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Improving Energy Efficiency in Industrial Energy Systems

An Interdisciplinary Perspective on Barriers, Energy Audits, Energy Management, Policies, and Programs

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To my dear wife Sara for all the support throughout the years, for being such a precious jewel, a wonderful wife and my very best friend! Great thanks also to my lovely children David, Johannes, Hanna, Simon, Lina, and Josefin

PT

To my dear husband Jonas, and to our lovable children Kia and Oliver, for all the laughs and great patience during the periods of never-ending writing

JP

This book is based on work conducted within the interdisciplinary post-graduate school Energy Systems. The national Energy Systems Programme aims at creating competence in solving complex energy problems by combining technical and social sciences. The research program analyzes processes for the conversion, transmission and utilization of energy, combined together in order to fulfill specific needs.

PROGRAM
ENERGISYSTEM
Forskning och forskarskola

The research groups that participate in the Energy Systems Programme are the Department of Engineering Sciences at Uppsala University, the Division of Energy Systems at Linköping Institute of Technology, the Department of Technology and Social Change at Linköping University, the Division of Heat and Power Technology at Chalmers University of Technology in Göteborg as well as the Division of Energy Processes at the Royal Institute of Technology in Stockholm.

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Preface

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Contents

Abbreviations

AEPS	Asymmetric energy policy shocks
CE-standard	Conformité européenne
CNC	Computer numerical control
CoP	Communities of practice
DC motor	Direct current
DSM	Demand side management
EEAP	Enterprise Energy Audit Programme
EEC	Energy Efficiency Committee
EMS	Environmental management system
ESD	Energy End-use Efficiency and Energy Services Directive
EU	European Union
EUAs	EU Allowances (EUAs)
EU ETS	EU Emissions Trading Scheme
GDP	Gross domestic product
HVAC	Heating, ventilation and air conditioning
HF-operation	High frequency
IAC	Industrial Assessment Center
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KWh	Kilowatt hour
LTA	Long-Term Agreement
MIND	Method for analysis of industrial energy systems
MWh	Megawatt hour
NEEAP	National Energy Efficiency Action Plan
NGO	Non-Governmental Organization
PDCA	Plan–do–check–act
PFE	Programme for Improving Energy Efficiency in Energy-Intensive Industry
PPI	Pulp and paper industry

R&D	Research and development
SCC	Swedish Climate Committee
SCOT	Social construction of technology
SME	Small and medium-sized enterprise
STS	Science and technology studies
TA	Transactional analysis
TNS	The Natural Step
VAV	Variable air volume
VSD	Variable speed drive

Chapter 1
Setting the Agenda

Abstract The improvement of energy efficiency in industry is the focus of this book. We apply an interdisciplinary perspective in examining energy efficiency in small- and medium-sized enterprises. In this introductory chapter, we present the book's aim and contributions. We discuss various perspectives on energy systems and why an interdisciplinary approach to energy efficiency in industry is urgently needed. We elaborate on interdisciplinarity and what it means in practice. The chapter also includes a brief discussion on sustainability and its principles, the differences between the perspectives of individual companies and of the government, and ends by outlining how the book is organized.

1.1 Introduction

Most of the scientific community agrees that increased global warming, due mostly to anthropogenic carbon dioxide emissions, in fact poses a major threat to the environment. As industry is one of the highest energy-using sectors in the world (IEA 2007), a shift toward improved energy efficiency in industry is crucial to limiting carbon dioxide emissions.

According to IPCC (2007), improving industrial energy efficiency is one of the most important ways to reduce the threat of increased global warming. In this chapter, we will discuss earlier research into the often acknowledged "energy efficiency gap". This concept refers to the assumption that though technologies, methods, and processes exist for reducing energy use in industry, barriers hinder their implementation. Overcoming such barriers to improved energy efficiency is thus of great importance.

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However, this energy efficiency transformation will not come easily and great challenges face decision-makers at all levels of society. Even from the most "techno-optimistic" perspective, industrial energy use is projected to increase over the coming 50 years (Gielen and Taylor 2007). How industry can be transformed so as to radically improve its use of energy will determine society's ability to create long-term sustainable energy systems. This transformation can be facilitated by policy means and government initiatives, such as taxation, standards, subsidies, information campaigns, and energy audits. However, there is a risk that these measures will not take us as far as is needed. Research demonstrates that the normal outcome of any industrial energy program is that about 40–50 % of the proposed measures are implemented (Thollander et al. 2012), i.e., half the technical potential for improved energy efficiency is left unexploited. Shifting energy systems toward improved sustainability will require not only that users invest in more energy-efficient equipment, but that they "transform" their attitudes, behaviors, values, and routines to favor improved energy efficiency. Ultimately, such a shift, as argued later in this book, must be complemented by different theoretical approaches from those applied in the past.

1.1.1 Aim

The improvement of energy efficiency in industry is the focus of this book. We apply an interdisciplinary perspective in examining energy efficiency in industrial energy systems, and discuss how "cross-pollinating" perspectives and theories from the social and engineering sciences can enhance our understanding of barriers, energy audits, energy management, policies, and programs as they pertain to improved energy efficiency in industry.

