason, the research process combines both reductionist and holistic methods. This is necessary in order to identify the constituting parts of the system in question, and to ensure an appropriate level of resolution of the hierarchical problem situation. As Flood and Carson (1990, 14) argue, a systems researcher has to be both holistic and reductionist at the same time. Therefore, in addition to the collection of research material via thematic interviews, the empirical part of this research can be distinguished into two separate phases. The first phase demonstrates a reductionist research method, whereas the second phase demonstrates holistic research methods.

5.4.1 Thematic analysis

In order to identify the barriers in the research material, being parts of the whole, a reductionist analysis method is needed. A suitable method for this purpose is thematic analysis, which is the most commonly used analysis method in qualitative research (Guest et al., 2012, 11). The use of thematic analysis is justifiable in the context of this study, as it is a consistent way of analyzing data that has been gathered through thematic interviews. Most importantly, the information produced by thematic analysis is both adequate and indispensable for the subsequent phase of the empirical research.

As Guest et al. (2012, 10) argue, thematic analysis is a method that requires involvement and interpretation from the researcher. In essence, the researcher has to be able to identify and describe both implicit and explicit ideas within the collected research data. These identified ideas are known as themes. In a typical research process, codes are developed to represent these themes. The codes are utilized in the later analysis, as they also link the themes to the collected research data. Due to it's characteristic methods, thematic analysis includes relatively more issues with reliability than other strictly word-based analysis methods. This is because thematic analysis requires more interpretation in the process of defining codes and applying these codes to a mass of text. (Guest et al., 2012, 10-11.)

In the context of this study, thematic analysis is used as a method to reduce the collected research material into parts that constitute the whole. The thematic analysis is conducted from the perspective of abductive reasoning, where the adopted theoretical framework guides the identification of themes from the collected research material. In this sense, the role of theoretical framework is solely directional, not restrictive. This is in line Eskola and Suoranta's (1998, 175) argument that the interaction of theoretical framework and empirical research is the key to a successful thematic analysis. The objective of this first phase of empirical research is to identify and describe the present themes, i.e. barriers to the implementation of energy efficiency measures, in the collected research material. These identified themes are applied in the subsequent research phase, where the research problem situation is perceived from a holistic viewpoint.

5.4.2 System modelling in SSM

As Checkland and Scholes (1999, 28) argue, SSM is interested in ”problem situations that should be managed and improved”. The modal verb ”should” in this phrase is of highest importance, as it reflects a subjective view on the situation. In essence, this subjectivity makes the problem situation meaningful, and the action to improve it purposeful. This purposefulness makes the action of improvement, or a system, relevant to the problem situation, as no system is intrinsically relevant to any problem situation. In fact, the conceptual models in SSM can be described as ”carefully built models of systems to carry out purposeful activity”. Therefore, the selection of relevant systems to be modelled is the premise of SSM. (Checkland and Scholes (1999, 6-31.)

A central aim of SSM is to create conceptual models that illuminate a perceived problem situation. In essence, the models serve to structure a debate about change, as they are compared with the real world. The objective of this debate is to induce changes that could be implemented in the real world in order to improve a perceived problem situation. The conceptual models are created through a logic-based enquiry, which includes methods such as root definitions, CATWOE analysis, and modelling of the systems. (Checkland and Scholes, 1999, 29-31; Checkland, 1981, 161-183; Flood and Carson, 1990, 116-126.)

In practice, root definitions are concise descriptions of systems. They held a certain perception of reality, and work as a basis for building conceptual models. Most importantly, root definitions explicitly state the core purpose a system. The core purpose is always described as a transformation process, in which an entity is transformed into a new form of the same entity (figure 10). (Checkland and Scholes, 1999, 22-33.)

FIGURE 10 Transformation process (Checkland and Scholes, 1999, 34.)

Furthermore, a history of SSM research has shown that a successful root definition tends to incorporate certain factors within its formulation. These factors of a well-defined root definition are embodied in the so-called CATWOE analysis. The CATWOE analysis is a mnemonic for the six fundamental factors of a root definition. These factors are described in table 3. A central aspect of CATWOE analysis is the pairing of world view (W) and the transformation process (T). This makes the transformation process meaningful in context, i.e. it becomes a purposeful activity. A world view is inherently subjective by nature, and a single transformation process can be perceived from a variety of different world views. The other factors in CATWOE analysis imply that someone will carry out the purposeful activity, someone could stop it, someone will be a beneficiary or a victim of it, and that the system will take some environmental constraints as given. A conceptual model can be successfully modelled if it is based on a root definition which formulation embodies these six different factors. (Checkland, 1981, 316-317; Checkland and Scholes, 1999, 35.)

Factors of CATWOE	**Description**
(C) Customers	The victims or beneficiaries of T
(A) Actors	Those who would do T
(T) Transformation process	The conversion of input to output
(W) World view	The worldview which makes this T meaningful in context
(O) Owners	Those who could stop T
(E) Environmental constraints	Elements outside the system which it takes as given

TABLE 3 The CATWOE mnemonic (Checkland and Scholes, 1999, 35.)

Checkland (1981, 169) has given the following definition for the relationship between root definitions and conceptual models: *"The [root] definition is an account of what the system is; the conceptual model is an account of the activities which system must do in order to be the system named in the definition."* In other words, the conceptual models can be defined as mental constructs, or epistemological devices, for understanding reality (Jackson, 2004, 182-185). Once a conceptual model has been created, it may be used structure enquiry into the associated problem situation. (Checkland and Scholes, 1999, 41.)

A conceptual model portrays the transformation process according to the associated root definition and CATWOE elements, and the structuring of the models is based on logical contingency (Checkland and Scholes, 1999, 36). In essence, the models should include only the minimum amount of necessary activities that are needed for realizing a system articulated in a root definition (Checkland, 1981, 313).

According to the principles of SSM, a conceptual model is not ephemeral, but has the ability to recover after some degree of disturbance (Checkland, 1981, 174). For this reason, a conceptual model has to incorporate processes of monitoring and control which ensure that the created entity could survive in a changing environment. The processes of monitoring and control are founded on three distinct criteria, through which the successfulness of the transformation process (figure 10) can be judged. The first criterion, efficacy, monitors whether the output can be produced with the chosen means. The second criterion, efficiency, inspects whether the transformation process is performed with minimum resources. The third criterion, effectiveness, checks whether the transformation process is able to meet the long-term aim of the model. (Checkland and Scholes, 1999, 38.)

6 RESULTS

6.1 Empirically identified barriers

In the first part of the empirical research, thematic analysis was used to identify relevant barriers from the collected research material. The general aim was to answer the first research question of this study, and to provide necessary information for the subsequent part of the empirical research. Table 4 presents a summary of the identified barriers from the conducted interviews, portraying a total of 12 distinct barriers. The barriers are presented in no order of significance. In addition, the barriers are theoretically disaggregated under five different categories found in the extant literature. The five distinct categories are economic non-market failure or market barriers (Brown, 2001; Sorrel et al., 2000), economic market failure (Brown, 2001; Sorrel et al., 2000), organizational barriers (Sorrel et al., 2000), behavioral barriers (Sorrel et al., 2000) and barriers related to design and technology (Sivill et al., 2013). The alphabetical columns indicate the individual barriers that were identified during each interview.

Category	Identified barriers	Interviewed organizations														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Economic non-market failure or market barriers (Sorrel et al., 2000; Brown, 2001)	Lack of resources (financial, time or staff)			X		X	X	X	X	X	X	X			X	
	Uncertainty about future energy price		X	X	X											
	Other issues prioritized over energy efficiency			X			X				X					
	Perceived high cost of energy investment	X	X				X									X
Economic market failure (Sorrel et al., 2000; Brown, 2001)	Difficulty of finding new opportunities to energy saving													X		X
Organizational barriers (Sorrel et al., 2000)	Lack of commitment					X			X		X					
	Information delivery	X	X							X		X				
Behavioral barriers (Sorrel et al., 2000)	Resistance to change						X		X							
Barriers related to design and technology (Sivill et al., 2013)	Lack of energy metering	X				X	X			X	X					X
	Difficulty of demonstrating and quantifying the impact of energy efficiency investments	X		X				X	X		X		X	X	X	
	Difficulty of data integration		X	X											X	
	Insufficient level of automation	X		X							X					X

TABLE 4 Barriers identified from the conducted interviews

A majority of the identified barriers are familiar from the extant literature on energy efficiency barriers (see table 1 in chapter 4.1). However, in the light of the reviewed literature, this study presents two novel barriers related to issues with design and technology. These barriers are the difficulty of data integration, and the insufficient level of automation. These are arguably important barriers from the perspective of energy performance measurement, as they strongly influence the possibilities to implement various indicators within organizations.

It is recognized that the identified barriers in this study incorporate some overlaps between one another, which has been a typical aspect also in prior barrier research. As Cagno et al. (2013, 306) argue, the presence of these overlaps may lead to misleading and incorrect classification of barriers. In this study, the disaggregation of the identified barriers has been founded on the extant literature on energy efficiency barriers. However, it turns out that the reviewed literature shows inconsistency in the classification of certain barriers. Lack of energy metering, for example, has been classified as an organizational barrier by Chai and Yeo (2012, 463), and as a design and technology barrier by Sivill et al. (2013, 945). Therefore, in such cases, some interpretation was required during the classification process.

It is important to highlight that the distinct organizations presented in the table are not comparable with each other. In addition, the frequency of different barriers within each individual interview do not indicate the state of energy management in a certain organization. This is due to the dynamic nature of the barriers, and several distinct human factors. Firstly, some of the interviewees may have been relatively more transparent, open and capable in their communication. Furthermore, it is possible that some of the interviewees may have experienced the interview as a representational situation, and felt the need to represent their organization in a favourable light. It is also important to notice that the interviews covered a variety of themes from management to communication and technical issues. Naturally, some of the themes may have been outside the main expertise field of the interviewees. For these reasons, it is possible that the results do not portray all the barriers that actually take place in the organizations.

Secondly, the focus of this research is not to create a deep case-specific insight of the barriers within each individual organization, but to develop a general picture of the barriers inhibiting the development of energy performance measurement. This is an important aspect, as it influences the interpretation of the answers given by the interviewees. At times, for example, it was challenging to distinguish whether the interviewee talks about a barrier on a general level or in the context of the operations of particular organization. The interviewees may also have been dubious about the significance of certain barriers. Due to the chosen research focus, the answers were interpreted broadly in such situations.

Thirdly, the answers of the interviewees may have been affected by the hidden effect as described by Cagno et al. (2013, 305). In other words, the interviewees may have not been aware of a barrier A if their conception was affected by a barrier B. As a practical example, an interviewee may consider the existing technology as inadequate (barrier B), although this perception is solely due to the inaccurate information of the interviewee (barrier A). The identified barriers in this study are therefore affected by subjective perception, and the results may portray so-called perceived barriers in addition to real barriers. (Cagno et al., 2013, 300-305.) In order to distinguish the perceived barriers from the real barriers, a deep case-specific study would be needed.

In the following subchapters, the identified barriers are described in more detail. Some verbatim quotes from the interviewees are brought up as concrete examples to support the interpretations. Furthermore, the findings are also brought into the context of former relevant scientific literature. Finally, before moving to the next phase of empirical analysis, the presented initial findings are shortly contemplated.

For the sake of clarity, it is important to point out that the following subchapters utilize the terms of energy efficiency and energy performance. Energy efficiency, in the context of this empirical research, refers to the first structural factor of energy performance, which is *the efficiency of energy production and consumption* (Sivill, 2011, 31). Energy performance, on the other hand, refers to the concept as a whole (see chapter 3.2).

6.1.1 Economic non-market failure or market barriers

Lack of resources

Lack of resources forms a central barrier as it may inhibit the implementation of change. Implementation of change may refer to the adoption of new organizational routines, development of new skills, and learning new ways of doing things. (Morrison, 2008, 1189.) The interviewees reported shortages from a variety of different organizational resources. These were the lack of time, lack of staff, and lack of financial resources. During the interviews, it became clear that these different types of resource shortages often exist simultaneously, and partly overlap with each other. Lack of time may be due to staff shortage, or lack of staff may be due to insufficient financial resources. Furthermore, sometimes it was challenging to distinguish what exact type of resource shortage the interviewee refers to when he or she talks generally about a resource shortage. Hence, it was decided to present these different resource shortages as a single united barrier.

During the interviews, lack of time turned out to be one of the most frequent barriers to the promotion of energy efficiency:

> *"There's always a limited amount of time - - if we had more resources we could certainly do more as we would not have to allocate time for other matters." (Sustainability Specialist, Organization G)*

> *"The resources we had before are now used in other matters. I myself came here to work on energy efficiency, but currently I can devote 1% of my work time for the matter. Before it was 100%." (HVAC Engineer, Organization I)*

Lack of financial resources was also a commonly reported barrier. The tight economic situation was reflected especially in the public sector, but was nevertheless also present in the discussions with interviewees working in the private sector:

> *"Investment funds are getting smaller every year." (HVAC Engineer, Organization I)*

> *"…in the first two years we have not been able to make any investments. But on the other hand we get support [from top management] in the way that energy efficiency is seen as an important issue." (EHSQ Manager, Organization E)*

It turned out that the economic situation and pursued financial goals also have an effect in the organizational personnel structures. During downsizing programs, for example, the functions outside the core business area may turn out as apparent reduction targets:

> *"I think that this matter [energy efficiency] was forgotten by the management during the downsizement of staff. Quite a lot of personnel who used to work with energy matters had to retire early. So there has not been much devotion to the developmental side." (Electrical Engineer, Organization J)*

As can be expected, lack of staff was also a common barrier among the interviewed organizations. Some of the interviewees reported to be able to concentrate on energy efficiency matters only alongside their main jobs: *"…actually we do not have a person to work solely with these (energy efficiency) matters" (Automation Engineer, Organization K)*. In addition to the shortage of staff, the importance of the technical capabilities of personnel was strongly emphasized in the interviews:

> *"The challenge is certainly the fact that the resources of the property organization are slim. Progress could be made more easily if someone would take the ball and take care of it from the start till the end. I find that as the paramount. One has to be especially acquainted on the matter in order to manage different technologies and problems associated with the matter. Although we surely have those kind of persons." (Energy Specialist, Organization N)*

As one of the interviewees pointed out, allocating organizational resources for a certain matter "*is always a compromise from the achievable results" (Factory Service Manager, Organization F)*. As organizations have a restricted amount of available resources, allocating them to the promotion of energy efficiency may reduce the resources allocated for some other matters. Therefore, resource allocation is always a question of prioritization. Importantly, interviewees also emphasized that the necessary resources can be purchased from outside the organization. In this way, organizations can focus on their core competencies while having an access to the expertise offered in the markets. "*That is the thing what we look for in* *our partnerships, so that we would not grow our own staff too much." (Sustainability Specialist, Organization G.)*

Uncertainty about the future energy price

As can be expected, the development of market prices of energy affect the attractiveness of energy saving and the profitability of energy efficiency investments. *"As energy gets more affordable, the less profitable or interesting the measures turn out" (Senior Energy Expert, Organization C).* Thus, low market prices of energy constitute a barrier for the implementation of energy efficiency investments. This issue was explicitly stated by one of the interviewees:

> *"Energy costs should first increase in order to make the investment really matter." (Technical Manager, Organization B)*

The predictability of future energy prices was also seen as an important factor for promoting energy efficiency. Based on the interviews, uncertainty about the future energy price is a risk that may inhibit the implementation of energy efficiency investments:

> *"In this industry, two or three years is a relatively short time period from the viewpoint of investments. It is always a risk if one does not know how much the energy will cost. A great risk in this type of industry." (Energy Engineer, Organization D)*

Some of the interviewees perceived energy price as a twofold problem: In terms of business, it is desirable to have low energy prices, but from the perspective of environmental protection, the prices should still reflect certain governmental control measures:

> *"…of course I hope that the taxation and subsidization policies of energy production would favor emission-free energy sources, so that even if we use more energy it would be less polluting." (Senior Energy Expert, Organization C)*

Other issues prioritized over energy efficiency

This barrier was identified when interviewees reported that energy efficiency had a low priority in an organization, and when some other more urgent matters were prioritized over energy efficiency. Understandably, in a busy organization with limited resources energy efficiency has to compete for the attention with other important matters:

> *"Everything currently aims at keeping this factory running and therefore energy efficiency may not be the most important issue." (Electrical Engineer, Organization J)*

The interviewees highlighted that the promotion of energy efficiency is problematic due to certain conflicting interests within organizations. The prioritization of energy efficiency was also strongly dependent on how important energy-related matters are for the continuity of the organization. This issue can be approached from the viewpoint on of how significant proportion the energy costs constitute from the production costs, for example.

> *"In this sense, energy costs are not so important for our business. Still, energy efficiency is important when firms aim to gather all the little pieces together in order to bring results and development." (Factory Service Manager, Organization F)*

As the quotation presented above points out, energy efficiency is just one part of the organization's activities that aim to bring organizational results. In this sense, it is important to perceive energy efficiency in relation to other organizational matters; compromises are needed as energy efficiency is a part of a wider entity. One interviewee summarized this fact as follows:

> *"What has become clear is that energy efficiency is a part of the whole. It should be integrated to the organization's daily activities, and not considered as a separate issue but as a part of every function - - and should be evaluated together with all the other matters. That's where the catch is." (Energy Engineer, Organization D)*

Perceived high cost of energy investment

The interviews showed that the perceived high cost of energy efficiency measures acts as a central barrier for energy efficiency improvement. The interviewees reported that some profitable energy efficiency investments could not be realized due to high initial costs and long payback periods:

> *"The factory has enormous energy saving potential but the investments have so long payback periods that their execution would need some kind of financial support. There are great opportunities for energy saving but they are unreasonably costly. They are profitable but they also have long payback periods." (EHSQ Specialist, Organization O)*

Although energy metering was commonly perceived as an important factor for improving energy efficiency, the installation of additional instrumentation was seen as an investment which costs would exceed its benefits. This is a central challenge for the development of energy performance measurement, as lack of measurement data restricts the application of energy efficiency indicators.

> *"There is this problem that energy metering is excessively costly. The investment will not ever pay itself back if 100 000 € investment achieves 1000 € annual returns." (Real Estate Manager, Organization A)*

According to the interviewees, the high cost of energy metering leads to the fact that energy consumption is monitored on a larger system level (see figure 4 in chapter 3.2). Due to the lack of submetering, the available data may be insufficient to demonstrate and quantify the impact of certain energy efficiency investments:

> *"The measurement of small consumption units may turn out unreasonably expensive. The measurement instruments are so expensive that the investment will not pay itself back. It is simply not worth doing. Therefore the measurement is executed on a larger level, and significant energy efficiency improvements on small consumption units may not show up at all in this larger picture. This is one of the biggest challenges." (Factory Service Manager, Organization F)*

6.1.2 Economic market failure

Difficulty of finding new opportunities to energy saving

The interviewees reported that it is increasingly difficult to identify new opportunities to energy saving after the most apparent and profitable measures have been implemented. The issue came up especially in the context of organizations that had a relatively long history of improving energy efficiency.

> *"When improving energy efficiency, it is always easy to find and collect the ripe berries. But when they have been collected, one has to focus on smaller and smaller issues which makes it a challenging task." (Performance Manager, Organization M)*

As Senior Energy Expert (Organization C) pointed out, a location that has not implemented any energy efficiency measures will likely have relatively more accessible energy saving potential than another location that has been active in energy efficiency matters for a longer time. Understandably, the challenge of finding new energy efficiency measures has raised concerns in some of the organizations:

> *"There's not much to be done. It especially worries me if law imposes further requirements for all functions and premises. It feels so sad since we've done it all a long time ago. We have already saved the world for our part, and we are energy efficient when compared with the general level in Finland." (EHSQ Specialist, Organization O)*

The categorization of this barrier was seen as problematic, as it can be an outcome of several different factors. The barrier can be categorized as economic market failure, if it's due to insufficient information with respect to energy saving opportunities. On the other hand, the difficulty of finding new energy saving opportunities may stem from the constraints posed by the currently adapted technology. In this case, this barrier could be categorized as a design and technology barrier. In essence, this problem brings out the issue of misleading categorization of barriers in the current literature. As Cagno et al. (2013, 307) argue, there exists a need for new taxonomy to reduce the barriers to minimum independent terms.

The difficulty of finding new opportunities to energy saving is also an interesting issue from the perspective of organizational rewarding. How to organize rewarding practices fairly among the personnel if some personnel have access to greater energy efficiency improvement opportunities than others? If the rewarding focuses on the improvement of energy efficiency, some personnel may find the situation unjust. One of the interviewees proposed a following perspective on the matter:

> *"…is it possible to reward those personnel who are able to maintain an adequate level [of energy efficiency], as it is not realistic for them to achieve significant reductions? The consumption levels would start to rise if they stopped caring, after all." (Senior Energy Expert, Organization C)*

As the interviewee points out, the rewarding could also focus on maintaining a certain accepted level of energy efficiency. This perspective may be worthwhile to consider if personnel within an organization perceive the current rewarding practices for energy efficiency as unequal.

6.1.3 Organizational barriers

Lack of commitment

The interviewed organizations seemed to be largely aware about the significance of energy efficiency in the context of their operations. In some of the cases, however, lack of commitment seemed to hinder the efforts of taking energy efficiency further: *"The attitude is not negative, but still not committed enough to take energy efficiency into account among other things." (Real Estate Manager, Organization H)*. The interviews revealed that the lack of commitment occurred both on the management level and on the level of personnel. Two of the interviewees described the lack of management support towards energy efficiency as follows:

> *"Our top management is more interested in the stock markets, and they have given us free hands to work on this side." (Electrical Engineer, Organization J)*

> *"Up to this point, I think that the management has not supported [energy efficiency] enough. Although we have shown what kind of savings could be made through it. But now the prioritization is changing." (EHSQ Manager, Organization E)*

According to the interviewees, lack of managerial commitment may manifest itself in various different ways. For example, one interviewee reported that the management had not set any specific organizational targets for energy efficiency. This was accompanied by the fact that the management had not taken any position on what kind of energy-related reports they would like to receive from the personnel. In the absence of management's effort, personnel may perceive energy efficiency as a vague and non-motivating matter.

Many of the interviewees also reported that it is challenging to obtain management funding for energy efficiency investments. Profitable energy efficiency investments easily fail to get funding if they incorporate payback periods of a several years. According to interviewees, this was due to the short-term planning of management. Also the current literature on energy efficiency barriers (Zilahy, 2004; Sola and Xavier, 2007; Viinikainen and Soimakallio, 2007) has identified the short-term planning of organizations as a hindrance for energy efficiency improvement.

> *"If we propose investments that have payback periods of 4-5 years we won't get funding for them. The perspective of management is currently not that long, at least for now. Still, they are investments that will certainly pay themselves back, but not within the first year." (Electrical Engineer, Organization J)*

As previously mentioned, lack of commitment among the personnel came up during the interviews in addition to the lack of managerial commitment. Some of the interviewees reported that although energy efficiency is brought up from time to time, it has not yet become concretised to anyone in the organization. With no one responsible for energy efficiency, personnel may have adopted a "none of my business" –mentality on the matter. In some situations, interviewees argued that personnel do not have a chance to focus on energy efficiency due to lack of time. In practice, lack of commitment of the personnel may manifest itself in a way that certain reports on energy efficiency are disregarded:

> *"We have this report that is distributed monthly, but it does not in fact tell anything and it is not read frequently. At the moment, there are two larger deficiencies present, but no one has even noticed them." (Electrical Engineer, Organization J)*

The interviewees reported that it would be possible to enhance the commitment of personnel through certain management practices. Practices such as target setting, rewarding and training came up in the interviews. This perception is in line with the research findings of Babakus et al. (2003, 274), who studied the effect of management practices on employees' commitment and performance outcomes in the context of service quality.