1.2 Perspectives on Energy Systems

The energy debate has tended to focus on the supply of energy. Generally, the outcome of this debate has depended on two matters: the perspective addressed and the system boundaries defined, time possibly being included in the latter. These two matters greatly affect the outcome of any discussion of energy systems and ultimately define what a person, organization, or society considers the right or wrong thing to do.

A systems approach, according to Churchman (1968), begins by seeing the world through the eyes of others, i.e., when a problem is viewed from several directions. Churchman (1968) cites examples of how several problems facing the world could in theory be solved using modern technology, yet nonetheless remain unsolved, a conundrum that stresses the need to apply a systems approach. When conducting systems analysis, one must define what is inside the system and what belongs to the environment. In essence, the analysis considers what is inside the system boundaries and all aspects that are outside the system is seen as the environment that is excluded from the analysis. For example, when conducting an energy audit, a technical approach is often used in studying the technology (e.g., the use of variable speed drivers for electric motors) and its energy-saving potential, while issues such as energy management are overlooked. In such an analysis, company staff may be seen as outside the system boundary, i.e., as part of the environment, as the analysis does not consider the staff's effect on the technology. This narrow way of conducting system analysis, as stated later in the book, calls for a change.

Another way to view systems is to categorize them depending on their degree of complexity. Boulding (1956) categorized systems into nine levels of complexity, beginning with static mechanics at the first level and leading to humans and the interaction between them at higher order levels.

From a government point of view, the importance of energy efficiency may be viewed from various perspectives. Stern and Aronson (1984) claim that four perspectives can be applied to the energy issue. First, energy is often seen as a commodity, or more accurately, a collection of commodities. Second, energy can be viewed as an ecological resource. The third major perspective that they identify, which has increased in importance in recent years, is energy as a social necessity; from this perspective, consumers are said to have a right to receive energy. The fourth significant perspective on energy is that it constitutes a strategic material or resource. From this perspective, the important properties of each energy carrier include its geographical location in the world, the political stability and orientation of the countries where it is located, whether it is located in an unstable area, and the availability of domestic or other reliable substitutes (Stern and Aronson 1984).

Regarding European energy politics, there is also another perspective. The European Union (EU) started out as a coal and steel union granting large subsidies to the coal and steel industries, for example. The range of views on energy make energy politics, and energy efficiency in particular, a complicated matter, and a strong emphasis on one perspective, may lead to a lower priority being assigned to, for example, energy end-use efficiency policies.

Yet another perspective, although closely related to Stern and Aronson's (1984) concept of energy as an ecological resource, concerns the issue of increased global warming. Regarding the issue of governance of the security of energy supply, energy efficiency is stated to be a major concern. From a government perspective, energy efficiency can be concluded to be crucial to the strategic governance of any country or region.

From the perspective of industrial companies, however, neither the energy supply security nor the threat of increased global warming may receive much attention from most directors, CEOs, or mid- and lower level executives. Meeting owners' goals for profitability, productivity, safety, and indoor environment all demand greater management time and attention. Of course, there are exceptions to this pattern, as some companies are now leaping into "going green" (Nattrass and Altomare 2001). In general, however, we argue that these "green" companies represent exceptions, and that most companies have made energy efficiency a low organizational priority.

A large survey of companies in the EU found that nearly two thirds (63 %) of small and medium-sized enterprises (SMEs) in the EU lack even simple rules or devices for saving energy, while only 29 % have introduced any measures to save energy and resources in their operations. Furthermore, only 4 % of SMEs in the EU have environmental management systems in place; for larger companies, this proportion is 19 %. Regarding attitudes toward energy savings, 70 % of SMEs in the EU with fewer than 10employees, 57 % with fewer than 50 employees, and 44 % with fewer than 250 employees stated that they did not care; 30 % of large companies expressed the same indifference (EC 2007).

Understanding energy use and efficiency in industry calls for the use of a range of perspectives, theories, and methods. This leads us to the interdisciplinary approach, on which we will elaborate next.

1.3 An Interdisciplinary Approach to Efficiency in Industry

Interdisciplinarity is found when various knowledge areas interact to solve a shared problem. In interdisciplinary research, the researcher crosses disciplinary boundaries, defining a new problem area or research field. Such research goes beyond the questions and answers established in any one discipline to form something new. To understand the ideas underlying interdisciplinarity, it can be useful to reflect on what a discipline is.

Disciplines usually coincide with academic departments or divisions that have been established as social structures for organizing knowledge. A discipline's continuity is insured by the training of new students (Greckhamer et al. 2008). A discipline constitutes a way of knowing and has distinctive tools, concepts, methods, and language (Coast et al. 2007). This idealized picture can of course be problematized by the fact that disciplines also have internal conflicts that can make their exponents disagree on methodology, how to understand the empirical field, and how to analyse results. Be that as it may, we can still use this description as an ideal against which to consider interdisciplinarity.