The interviewees perceived energy efficiency rewarding as desirable and interesting, but also as a challenging issue. It was emphasized that the rewarding should be coherent with the general goals of the organization, keeping in mind that "*rewarding the performance of a single process step is a dangerous and challenging path" (Energy Engineer, Organization D)*. On the other hand, the interviewees also reported that rewarding should be based on indicators that are sufficiently small-scale in order to make energy efficiency more comprehensible for personnel.

> *"If we move too much on the general level, it [energy efficiency indicator] will not concretise to anyone, and no one will be motivated by it. Sufficiently precise, specified and concrete things, that's how it is done. - - If it [energy efficiency indicator] is defined vaguely it will not be motivating, but the opposite." (Electrical Engineer, Organization J)*

As the interviewee points out, in order to be motivating, the energy efficiency indicators have to be relevant for whom they are directed at. This highlights the importance of organizational, systemic and temporal dimensions of energy performance measurement (see figure 4 in chapter 3.2). An annual, and company-wide indicator may be relevant for the decision making of top management, but personnel on operational level may find an indicator incorporating a more specific system level and a shorter time span more useful and motivating for their needs.

Information delivery

> *"Communication, that is a very challenging skill." (Technical Manager, Organization B)*

As the citation above implies, several of the interviewed organizations reported varying difficulties with energy efficiency communication. Communication problems touched both internal and external communication, giving feedback, and sensible communication about technical matters. The connecting factor with these problems was identified to be the challenge of information delivery, i.e. how to communicate energy efficiency properly to the right persons. In order to improve energy efficiency in organizations, successful communication was seen as particularly important: *"That is where the saving starts, knowledge should be disseminated." (Technical Manager, Organization B)*.

In the interviews, it frequently came out that it's not enough that the technical personnel understand the energy efficiency indicators. Quite often the persons who are capable of influencing energy efficiency through their actions are not familiar with energy technology. Therefore, a common challenge was how to successfully communicate technical issues in a sensible manner.

> *"It necessitates informing from an own kind of perspective, and it should not be done as technically as a technocrat would do it. One has to be almost a cross-breed of a humanist and technocrat in order to communicate it sensibly." (HVAC Engineer, Organization I)*

The comprehensibility of indicators is an important aspect from the perspective of performance measurement, as the utilized indicators should be understandable by nature (Merchant and Stede, 2012, 36-39). In essence, personnel should understand how to influence the indicators which they are being held accountable for. Some of the interviewees emphasized that increased visualization could facilitate the comprehensibility of energy reports. The utilization of modern information systems was seen as an enabling factor for making energy efficiency visualized, simple and monitorable. By making energy efficiency more apparent, increased visualization was seen as a way to motivate people. This view is supported by Thollander and Ottosson (2008, 25) who argue that if information is presented in a vivid and personalized manner, people are more likely to act on it. This personalized view on information was also apparent in the answers of the interviewees. Many saw that it was necessary to bring energy efficiency matters to an individual level, instead of treating the subject as a common concern of the organization.

> *The challenge is mostly how to get personnel interested in the subject [energy efficiency]. So that it would concretely touch everyone." (Real Estate Manager, Organization A)*

> *"It has to be conveyed the right way. If a person is told that this will bring added value to the corporation then he won't see how it is connected to him personally." (Electrical Engineer, Organization J)*

This perspective was followed by a resulting problem: how to bring energy issues close to the work of an individual? The key challenge seems to lie in finding both meaningful and valid units in which the energy consumption could be reflected.

> *"It's a question of presentation: an economist understands euros, an engineer understands megawatt hours - - it has to be contemplated what unit is concrete for whom. It's a great deal of work to make it comprehensible" (Energy Specialist, Organization N)*

Another interesting finding was that energy efficiency related communication was not seen only as an opportunity, but was also identified as a business risk. This perspective arose in the context of external communications. It turned out that some organizations are hesitant to report energy indicators and other related data to the public, as there is limited controllability over these measures. This uncontrollability exposes organizations to the risk of showing their operations in a bad light. This observation is in line with an earlier similar research finding made by Sivill et al. (2013, 948). One of the interviewees described their situation as follows:

> *"We might not want to show that we are constantly in energy class G, which partly stems from our property type and our actions, but partly it results from a wrong comparison group. If we had a suitable comparison group, it would enable an adequate comparison. But currently it shows us in a really bad light if we are in G class." (Real Estate Manager, Organization H)*

6.1.4 Behavioral barriers

Resistance to change

One behavioral barrier, resistance to change, was identified during the conducted interviews. In the light of this research, it seems that the prevalence of the barrier is not very large, or it just possibly did not come across in the interviewees' responses. However, in some cases, it was reported that personnel may be content with the current status quo, and also possibly wish to maintain it. Any apparent reasons for this behavior did not come up in the interviews, apart from the lack of initiative attitude.

> *"Everything that would require initiative attitude or changing one's behavior is not especially apparent. The attitude [towards energy efficiency] may be positive but the actions remain scarce." (Real Estate Manager, Organization H)*

According to Nagesha and Balachandra (2006, 1978), personnel may find new energy efficient technology as a risky endeavour. Implementation of new energy efficiency measures may therefore evoke resistance among the personnel. One of the interviewees argued that the personnel in the conventional industry may not be conscious about the significance of energy efficiency, which might explain the resistance.

> *"They [personnel] may not pay attention to it [energy efficiency] and may carry on working as they have always done. That is the thing in old industrial factories like this, getting the change happen" (Factory Service Manager, Organization F).*

6.1.5 Barriers related to design and technology

Lack of energy metering

In this study, lack of energy metering refers to the availability of measurement instrumentation in organizations. Importantly, this separates it from another barrier: the difficulty of demonstrating and quantifying the impact of energy efficiency investments. To my view, this latter barrier is primarily concerned with indicators, i.e. bringing energy measurement data into a context. In contrast, Chai and Yeo (2012, 469) seemingly discussed these two barriers synonymously. I argue that the separation of these two barriers is justified, as the availability of measurement instrumentation is not necessarily solely sufficient to demonstrate the impact of energy efficiency measures; the measured data has to be first processed, interpreted and brought into a context.

Some of the interviewees found the current level of energy metering insufficient for the needs of energy management. The interviewees also generally felt that investments should be made in order to extend the current instrumentation. Although the subject had been discussed in organizations, any actual measures had not typically taken place. Interviewees also saw that savings could be made if more sub-measuring would take place, as some of the organizations currently had instrumentation only for metering the total consumptions. In industrial context, it was reported that increased instrumentation would allow the benchmarking of similar production lines both within the factory and between factories.

> *"…we do not have the metering at appropriate level. We know that this converter powers those three devices, and we know that we can monitor the changes on the converter-level. But the monitoring of a single unit, that we generally do not have. In the future we could have, as there has been a lot of discussion about making the metering more precise." (EHSQ Specialist, Organization O)*

> *"We have had discussions that in some cases it would be good to get building-specific information, but we still haven't started to take further measures." (EHSQ Manager, Organization E)*

Lack of energy metering can be seen as a central barrier inhibiting the application of energy performance measurement. If the available instrumentation allows the measurement to take place only on a large system level, building reliable indicators on a more specific level may not be possible. In other words, the barrier restricts the system level in which the measurement takes place (see figure 4 in chapter 3.2).

In some organizations, it was common to collect energy measurement data manually. In contrast to automatic data collection, the manual collection of data may further restrict the application of energy performance measurement from the temporal dimension. Furthermore, the interviewees reported that manual data collection enables the realization of errors during the data entry phase, which may undermine the trustworthiness of the collected data. The observed problems with manual data collection are challenging from the perspective of performance measurement; in order to be adequate, the measures of performance should be available in a timely manner and meet a satisfactory degree of precision (Merchant and Stede, 2012, 36-39).

> *"No we can't [get adequate information from metering], not to mention that the information would be accurate. A lot of information is collected manually. - - It can be noticed from the readings when a year has passed that "wait a minute, this can't be right". And still there are no any temporary reports or notices from anyone. So it is very unstable, and the information that comes should be accurate and trustworthy. It is the foundation of everything." (HVAC Engineer, Organization I)*

The interviewees also brought up that information should be produced only for a legitimate need. In other words, it was emphasized that measurement should not be solely done for the sake of getting figures. Above all, the measurement should be founded on the determined targets on organizational issues wished to be improved. The achievement of these targets is the focus of measurement, and the methods of measurement should also be set against that background. *"Measurement should not be an end in itself. Then it would be useless, only an item of expenditure" (EHSQ Specialist, Organization O).*

Difficulty of demonstrating and quantifying the impact of energy efficiency investments

> *"It is a challenge to make it [energy efficiency] sensible, understandable, concrete, one could say. In the sense where everything comes from and where certain benefits are derived." (Real Estate Manager, Organization A)*

The quotation presented above captures the essence of this barrier. As the name of the barrier implies, it incorporates various factors that make the demonstration of energy efficiency challenging. These factors affect the reliability, precision and controllability of energy efficiency indicators. This makes the utilization of energy efficiency indicators challenging from the perspective of performance measurement (Merchant and Stede (2012, 36-39).

In order to describe the progress of energy efficiency in a certain entity, the energy consumption data has to be brought into a context. This is done by comparing a certain useful output to a relevant input of energy. Specific energy consumption (SEC) was the most commonly used indicator for describing energy efficiency among the interviewed organizations (see chapter 2.1.1). Naturally, the applied useful outputs varied greatly between organizations and within organizations. Often, comparing energy consumption to surface area was seen as the easiest and most adequate indicator for describing the energy efficiency of a property. However, an indicator of this kind was not seen as completely satisfactory:

> *"There is an ongoing discussion if this is the right unit. I myself think it might not be, because energy efficiency measures what outcome is gained with the used energy input. But what is the outcome, that is where the problem lies. For example there are many kinds of different surface areas. What is the right one is the question." (Energy Specialist, Organization N)*

As the interviewee states, the determination of an useful output for a relevant system boundary is not a straightforward task. Interviewees reported challenges especially in the context of a complex production processes, where the data acquired from enterprise resource planning systems had a substantial role in describing energy efficiency. However, the basic production data, such as production tonnes, was often insufficient to describe the state of energy efficiency. For this reason, the SEC's were typically accompanied with other relevant information, such as the composition of used raw material. Furthermore, as one of the interviewees pointed out, finding the right indicators is not solely enough for improving energy efficiency, but an active participation is needed: *"we have to actually monitor our actions, meaning that were not just doing something and looking back afterwards how things went" (Performance Manager, Organization M).*

An important aspect that was brought up in the interviews was that in order to demonstrate the impact of energy efficiency reliably, it should be measured through multiple different indicators. The interviewees emphasized that monitoring of a single indicator may easily lead to false conclusions, and steer behavior in an unwanted direction. In addition to having a sufficient variety indicators, it was pointed out that certain useful outputs should be monitored on multiple system levels. However, in the absence of a perfect measure, a certain amount of uncertainty has to be tolerated.

> *"There are many different methods for calculating energy efficiency, and it's not possible to have just one indicator that would be enough. There exists no ceteris paribus -situation, showing the total impact of a single investment." (Sustainability Specialist, Organization G)*

> *"It is a constant burden that we do not have this indicator that would take the utilization rate into account - - improvement of energy efficiency does not show up on the small unit level but on the level of community it might show up. For that reason we should not focus solely on specific energy consumption, and we should always take the larger perspective into account." (Senior Energy Expert, Organization C)*

Several interviewees perceived current indicators as challenging as they are affected by factors beyond the controllability of personnel. Lack of controllability is a central problem from the perspective of energy management, as performance measures are useful only to the extent to which they provide information about the executed actions (Merchant and Stede, 2012, 36-39). If uncontrollable external factors affect the results of the measurement, it becomes difficult to demonstrate the actual impact of energy efficiency investments.

> *"If we monitor things such as the factory's overall electricity consumption per production tonne, it would include a lot of factors we could not influence one bit. One flawed batch can ruin the whole thing even if we would have the most efficient equipment." (Electrical Engineer, Organization J)*

One of the main external factors influencing the results of energy efficiency measurement is the effect of weather. The normalization of heat consumption is an established attempt to internalize the effect of weather in calculations. However, some of the interviewees saw the current instructions for normalizing heat consumption as somewhat flawed. Generally, measuring the efficiency of electricity consumption was perceived as relatively easier than measuring the efficiency of heat consumption. However, the interviewees were also conscious of the electricity consumption being also dependent on outside temperature. In addition to the impact of weather, the indicators were reported to be affected by other various factors.

> *"…finding the unusual factor, if there has been one. That is a challenge sometimes. But then we utilize our tools to find the actual root causes." (Performance Manager, Organization M)*

Difficulty of data integration

A common aspect brought up in the interviews was that information was largely scattered across different systems. According to the interviewees, this has caused practical difficulties with data integration. As energy efficiency can be described as a ratio between an output of performance, service, goods, or energy, and an input of energy (EU, 2012), data integration can be seen as an integral component of measurement practices. In other words, scattered information systems cause practical challenges to the combination of energy consumption data with the relevant output data.

> *"We still lack a database which all these systems could utilize, and that is a significant deficiency we will address in the future. We have concluded that we are lacking the link between the existing systems." (Technical Manager, Organization B)*

> *"…these are the things that we would want to combine with the consumption readings. This is an issue that is not taken into account in the currently offered systems." (Senior Energy Expert, Organization C)*

The interviewees reported that financial data, rental management data and various technical data were located in different systems. In some cases, location specific control systems included the measurement of temperature, indoor moisture and carbon dioxide levels. Currently, the combination of the various information with energy consumption readings was not seen as possible in practice. In essence, what the organizations seemed to be lacking was a system, or a link, in order to bring the relevant information together. Without automated data processing, the process of data integration was seen as burdensome in practice.

> *"…getting this kind of data into the same system, as they are currently scattered in different systems, will demand a lot of work." (Energy Specialist, Organization N)*

Insufficient level of automation

During the interviews, it turned out that the monitoring process of energy related data included a substantial amount of manual work. Although some of the interviewed organizations had constructed thresholds alerts for energy consumption in their systems, they might still perceive the current state of automation as insufficient. *"It would be lovely to say that everything would be collected and analyzed automatically… it involves a lot of manual work when one figures out which changes demand more analyzing and control actions" (Senior Energy Expert, Organization C).*

In essence, the composition of energy related reports for decision making seemed to demand currently a significant amount of manual labour.*"The monitoring of energy data is in pretty bad state, all reporting is currently done manually as a general rule" (Electrical Engineer, Organization J).* The interviewees felt that the process could be made more efficient through increased automation. In some cases, the interviewees saw that the donated time for composing energy reports outweigh the benefits that can be derived from them.

> *"I have to filter, read, make conclusions and construct a presentation about the current situation. The manager has about a half of a minute for the issue, whilst I have put a day of work into it."(EHSQ Specialist, Organization O)*

According to one of the interviewees, the problem of insufficient automation was not, however, only restricted to the context of energy reporting. Personnel, whose effort could be utilized effectively in other organizational tasks, currently compose various reports as their daytime job.

6.1.6 Reflection on the initial findings

The former subchapters provided an overview of the relevant barriers that were identified in the collected research material. In combination with the theoretical framework, these initial research findings contribute to the first two stages of SSM. Furthermore, according to the adopted methodology, these two stages constitute the "finding out" –phase of this research (see figure 9 in chapter 5.2). The aim of this phase was to gain a better understanding on the perceived problem situation. This aim was achieved by getting acquainted with the relevant scientific literature, and by supplementing this initial information with the empirical findings from thematic interviews.

The achieved results imply that it is possible to enhance the commitment of personnel towards energy performance through certain management practices, such as rewarding. However, finding a relevant indicator for the basis of compensation is a challenge, as the temporal, systemic and organizational dimensions of energy performance measurement need to be addressed. As rewarding should be congruent with the general objectives of an organization (Merchant and Stede, 2012, 36-39), and compensating personnel on multiple performance measures has proven to be extremely challenging (Meyer, 2003, 54), this study suggests that rewarding personnel for energy performance should be applied only in situations where it significantly promotes the achievement of organizational objectives.

Furthermore, the interviews revealed that some of the identified barriers (lack of energy metering; perceived high cost of energy investment; information delivery; difficulty of demonstrating and quantifying the impact of energy efficiency investments) demonstrated practical difficulties with the controllability, precision, timeliness, understandability and cost-effectiveness of energy performance indicators. According to Merchant and Stede (2012, 36-39), such shortcomings undermine the applicability of indicators as a performance measure. Therefore, these findings question the applicability of energy performance indicators as a basis for compensation. This interpretation is in line with the findings of Virtanen et al. (2013, 412), who argue that it is challenging to motivate personnel to work towards energy efficiency, as the inherent complexities in the measurement process hinder the effective use of management control systems.

The conducted interviews also showed that the organizations had differing needs regarding their energy management. In essence, the interest towards improved measurement systems was more apparent in organizations with a longer history in energy management, and especially in industrial companies with relatively complex production systems. Some of these organizations had already invested or were planning to invest in more sophisticated measurement systems. One of the interviewees had the following to say about investing in energy performance measurement:

> *"The unfortunate truth is that one gets what one measures. In order to improve energy efficiency, it has to be first carefully measured and monitored. But in all honesty, it needs to be said, that in the past we have successfully promoted energy efficiency even without a huge measurement system." (Factory Service Manager, Organization F).*

As the above quotation indicates, it is possible to promote energy efficiency without implementing a sophisticated energy monitoring system. Naturally, organizations are likely to first collect the "ripe berries", i.e. the most accessible and profitable energy efficiency investments. However, investing in measurement systems may become more attractive after these initial investments have been implemented, and organizations start to seek energy saving possibilities through increased monitoring of energy consumption patterns. This interpretation is in line with the research of Sivill et al. (2013, 936), who argue that the development priorities of different energy management factors are dependent on the organization's position on the learning curve of energy management. Specifically, the researchers argued that energy performance measurement is a topical factor in the most advanced industrial sectors in the energy management learning curve (Sivill et al., 2013, 948-949).

6.2 Formulation of the root definition

From the perspective of SSM, the preceding part of the empirical research represents the real-world phase of the methodology (see figure 9 in chapter 5.2). This chapter begins the subsequent part of the empirical research, which represents the process and central findings of the systems thinking phase of the study. The theoretical framework and achieved initial empirical findings form the basis for the conduction of this phase.

The overall goal of the systems thinking phase is to create a conceptual model of the system in question. The purpose of the conceptual model is to structure enquiry and to create further understanding of the studied problem situation (Jackson, 2004, 182-185). First, in order to enable the successful modelling of the system, an adequate root definition has to be formulated. In order to create the root definition, this study utilizes CATWOE analysis its formulation. Formulating a root definition using the CATWOE analysis is an established practice among the users of SSM. In essence, the analysis ensures that the formulated root definition represents all the necessary characteristics required for the successful modelling of a particular system. (Checkland and Scholes, 1999, 35-36.)

The CATWOE analysis began by defining the ″customers″ of the system, which are the beneficiaries or victims affected by the systems activities. In practice, the ″customers″ can exist both within or outside the system in question. (Checkland, 1981, 224-225.) As previously stated, Sivill (2011, 31) argues that the aim of energy performance is to increase the margin of profit or the growth of revenue of an organization. Based on this view, this study defines the ″customer″ of the system as the organization wishing to develop energy performance measurement. In addition, the same organizational agent was identified as the ″owner″ and ″actor″ of the system. According to Checkland (1981, 224), the ″owner″ has the prime concern for the system, and has the possibility to cause the system cease to exist. The ″actor″ is an agent that causes the main activities of the system to be carried out. Reflecting on prior soft systems research (Checkland and Scholes, 1999, 65-70), it is typical for the root definition to share the same agent for the ″customer″, ″actor″, and ″owner″ of a system.

The fourth factor of CATWOE analysis is the transformation process, which can be considered as the core of any root definition. As earlier explained in chapter 5.4.2, a defined input is transformed into a defined output during a transformation process (see figure 10). In essence, the defined input and transformed output represent a single entity in a transformed state. (Checkland, 1981, 224.) In the context of this study, the point of interest is the implementation and development of energy performance measurement. Therefore, the transformation process considers the state of energy performance measurement in a transformed state.

Fifthly, the root definition should reflect a certain world view, an outlook, or framework which makes the formulated definition meaningful in context. Importantly, there are more than one possible world views, which is a central characteristic of soft systems research. For this reason, a separate root definition has to be formulated for each world view considered relevant. (Checkland, 1981, 225.) This study applies a world view that the development of energy performance measurement enables the further endeavours of energy management (Sivill, 2011, 34).

Lastly, any possible environmental constraints have to be defined for the system, which it takes as given. In essence, the system to be modelled is restrained by these predefined constraints. In practice, these environmental constraints are various features of the environment of the system. (Checkland, 1981, 225.) Typical examples of environmental constraints in former soft systems research have included corporate structure, available resources, technology and budget (Checkland and Scholes, 1999, 68-100). In the context of this study, the environmental constraints incorporate the various barriers identified in chapter 6.1, as they are perceived to hinder the development of energy performance measurement. Based on the conducted CATWOE analysis, a simple root definition was formulated. This root definition and its central CATWOE elements are represented in figure 11.

Root definition

An organization owned an staffed system to develop energy performance measurement in order to reach further efforts in energy management.

C Organization

A Organization

T Need for improved energy performance measurement and monitoring
→ The need met by developing energy performance measurement

W Development of energy performance measurement can help to reach further efforts in energy management

O Organization

E Various barriers identified via thematic analysis (see table 2)

FIGURE 11 Formulated root definition based on the CATWOE analysis

6.3 Systems modelling

The aim of this chapter is to describe the achieved results of building a conceptual model that meets the requirements posed by the previously defined root definition. The modelling process was executed according to the established practices of SSM. In practice, a conceptual model is a set of activities which the system must perform in order to be the particular system described in the root definition. In essence, the aim of a conceptual model is to describe *what* activities must take place in a system. These distinct activities are connected according to logical requirements, indicating any essential flows, whether of information, material, energy etc. The resulting model does not therefore portray *hows*, such as descriptions of how a specific activity is carried out, unless they are explicitly named in a root definition. They may, however, be included in succeeding models if the first-level model is later expanded to a more detailed level. (Checkland, 1981, 286-293.)

The resulting conceptual model (figure 12) was a product of an iterative process, formed in the interaction of the theoretical framework and empirical research. The structure of the model went through frequent changes until it reached its final form. The resulting model portrays a sequential, circular and process-oriented framework to describe the process of energy performance development. The model structure is founded on logical contingency, and it includes 8 activities, two subsystems, and three feedback loops. The influence of the theoretical framework is strongly present in the conceptual model, as it incorporates the 4-stage logic of Chai and Yeo's MCIR framework (see chapter 4.2.1). In essence, the conceptual model can be considered as an expanded version of the MCIR framework from the perspective of energy performance measurement. As the created conceptual model portrays a high level of abstraction, the first subsystem of the model was later expanded in order to allocate the formerly identified barriers into the model (see chapter 6.3.3).

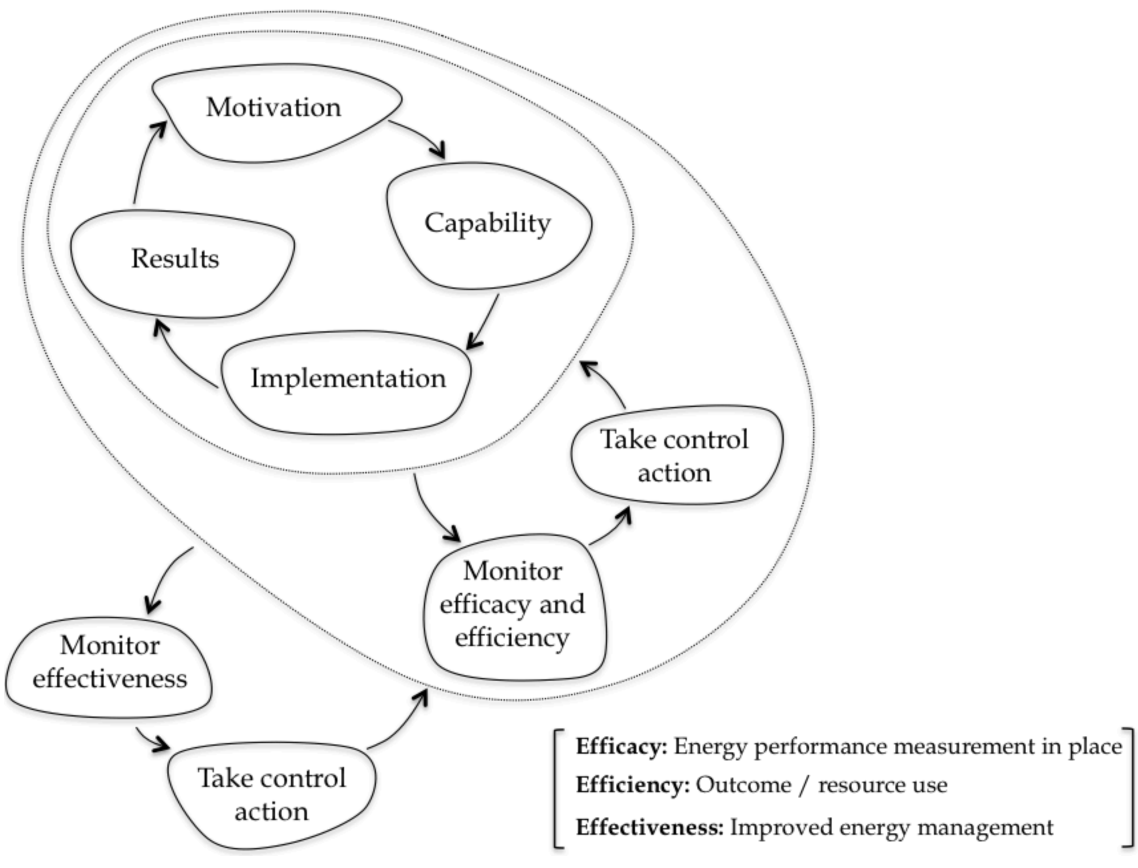

FIGURE 12 The conceptual model from the root definition of Figure 11.

6.3.1 Description of the created conceptual model

The ″motivation″, ″capability″, ″implementation″ and ″results″ stages form the first subsystem, and feedback loop, of the conceptual model. As in Chai and Yeo's model (2012, 468), the ″motivation″ stage of the conceptual model is concerned with the organization's awareness, interest and willingness to act towards improved organizational energy performance. Once an organization is aware of its plausible opportunities, the model continues to the ″capability″ stage. This stage is concerned with the organization's capabilities to pursue the activities wished to implement in the following stage of the model. The successfulness of the ″implementation″ stage is therefore dependent on the ″capabilities″ stage, i.e. whether the organization has adequate resources to implement desired changes.

It is important to note that the ″implementation″ stage of this model can be differentiated into two distinct activities. Firstly, the ″implementation″ stage refers to activities that aim to improve the energy performance of an organization. The energy performance of an organization can be improved through the selection of utilized energy sources, or through activities which influence the efficiency of energy production or consumption. These activities may include improvement of operations, acquisition of more efficient technology or improvement of process integration. (Sivill, 2011, 31-32.) Secondly, the ″implementation″ stage refers also to various activities that aim to improve the energy performance measurement of an organization.

The aforementioned distinction is seen as important, as these two types of activities interactively contribute to the outcome of the ″results″ stage of the model. Firstly, in order to deliver results, activities to improve energy performance need to be undertaken. Secondly, in order to quantify and demonstrate these delivered results, adequate measurement practices need to be deployed. Therefore, in order to create a positive feedback to the "motivation" stage, energy performance has to be both delivered and adequately demonstrated. The adequate level of measurement is dependent on the implemented activities and general needs of energy management. On the other hand, the improved measurement and monitoring may open up new possibilities for the further implementation of energy performance improvement activities. Therefore, the outcome of the ″results″ stage is dependent on the synergy between these two distinct activities.

The described subsystem is accompanied by two additional feedback loops, which form the necessary monitoring and control functions of the conceptual model. As this aspect is important in the use of SSM, the next subchapter explores the nature of these feedback loops in more detail.

6.3.2 System feedbacks

As a whole, the created conceptual model presents three distinct feedback loops. All these feedbacks are essential from the perspective of system dynamics, as they guarantee the long-term stability of the system. In essence, these feedbacks enable the system model to become a dynamic, self-perpetuating entity. (Checkland, 1981, 174.) The innermost feedback loop is concerned with *what* is measured in practice, e.g. the efficiency of carried out investments. The reviewed literature (Sivill, 2011, 39; Virtanen et al., 2013, 412-413; Bunse et al., 2011, 676-677; Chai and Yeo, 2012, 469) and the empirical findings of this study imply that the demonstration of results has a motivational effect on the promotion of energy efficiency. In the presented conceptual model, this effect is described as the feedback from ”Results” stage to the ”Motivation” stage. As Chai and Yeo (2012, 469) argue, the ability to demonstrate positive and convincing results may motivate top management to further invest in energy efficiency. However, based on the conducted interviews and empirical findings, this study argues that this feedback effect should be expanded to cover both operational and strategic levels. In essence, the interviews revealed that adequate and relevant indicators in the operational level have a considerable role in motivating personnel to work towards energy efficiency. This perspective is in line with Sivill's (2011, 38) definition of energy performance, as it is able capture both strategic and operational dimensions of energy management. In addition to the positive feedback effect, it is important to realize that the inability to demonstrate convincing or positive results may incorporate a demotivating effect towards top management and personnel.

In contrast to the first feedback loop, the second and third feedback loops of the model are concerned with evaluating the energy performance measurement *itself*. In essence, the foundation of these particular feedbacks lie in system dynamics, in order to ensure that the created entity ”could survive in a changing environment” (Checkland and Scholes, 1990. 38). Therefore, these two latter feedback loops function as the monitoring and control subsystems for energy performance measurement. In system terms, they judge whether the transformation process of the system is ”successful”. This successfulness is evaluated on three distinct criteria, which are the efficacy, efficiency and effectiveness of the system. (Checkland and Scholes, 1990, 39.)

The second feedback loop of the conceptual model is concerned with the efficacy and efficiency of energy performance measurement. Efficacy, in terms of systems thinking, refers to the evaluation whether the activities included in the system work as intended, i.e. does the process lead to the development of energy performance measurement. In this model, the criterion for efficacy is whether energy performance measurement has been implemented in the particular organization. Efficiency, in this context, refers to the ratio between the gained benefits from measurement, and resources allocated for measurement. (Checkland and Scholes, 1999, 38-39.) In practice, this may refer to the cost-effectiveness of energy performance measurement. Importantly, efficiency in this context is not to be confused with the actual measurement of energy efficiency, but as the efficiency of conducting the measurement itself. The second feedback loop results in taking control action, whether it is needed. Control action may be needed if the measurement practices turn out to be redundantly resource-intensive (that is, inefficient), for example.

The third feedback loop of the conceptual model monitors the effectiveness of the system as a whole. In terms of systems thinking, effectiveness refers to the evaluation whether the transformation process is able to meet the long-term aim of a particular system (Checkland and Scholes, 1999, 38-39). The long-term aim of the presented model can be derived from the adapted world-view, which in this case is the improvement of energy management. Therefore, the third feedback loop monitors whether the development process of measurement actually improves the state of energy management within an organization, and results in control action, if needed.

6.3.3 Mapping barriers into the model

This chapter attempts to describe how the identified barriers from the collected research material are formed from the perspective of the created conceptual model. In essence, the objective is to propose a certain view on how the barriers, their possible sequence and interactive relationships are formed. In order to achieve this objective, the first subsystem of the initial conceptual model (figure 12) is expanded and complemented with the various barriers presented in table 4. The sequence and positioning of the identified barriers was founded on the logical requirements of SSM, theoretical framework and hints from the conducted interviews. Most importantly, the process was guided by the former research of Chai and Yeo (2012, 469). The resulting model is presented in figure 13, and attempts to provide an answer to the second research question of this study.

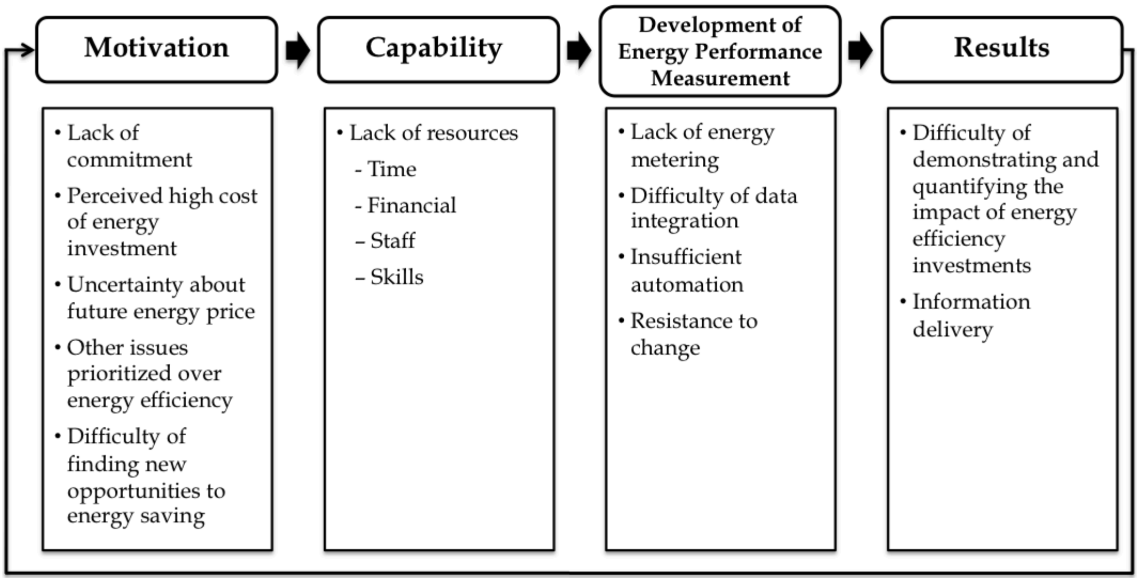

FIGURE 13 Barriers to the development of energy performance measurement.

Barriers within the ″motivation″ stage were identified to lower organizations' interest and willingness to act towards higher energy performance. These barriers are the lack of commitment, perceived high cost of energy investment, uncertainty about future energy price, other issues prioritized over energy efficiency and difficulty of finding new opportunities to energy saving. The barriers within the ″capability″ stage consist of various resource constraints identified during the interviews. These different resource shortages include the lack of financial resources, lack of time, lack of staff and lack of skills. Furthermore, the barriers within the ”development of energy performance measurement” stage (in figure 12 known as the ”implementation” stage) include various constraints to the realization of new measurement practices. These barriers include the lack of energy metering, difficulty of data integration, insufficient automation and resistance to change. The final stage, ”results”, embodies barriers that hinder the demonstration and communication of achieved results. The identified barriers within this stage were the difficulty of demonstrating and quantifying the impact of energy efficiency investments, and difficulties with information delivery. In essence, the barriers within this stage inhibit the demonstration of positive results, and the formation of the positive feedback effect to the ”motivation” stage.

Although the model proposes a certain sequence for the distinct barriers, it does not exclude the possible interactions of different barriers within a certain stage. For example, it is more than likely that the lack of commitment in the ”motivation” stage is affected by the other barriers within the same stage. It is also worth mentioning that the presented model embodies both strategic and operational levels of energy management, as it applies the concept of energy performance as defined by Sivill (2011, 38). In contrast, the original MCIR framework introduced by Chai and Yeo (2012, 469) reflects solely the perspective of top management, excluding the operational perspective from the model.

Finally, since the presented model was formed through a subjective process which is SSM, it should not be interpreted as definitive. However, as Chai and Yeo (2012, 469) argue, examining barriers from such perspective may help to identify possible chokepoints within the process. Therefore, it can be argued that the presented model offers a new perspective for understanding and potentially addressing the perceived problem situation of this study.

7 CONCLUSIONS

7.1 Main research findings

The aim of this research was to create a holistic understanding of the barriers that hinder the development of energy performance measurement. In order to achieve this aim, the problem situation was approached from a systems thinking perspective. Based on the research questions, theoretical framework and the principles of SSM, a specific methodology for the study was created (see chapter 5.2). The research material was collected in conjunction with a larger research project, using semi-structured thematic interviews. The interviewed organizations consisted of industrial companies, government entities, wholesale and retail companies and real estate companies. The interviewees consisted of managers and personnel responsible for energy and environment related issues.

The empirical part of this research was conducted in two distinct phases. The first phase utilized a reductionist research method, thematic analysis, with the aim to provide an answer to the first research question: *"What are the barriers that can be identified from the conducted interviews?"* The analysis resulted in the identification of 12 distinct barriers, which were categorized into five different barrier groups based on the adopted theoretical framework. The barriers included economic non-market failures or market barriers (lack of resources; uncertainty about future energy price; other issues prioritized over energy efficiency; perceived high cost of energy investment), economic market failures (difficulty of finding new opportunities to energy saving), organizational barriers (lack of commitment; information delivery), behavioral barriers (resistance to change) and barriers related to design and technology (lack of energy metering; difficulty of demonstrating and quantifying the impact of energy efficiency investments; difficulty of data integration; insufficient level of automation). Whereas a majority of the identified barriers are familiar from the extant research literature, this study succeeds to introduce two novel barriers: the difficulty of data integration and the insufficient level of automation. As stated, these two barriers are important from the perspective of energy performance measurement, as they strongly influence the possibilities to implement various indicators within organizations. In addition to providing an answer to the first research question of this study, these results indicate that the development of energy performance measurement is more topical factor for organizations with relatively more advanced practices in energy management. This interpretation is in line with the research of Sivill et al. (2013, 936).

The second research question of this study was formulated as follows: *"How are the barriers and their interactive relationships formed from the perspective of systems thinking?"* In order to provide an answer to this question, the second phase of the empirical research applied the established methods of SSM to create a conceptual model of the perceived problem situation. These methods included the formulation of a root definition, CATWOE analysis and conceptual model building. Firstly, the analysis resulted in a conceptual model that describes the process of developing energy performance measurement within an organization. Secondly, this initial model was expanded to include the barriers that were identified during the former empirical phase of the research. This expanded model is portrayed in figure 13 (chapter 6.3.3). A central achievement of the model is its ability to indicate which barriers are relevant to each distinct stage of the development process. Furthermore, the model proposes a logical sequence in which the barriers may occur. In essence, the model is able to point out the possible chokepoints during the development process. According to the recent literature, organizations currently struggle to make the benefits of energy efficiency visible, as they do not have adequate performance indicators for energy (Sivill, 2011; Virtanen et al., 2013; Bunse et al., 2011; Chai and Yeo, 2012). From the perspective of the created model, this observation indicates that barriers within the various stages of the model may form chokepoints that inhibit the formation of a positive feedback loop from the ″Results″-stage to the ″Motivation″-stage. Therefore, the proposed model potentially helps organizations to identify and address relevant barriers to their operations.

Moreover, as change is the only constant, the occurrence and significance of different barriers vary over time within organizations. This issue highlights the circular nature of the proposed model, as it enables the continuous assessment and improvement of the problem situation. The dynamic nature of the barriers also means that the proposed model should not be considered as comprehensive, but as a basis for further development.

As stated, the resulting model was a product of the interaction between the empirical findings and adapted theoretical framework, and was especially influenced by the pioneering work of Chai and Yeo (2012, 469). However, the proposed model incorporates central characteristics which differentiate it from Chai and Yeo's original MCIR framework. Firstly, the proposed model focuses solely on the development process of energy performance measurement. However, the model still takes into account the interdependency between the development of energy performance measurement and other activities that aim to improve energy performance. Secondly, on a higher level of abstraction, the development process of energy performance measurement is monitored and controlled through the criteria of efficiency, efficacy and effectiveness (figure 12, chapter 6.3). Thirdly, the model focuses on the concept of energy performance rather than the concept of energy efficiency, and is therefore able to encompass both operational and strategic dimensions of energy management. Therefore, in contrast to Chai and Yeo's model, the proposed model in this study is concerned with actors both on the strategic and operational levels.

By answering the research questions, this study was able to identify relevant barriers to the development of energy performance measurement, and to create a framework for understanding their interactive nature. Hence, this study has successfully reached its aim to deepen the understanding of the barriers that hinder the development of energy performance measurement. Importantly, the results of this study also proposed a new perspective to the paradox of Sivill et al. (see chapter 4.3), making the complex problem situation more explicit.

7.2 Rethinking energy efficiency?

Recently, Sivill (2011, 38) initiated a debate whether the focus of energy management should be shifted from improving energy efficiency to improving energy performance. According to Sivill, the concept of energy efficiency lacks to respond to the current needs in business management. In addition, the present state of scientific evidence leaves the environmental outcomes of energy efficiency more or less unanswered (see chapter 2.2.3). Thus, there exists a demand for a conceptual change that would enable organizations to reach concrete results from energy management while promoting sustainable development in a broader context. For this reason, this thesis focused on the concept of energy performance, as defined by Sivill (2011, 31), and its relationship to business goals and sustainable development. By doing so, this study has made its own contribution to the ongoing scientific discussion.

From a critical viewpoint, this study questions how well energy performance indicators succeed to demonstrate the required characteristics of business performance measurement, as defined by Merchant and Stede (2012, 36-39). The achieved findings demonstrate practical difficulties with the controllability, precision, timeliness, understandability and cost-effectiveness of energy performance indicators. Such shortcomings may undermine the applicability of the indicators as a basis for certain management practices, such as rewarding. These observations are congruent with the recent findings of Virtanen et al. (2013, 412). Also, this is an issue that seems to be left uncovered in Sivill's dissertation.

Furthermore, this study approached the concept of energy performance from the perspective of environmental protection, focusing on the rebound phenomenon. This study argues that the concept of energy performance offers a new perspective on the rebound problem by taking the utilized energy sources into account. By doing so, it may potentially address the increased CO_2 emission levels caused by the rebound effect. However, on a larger level, this causal relationship may not be as axiomatic as it seems. In order to have positive environmental impact, the increased collective demand for low-carbon energy sources should expand their relative share in the structure of energy supply. However, this is a subject for further study.

Altogether, this study encourages researchers and practitioners to contemplate energy performance further. As the concept is not yet institutionalized, it asks for critical evaluation, further development and practical applications.

7.3 Trustworthiness of the study

Assessing the rigor of a conducted study is an integral part of a research process. The research process of this study, combining both reductionist and holistic methods, makes the assessment of rigor an interesting aspect. Guest et al. (2012, 85) argue that the most critical question a researcher can ask in qualitative research is if the collected data and the interpretations made from it are valid. The rigorousness of thematic analysis is frequently evaluated against the criteria of validity and reliability. However, it turns out that the use of reliability and validity in qualitative context has been largely criticized due to their roots in quantitative research. The critics argue that it would be erroneous to apply criteria related to quantitative research to assess the worthiness of qualitative research. (Krefting, 1991, 214-215.) Due to the perceived inapplicability of validity and reliability in qualitative context, Guba (1981) has developed alternative criteria for ensuring rigor in qualitative inquiry. According to Guba and Lincoln (1989, 301-329), the rigor of qualitative research stems from trustworthiness, which is evaluated through four distinct criteria: credibility, transferability, dependability and confirmability. According to Morse (2015, 1212), these four criteria have remained in use to this day. In order to attain trustworthiness in qualitative research, Guba and Lincoln (1989, 301-329) proposed various strategies, or practices, to be utilized during the research process. These practices can be adopted in the stages of research design, data collection and data analysis (Miles and Huberman, 1994, 278). Morse (2015, 1219) highlights that all of these proposed practices are, however, not universally applicable, and can only be used with appropriate research methods. Furthermore, there exists no single guideline on how many of these practices should be utilized in order to achieve a rigorous inquiry (Creswell, 2012, 253).

Moreover, the utilization of SSM as a methodology brings a new dimension to the assessment of rigorousness of this study. An interesting aspect of conceptual models is the assessment of their adequacy, or validness: as Checkland and Scholes (1999, 41) argue, conceptual models are not manifestations of the real world, but models structuring our thinking in the meta-language of systems (Flood and Carson, 1990, 109). For this reason, the validity of these models cannot be checked against the real world. However, the models may be technically defensible or indefensible. The defensibility of a conceptual model is dependent on how the activities and connections in the model are linked to the root definition where it was originally derived from. (Checkland and Scholes, 1999, 41.) In order to demonstrate this defensibility, the research process has to portray an adequate level of transparency. Miles and Huberman (1994, 278) argue that the transparency of the research process is crucial for the demonstration of the trustworthiness of research findings. The transparency does not itself guarantee the trustworthiness of the research, but it provides the necessary information for others in order to assess the credibility of the research process (Morse, 2015, 1212; Guest et al., 2012, 85-86).

It is important to note that the chosen research approach of this study advocates the importance of subjectivity, and the utilized research methods require involvement and interpretation from the researcher (Jackson, 2004, 135; Guest et al., 2012, 10-11). Therefore, in order to enhance the trustworthiness of this research, the research design, data collection and analysis stages are described as accurately as possible. This includes the basis for the selection of the interviewees and the interview methods, as well as the description of the different stages of empirical analysis. In addition, the theoretical framework is based on the critical evaluation of high-quality scientific research. The sources used in the theoretical framework constitute of peer-reviewed literature accompanied with other high-quality sources such as reports released by the Intergovernmental Panel on Climate Change (IPCC). In addition, the utilized source material demonstrates a versatile use of sources from different scientific disciplines. The research process also included the following research practices:

- The used interview form was first pretested with two interviewed organizations. After the interviews, the interviewees gave a short feedback about the structure and content of the interview.
- The structure of the interview form was adjusted high enough to increase the ability to compare data across participants, time and geography.
- The interviews were carefully recorded and later transcribed using a consistent transcription procedure.
- In order to maintain the true meanings and perceptions of the interviewees, the transcribed interviews were translated from finnish to english using the best accuracy and care possible.
- The identified themes and interpretations were supported using verbatim quotes from the interviewees.

7.4 Limitations of the study and directions for future research

It is necessary to acknowledge that the chosen scope of this study sets several limitations. As the thematic interviews were carried out in Finland, the achieved results are sensitive to country-specific features such as local culture and national legislative scheme. The results are also susceptible to the challenging economic situation during the time of the conducted interviews. Also the national energy efficiency law, which was under preparation at the time of the data collection, had most likely an effect on the interviewees' responses. Therefore, conducting a similar research at a later time or in a different regional context could bring new and interesting results.

The choice of the interviewees also forms a limitation, as the selection of the interviewed organizations and personnel was influenced by the needs of the three distinct studies. On the other hand, this allowed the researcher to perform interviews in more organizations that would have been otherwise possible. However, the amount of interviews within each organization remained low, as only one or two interviews were performed per each organization. Therefore, another opportunity for future research would be to perform a similar study in the form of a case study. By doing so, it would be possible to create a deep case-specific insight of the barriers within an individual organization.

Moreover, the utilized interview form (Appendix 1) can be criticized for the fact that it mainly focused to the first structural factor of energy performance, which is *the efficiency of energy production and consumption*. Therefore, the second structural factor, *the sources of energy used for manufacturing products*, did not get as much attention in the interviews. This was partly due to the differing needs of the three separate studies, based on which the interview form was constructed.

Most importantly, this study was completed within a constrained timeframe, which significantly restrained the application possibilities of SSM. Due to the adopted timeframe, especially the participatory nature of the methodology was limited. Therefore, a natural direction for future research would be to carry out the remaining stages of SSM, with the aim to improve the perceived problem situation.

Lastly, a central limitation was the novelty of energy performance as a concept. As energy performance has not yet reached an institutionalised position, it continues to evolve in the interaction of performance measurement, environmental responsibility and sustainable development. As there exists a demand for a conceptual change, the future research should focus on critically evaluating and developing the concept of energy performance.

7.5 Concluding remarks

An essential, but commonly overlooked, characteristic of energy efficiency barriers is their ability to influence each other. The extant barrier research has focused on analyzing single barriers or barrier groups in isolation, leaving the potential interactions between the barriers unobserved. The objective of this study was to further the present state of knowledge by analyzing how the interactive relationships between the barriers are formed. In order to achieve this aim, the principles of systems thinking were applied during the research process. Therefore, this study departs from most previous barrier research by approaching the research problem from a holistic viewpoint, and contributes to a research area currently taking its first steps.

Based on the reviewed scientific literature, this thesis questions if energy efficiency, as a current concept, is able to respond to the extant needs in business management and environmental protection. Therefore, instead of adopting a conventional perspective on energy efficiency, this thesis focused on the concept of energy performance. Energy performance, as a broader concept, may potentially enable organizations to reach concrete results from energy management while promoting sustainable development in a larger context.

The limitations aside, the main achievement of this study was to introduce a model for understanding the interactive nature of the barriers to the development of energy performance measurement. From the perspective of business management, the created model works as a tool for the management of change, as it increases the understanding of the paradoxal problem situation and enables rational discourse to take place. By doing so, the model aims to address the current needs of organizations in developing specific and quantitatively measurable performance indicators for energy. Finally, this study has contributed in filling an existing research gap by creating a deeper understanding of the mechanisms that cause inertia in the progress of energy management.

REFERENCES

Alasuutari, P. & Alasuutari, P. 2011. Laadullinen tutkimus 2.0. Tampere: Vastapaino.

Alcott, B. 2008. The sufficiency strategy: Would rich-world frugality lower environmental impact? Ecological Economics 64 (4), 770-786.

Babakus, E. 2003. The effect of management commitment to service quality on employees' affective and performance outcomes. Journal Of The Academy Of Marketing Science 31 (3), 272-286.

Barton, J. & Haslett, T. 2007. Analysis, synthesis, systems thinking and the scientific method: rediscovering the importance of open systems. Systems Research and Behavioral Science 24 (2), 143-155.

Bateman, I. J. & Willis, K. G. 1999. Valuing environmental preferences : theory and practice of the contingent valuation method in the US, EU, and developing countries. Oxford: Oxford University Press.

Berkhout, P. H. G., Muskens, J. C. and W. Velthuijsen, J. 2000. Defining the rebound effect. Energy Policy 28 (6–7), 425-432.

Binswanger, M. 2001. Technological progress and sustainable development: what about the rebound effect? Ecological Economics 36 (1), 119-132.

Bithas, K. & Kalimeris, P. 2013. Re-estimating the decoupling effect: Is there an actual transition towards a less energy-intensive economy? Energy 51 (0), 78-84.

Boulding, K. E. 1956. General Systems Theory-The Skeleton of Science. Management Science 2 (3), 197-208.

Brännlund, R., Ghalwash, T. & Nordström, J. 2007. Increased energy efficiency and the rebound effect: Effects on consumption and emissions. Energy Economics 29 (1), 1-17.

Brown, M. A. 2001. Market failures and barriers as a basis for clean energy policies. Energy Policy 29 (14), 1097-1207.

Bunse, K. 2011. Integrating energy efficiency performance in production management - gap analysis between industrial needs and scientific literature. Journal of Cleaner Production 19 (6-7), 667-May,.

Cagno, E., Worrell, E., Trianni, A. & Pugliese, G. 2013. A novel approach for barriers to industrial energy efficiency. Renewable and Sustainable Energy Reviews 19 (0), 290-308.

Capehart, B. L., Turner, W. C. & Kennedy, W. J. 2012. Guide to energy management. (7th ed. painos) Lilburn GA Boca Raton FL: Fairmont Press ;.

Chai, K. & Yeo, C. 2012. Overcoming energy efficiency barriers through systems approach—A conceptual framework. Energy Policy 46 (0), 460-472.

Checkland, P. 1981. Systems thinking, systems practice. Chichester: Wiley.

Checkland, P. & Scholes, J. 1999. Soft systems methodology in action : a 30-year retrospective. Chichester: Wiley.

Churchman, C. W. 1968. The systems approach /. New York : Delacorte Press. A Delta book.

Chwastiak, M. 2006. Rationality, performance measures and representations of reality: planning, programming and budgeting and the Vietnam war. Critical Perspectives on Accounting 17 (1), 29-55.

Creswell, J. 2012. Qualitative inquiry and research design: Choosing among five approaches. Thousand Oaks, CA: Sage.

Creswell, J., & Plano Clark, V. 2011. Designing and conducting mixed methods research (2nd ed.). Thousand Oaks, CA: Sage.

Creyer, E., H. 1996. The impact of corporate behavior on perceived product value. Marketing Letters 7 (2), 173-185.

de Groot, H. L. F., Verhoef, E. T. & Nijkamp, P. 2001. Energy saving by firms: decision-making, barriers and policies. Energy Economics 23 (6), 717-740.

DeCanio, S. J. & Watkins, W. E. 1998. Information processing and organizational structure. Journal of Economic Behavior and Organization 36 (3), 275-294.

Delmas, M. A., Etzion, D. & Nairn-Birch, N. 2013. Triangulating Environmental Performance: what do Corporate Social Responsibility Ratings really Capture? Academy of Management Perspectives 27 (3), 255-267.

Dincer, I. 2003. On energy conservation policies and implementation practices. International Journal of Energy Research 27 (7), 687-702.

Epstein, M. J. cop. 2008. Making sustainability work : best practices in managing and measuring corporate social, environmental, and economic impacts. Sheffield: Greenleaf Publishing.

Eriksson, R. & Andersson, J. O. 2010. Elements of ecological economics. London: Routledge.

Eskola, J. & Suoranta, J. 1998. Johdatus laadulliseen tutkimukseen. Tampere: Vastapaino.

EU, 2012. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.

European Commission, 2009. Reference document on Best Available Techniques for energy efficiency, February, 2009.

Everett, J. & Neu, D. 2000. Ecological modernization and the limits of environmental accounting? Accounting Forum 24 (1), 5-29.

Flood, R. L. & Carson, E. R. 1990. Dealing with complexity /. (3rd pr. (with corr.)) New York : Plenum.

Franco-Santos, M., Kennerley, M., Micheli, P., Martinez, V., Mason, S., Marr, B., Gray, D. & Neely, A. 2007. Towards a definition of a business performance measurement system. International Journal of Operations and Production Management 27 (8), 784.

Gates, S. 1999. Aligning strategic performance measures and results. New York, NY: The Conference Board.

Goddard, M., Mannion, R. & Smith, P. 2000. Enhancing performance in health care: a theoretical perspective on agency and the role of information. Health Economics 9 (2), 95-107.

Gond, J., Grubnic, S., Herzig, C. & Moon, J. 2012. Configuring management control systems: Theorizing the integration of strategy and sustainability. Management Accounting Research 23 (3), 205-223.

Gray, D., Pavlov, A. & Micheli, P. 2015. Measurement Madness : Avoiding Performance Management Pitfalls. Chichester, West Sussex: Wiley. ID: 910163; Accession Number: 910163. Publication Type: eBook. Language: English. .

Gray, R. 2010. Is accounting for sustainability actually accounting for sustainability…and how would we know? An exploration of narratives of organisations and the planet. Accounting, Organizations and Society 35 (1), 47-62.

Greene, D. L., Kahn, J. R. & Gibson, R. C. 1999. Fuel Economy Rebound Effect for U.S. Household Vehicles. Energy Journal 20 (3), 1.

Grossman, G.M., Krueger, A.B., 1995. Economic growth and the environment. The Quarterly Journal of Economics 110 (2), 353–377.

Guba, E. G. 1981. Criteria for assessing the trustworthiness of naturalistic inquiries. Educational Resources Information Center Annual Review Paper, 29, 75-91.

Guba, E., and Lincoln, Y. 1989. Fourth generation evaluation. Newbury Park, CA: Sage.

Guest, G., MacQueen, K. M. & Namey, E. E. 2012. Applied thematic analysis. Thousand Oaks, CA: Sage.

Hall S. 1988. The rediscovery of 'ideology': return of the repressed in media studies. In: Storey, J. 2009. Cultural theory and popular culture : a reader. (4th ed.) Harlow England ; New York: Pearson Longman. Previous ed.: Harlow, England : Pearson/Prentice Hall, 2006.. p. 124–155.

Hanley, N., McGregor, P. G., Swales, J. K. & Turner, K. 2009. Do increases in energy efficiency improve environmental quality and sustainability? Ecological Economics 68 (3), 692-709.

Hasanbeigi, A., Menke, C. & Du Pont, P. 2010. Barriers to energy efficiency improvement and decision-making behavior in Thai industry. Energy Efficiency 3 (1), 33-52.

Herring, H. 2006. Energy efficiency—a critical view. Energy 31 (1), 10-20.

Herring, H. & Roy, R. 2007. Technological innovation, energy efficient design and the rebound effect. Technovation 27 (4), 194-203.

Herring, H., & Sorrell, S. 2009. Energy efficiency and sustainable consumption: The rebound effect. Basingstoke: Palgrave Macmillan.

Hirsjärvi, S., Remes, P. & Sajavaara, P. 2009. Tutki ja kirjoita. (15. uud. p. painos) Helsinki: Tammi. Lisäpainokset: 16. p. 2010. - 17. p. 2012. - [Lisäp.] 2013. - 18. p. 2013.

IEA, 2007. World Energy Outlook 2007. OECD/IEA, Paris.

IPCC. 2014. Climate Change 2014: Mitigation of Climate Change. Fifth assessment report. Retrieved August 11, 2015 from https://www.ipcc.ch/report/ar5/wg3/

International Organization for Standardization. 2011. EN ISO 50001:2011. Energy management systems. Requirements with guidance for use (ISO 50001:2011).

Ittner, C. D., Larcker, D. F. & Randall, T. 2003. Performance implications of strategic performance measurement in financial services firms. Accounting, Organizations and Society 28 (7–8), 715-741.

Jackson, M. C. 2003. Systems thinking : creative holism for managers. Chichester : John Wiley and Sons. Repr. 2011.

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

Jevons, W. S. & Flux, A. W. 1906. The coal question : an inquiry concerning the progress of the nation, and the probable exhaustion of our coal-mines. (3. ed., rev.) New York : Kelley. Repr. 1965.

Kaika, D. & Zervas, E. 2013. The Environmental Kuznets Curve (EKC) theory—Part A: Concept, causes and the CO2 emissions case. Energy Policy 62 (0), 1392-1402.

Kankkunen, K., Matikainen, E. & Lehtinen, L. 2005. Mittareilla menestykseen : sokkolennosta hallittuun nousuun. Helsinki : Talentum.

Kaplan, R. S. & Norton, D. P. 1996. The balanced scorecard : translating strategy into action. Boston, MA: Harvard Business School Press.

Klein, J. & Dawar, N. 2004. Corporate social responsibility and consumers' attributions and brand evaluations in a product–harm crisis. International Journal of Research in Marketing 21 (3), 203-217.

Kolk A. & van Tulder R. International business, corporate social responsibility and sustainable development. International Business Review 2010; 19 (2):119–125.

Kostka, G., Moslener, U. & Andreas, J. 2013. Barriers to increasing energy efficiency: evidence from small-and medium-sized enterprises in China. Journal of Cleaner Production 57 (0), 59-68.

Krefting, L. 1991. Rigor in qualitative research: the assessment of trustworthiness. The american journal of occupational therapy 45 (3), 214-222.

Kuznets, S. 1955. Economic Growth and Income Inequality. The American Economic Review 45 (1), 1-28.

Laine, M. 2005. Meanings of the term 'sustainable development' in Finnish corporate disclosures. Accounting Forum 29 (4), 395-413.

Madlener, R. & Alcott, B. 2009. Energy rebound and economic growth: A review of the main issues and research needs. Energy 34 (3), 370-376.

Merchant, K. A. & Van der Stede, W. A. 2012. Management control systems : performance measurement, evaluation and incentives. (3rd ed. painos) Harlow : Financial Times/Prentice Hall.

Meyer M. 2003. Finding performance: The new discipline in management. In Business performance measurement: Unifying theory and integrating practice, Neely A (ed.). 2nd edn. Cambridge University Press: Cambridge, 2003; 51–65.

Micheli, P. & Manzoni, J. 2010. Strategic Performance Measurement: Benefits, Limitations and Paradoxes. Long range planning 43 (4), 465-476.

Miles, M., and Huberman, A. (1994). Qualitative data analysis (2nd ed.). Thousand Oaks, CA: Sage.

Morrison, J. B. 2008. Putting the learning curve in context. Journal of Business Research 61 (11), 1182-1190.

Morse, J. M. 2015. Critical Analysis of Strategies for Determining Rigor in Qualitative Inquiry. Qualitative health research 25 (9), 1212-1222.

Moullin, M. 2002. Delivering excellence in health and social care : quality, excellence and performance measurement. Buckingham : Open University Press.

Moullin, M. 2007. Performance measurement definitions. International journal of health care quality assurance 20 (3), 181-183.

Nagesha, N. 2006. Barriers to energy efficiency in small industry clusters: Multi-criteria-based prioritization using the analytic hierarchy process. Energy 31 (12), 1969-1983.

Neely, A., Adams, C. & Kennerley, M. 2002. The performance prism : the scorecard for measuring and managing business success. Harlow : Financial Times Prentice Hall.

Niemelä, M., Pirker, A. & Westerlund, J. 2008. Strategiasta tuloksiin : tehokas johtamisjärjestelmä. Helsinki: WSOYpro. Ekonomia ISSN.

O'Callaghan, P. W. & Probert, S. D. 1977. Energy management. Applied Energy 3 (2), 127-138.

O'Driscoll, E. 2013. The development of energy performance indicators within a complex manufacturing facility. The International Journal of Advanced Manufacturing Technology, 2205.

Otley, D. 1999. Performance management: a framework for management control systems research. Management Accounting Research 10 (4), 363-382.

Paavola, S., Hakkarainen, K. 2006. Entäpä jos…? Ideoiden abduktiivinen kehittely tutkimusprosessin olennaisena osana. In: Rolin, K., Kakkuri-Knuuttila, M., Henttonen, E. & Eräranta, K. 2006. Soveltava yhteiskuntatiede ja filosofia. Helsinki: Gaudeamus. Writers: Kirsi Eräranta et al.

Palme, U. & Tillman, A. 2008. Sustainable development indicators: how are they used in Swedish water utilities? Journal of Cleaner Production 16 (13), 1346-1357.

Patterson, M. G. 1996. What is energy efficiency?: Concepts, indicators and methodological issues. Energy Policy 24 (5), 377-390.

Peloza, J. & Shang, J. 2011. How can corporate social responsibility activities create value for stakeholders? A systematic review. Journal of the Academy of Marketing Science 39 (1), 117-135.

Petersen, H. & Vredenburg, H. 2009. Corporate governance, social responsibility and capital markets: exploring the institutional investor mental model-null. Corporate Governance 9 (5), 610-622.

Phylipsen, G. J. M., Blok, K. & Worrell, E. 1997. International comparisons of energy efficiency-Methodologies for the manufacturing industry. Energy Policy 25 (7–9), 715-725.

Princen, T. 2005. The logic of sufficiency. Cambridge, MA: MIT Press.

Potter, J. 1996. Representing reality : discourse, rhetoric and social construction. London: SAGE.

Propper, C. & Wilson, D. 2003. The Use and Usefulness of Performance Measures in the Public Sector. Oxford Review of Economic Policy 19 (2), 250-267.

Ren, T. 2009. Barriers and drivers for process innovation in the petrochemical industry: A case study. Journal of Engineering and Technology Management 26 (4), 285-304.

Rohdin, P. & Thollander, P. 2006. Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. Energy 31 (12), 1836-1844.

Sardianou, E. 2008. Barriers to industrial energy efficiency investments in Greece. Journal of Cleaner Production 16 (13), 1416-1423.

Saunders, H. D. 2000. A view from the macro side: rebound, backfire, and Khazzoom–Brookes. Energy Policy 28 (6–7), 439-449.

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

Schönsleben, P., Vodicka, M., Bunse, K. & Ernst, F. O. 2010. The changing concept of sustainability and economic opportunities for energy-intensive industries. CIRP Annals - Manufacturing Technology 59 (1), 477-480.

Senge, P. M. 1993. The fifth discipline : the art and practice of the learning organization. (Paperback ed. painos) London: Century Business.

Siitonen, S. & Holmberg, H. 2012. Estimating the value of energy saving in industry by different cost allocation methods. International Journal of Energy Research 36 (3), 324-334.

Siitonen, S. 2010. Implications of energy efficiency improvement for CO2 emissions in energy-intensive industry. Aalto University, School of Science and Technology.

Sivill, L. 2011. Success factors of energy management in energy-intensive industries : energy performance measurement. Aalto University, School of Engineering.

Sivill, L., Manninen, J., Hippinen, I. & Ahtila, P. 2013. Success factors of energy management in energy-intensive industries: Development priority of energy performance measurement. International Journal of Energy Research 37 (8), 936-951.

Smith, P. 1995. On the unintended consequences of publishing performance data in the public sector. International Journal of Public Administration 18 (2-3), 277-310.

Sola, A. V. H. & Xavier, A. A. d. P. 2007. Organizational human factors as barriers to energy efficiency in electrical motors systems in industry. Energy Policy 35 (11), 5784-5794.

Soroye, K. L. & Nilsson, L. J. 2010. Building a business to close the efficiency gap: the Swedish ESCO Experience. Energy Efficiency 3 (3), 237.

Sorrell, S., Dimitropoulos, J. & Sommerville, M. 2009. Empirical estimates of the direct rebound effect: A review. Energy Policy 37 (4), 1356-1371.

Sorrell, S., Schleich, J., Scott, S., O'Malley, E., Trace, F., Boede, U., Ostertag, K., Radgen, P., 2000. Barriers to Energy Efficiency in Public and Private Organizations. Final Report to DG Research Under the Project 'Barriers to

Energy Efficiency in Public and Private Organizations'. SPRU—Science and Technology Policy Research, University of Sussex, Brighton.

Stern, D. I. 2010. Between estimates of the emissions-income elasticity. Ecological Economics 69 (11), 2173-2182.

Stern, P. C. 1992. What psychology knows about energy conservation. American Psychologist 47 (10), 1224-1232.

Tanaka, K. 2008. Assessment of energy efficiency performance measures in industry and their application for policy. Energy Policy 36 (8), 2877.

Thollander, P., Backlund, S., Trianni, A. & Cagno, E. 2013. Beyond barriers – A case study on driving forces for improved energy efficiency in the foundry industries in Finland, France, Germany, Italy, Poland, Spain, and Sweden. Applied Energy 111 (0), 636-643.

Thollander, P. & Dotzauer, E. 2010. An energy efficiency program for Swedish industrial small- and medium-sized enterprises. Journal of Cleaner Production 18 (13), 1339-1346.

Thollander, P. & Ottosson, M. 2008. An energy efficient Swedish pulp and paper industry - exploring barriers to and driving forces for cost-effective energy efficiency investments. Energy Efficiency 1 (1), 21-34.

Trianni, A., Cagno, E., Thollander, P. & Backlund, S. 2013. Barriers to industrial energy efficiency in foundries: a European comparison. Journal of Cleaner Production 40, 161-176.

Tung, A., Baird, K. & Schoch, H. P. 2011. Factors influencing the effectiveness of performance measurement systems. International Journal of Operations and Production Management 31 (12), 1287-1310.

Tuomaala, M. 2012. Energiatehokkuuden mittarit ja potentiaalit. [Espoo]: Aalto-yliopisto, insinööritieteiden korkeakoulu. Aalto-yliopiston julkaisusarja. Tiede + teknologia, ISSN 1799-487X ; 1/2012. Kannessa myös: Tutkimusraportti.

Tuomi, J. & Sarajärvi, A. 2009. Laadullinen tutkimus ja sisällönanalyysi /. (5., uud. laitos. painos) Helsinki : Tammi.

Turner, K. & Hanley, N. 2011. Energy efficiency, rebound effects and the environmental Kuznets Curve. Energy Economics 33 (5), 709-720.

UNEP, 2006. Barriers to Energy Efficieny in Industry in Asia. United Nations Environment Program.

United Nations, 2014. Prototype global sustainable development report. New York: United Nations department of economic and social affairs, division for sustainable development.

Upadhaya, B., Munir, R. & Blount, Y. 2014. Association between performance measurement systems and organisational effectiveness. International Journal of Operations and Production Management 34 (7), 853.

Viinikainen, S. & Soimakallio, S. 2007. Energy use : visions and technology opportunities in Finland. [Espoo] : [Helsinki] : VTT ; Edita.

Virtanen, T., Tuomaala, M. & Pentti, E. 2013. Energy efficiency complexities: A technical and managerial investigation. Management Accounting Research 24 (4), 401-416.

Vollebergh, H. R. J., Melenberg, B. & Dijkgraaf, E. 2009. Identifying reduced-form relations with panel data: The case of pollution and income. Journal of Environmental Economics and Management 58 (1), 27-42.

Wagner, M. 2007. Integration of Environmental Management with Other Managerial Functions of the Firm: Empirical Effects on Drivers of Economic Performance. Long range planning 40 (6), 611-628.

Wagner, M. 2008. The carbon Kuznets curve: A cloudy picture emitted by bad econometrics? Resource and Energy Economics 30 (3), 388-408.

Wang, G. 2008. Analysis of interactions among the barriers to energy saving in China. Energy Policy (6), 1879.

Weber, L. 1997. Some reflections on barriers to the efficient use of energy. Energy Policy 25 (10), 833-835.

World Commission on Environment and Development. & Brundtland, G. H. 1987. Our common future. (Repr. 2009. painos) Oxford ; New York N.Y.: Oxford University Press.

Zeng, S. X., Shi, J. J. & Lou, G. X. 2007. A synergetic model for implementing an integrated management system: an empirical study in China. Journal of Cleaner Production 15 (18), 1760-1767.

Zilahy, G. 2004. Organisational factors determining the implementation of cleaner production measures in the corporate sector. Journal of Cleaner Production 12 (4), 311-319.

APPENDICES

Appendix 1. Survey on the current state of energy management

1. Preparations and introduction to the subject
- General objectives of the research
- Utilization of collected data

2. Background information
- Job description
- Former relevant work experience and education

3. Warm up questions
- Meaning of energy efficiency to the organization
- Meaning of energy efficiency to the interviewee

4. Decision-making and cooperation
- Interviewees possibilities to influence decision-making and practices
- Other employees possibilities to influence decision-making and practices
- Cooperation with the management
- Cooperation with other employees (e.g. energy management team)
- How is energy efficiency visible in employees' daily work?

5. Motivation
- Attitudes and motivation towards energy efficiency
- Suggestion on improving employee motivation

6. Management support
- Management's roles in decision-making
- Management support in relation to energy efficiency practices

7. Information systems
- Relevant information systems to energy efficiency
- The general role of information systems

8. Energy metering
- What is being measured?
    - On what system level?
    - On what temporal level?
    - Personnel currently utilising this information?
- Description of how the data is analysed
- Sufficiency of current instrumentation
- Developmental issues

9. Energy efficiency indicators
- Description of the currently utilized indicators
- Verifiability of energy efficiency
- Utilization of indicators in practice

- Presentation of information
- Understandability, controllability
- Benchmarking
- Developmental issues

10. Energy efficiency measures
- Realistic energy efficiency potential
- Energy efficiency investments, utilized criteria and monitoring
- Role of energy efficiency in budgeting
- Resources

11. Compensation and feedback
- Description of the compensation methods related to energy efficiency
- Indicators used for compensation
- Suggestions for improvements
- Benefits of compensation
- Methods used for giving and receiving feedback
- People involved with giving and receiving feedback
- Benefits of giving/receiving feedback
- Suggestions for improvements

12. Communication and training
- Channels used for external and internal communication
- Contents of external and internal communication
- Suggestions for improvements
- The effects of communication on motivation towards energy efficiency
- Description of the training organised for the employees
- Frequency of training
- Benefits of training
- Suggestions for improvements

13. Conclusion
- Future perspectives
- Other developmental needs
- Additional comments