There are also various levels of interdisciplinarity. A lower degree of interdisciplinarity is found in multidisciplinarity, in which researchers from various disciplines work together without altering their own methods, analytical tools, or assumptions regarding the world (Coast et al. 2007). This is the most frequently encountered form of interdisciplinarity. Transdisciplinarity lies at the other end of this scale, and entails a very high degree of integration of theories, models, and methods (Coast et al. 2007). This is the most difficult form of interdisciplinarity to apply, because its practitioners must understand more than just their own paradigm.[1] Fig. 1.1 visualizes the difference between multi- and transdisciplinarity.

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[1] "Paradigm" refers to the characteristic thought pattern of any scientific discipline.

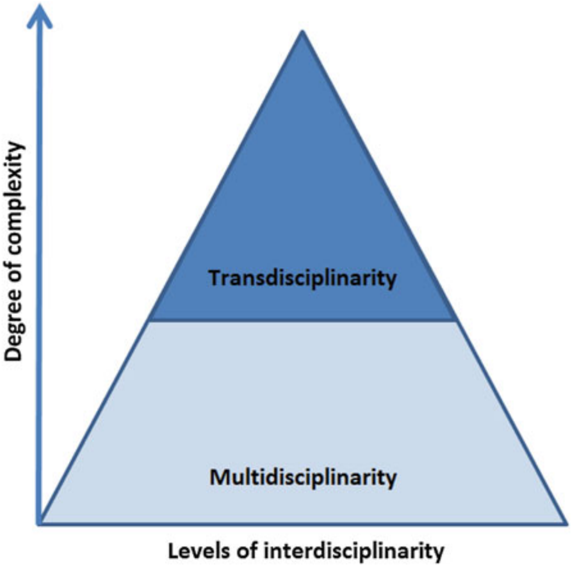

Fig. 1.1 Different levels of interdisciplinary research (based on Coast et al. 2007)

This book is an interdisciplinary approach similar to the transdisciplinarity definition. We will integrate technical, economic, behavioral, and other perspectives in various ways in discussing industrial energy efficiency. Interdisciplinarity represents the confluence of various knowledge perspectives. According to Bruun (2001), this confluence can facilitate: (1) the integration of knowledge from other fields, leading to a changed knowledge perspective; and (2) collaboration among scientific fields with discrete knowledge perspectives (Bruun 2001). According to Bruun, interdisciplinary research has three key components, i.e., depth, breadth, and synthesis: *depth* refers to the extent of knowledge within a single knowledge perspective; *breadth* refers to the number of knowledge fields with which one is adequately familiar; and *synthesis* refers to the integration of a variety of knowledge perspectives into a “whole” representing greater knowledge.

If depth and breadth are the only components of an approach, Bruun would claim this represents a lesser degree of interdisciplinarity, referred to above as multidisciplinarity. Synthesis is also required to achieve full interdisciplinarity, but synthesis, or transdisciplinarity, is difficult to achieve. It requires the development of common language and concepts. Strober (2006) also emphasizes that interdisciplinarity is a social process in which existing disciplinary social boundaries built up by cultures of language and ideas must be broken down. As we will demonstrate, a variety of perspectives, theories, methods, and models can be used to analyse energy systems, all of which help improve our understanding of the energy systems (Palm et al. 2010) that need to be synthesized to improve energy efficiency in industry. Accordingly, our approach applies a mixture of perspectives, theories, and results from technically and socially oriented research. The aim is to problematize and reflect on how questions relating to improved energy efficiency can be

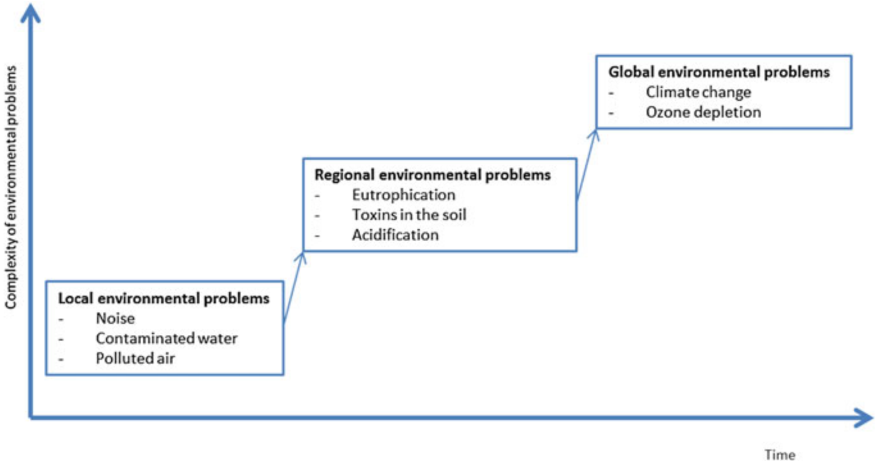

Fig. 1.2 Character of environmental problems over time

framed within a wider perspective. Our broader aim is to integrate social science perspectives in the often technical and economic discussion of improved energy efficiency, to contribute to a deeper problematization of issues related to behaviors, attitudes, decision processes, etc.

1.4 Sustainability Principles

In essence, three major factors related to human activity affects the environment, population growth, material use, and energy use. The earth's environmental problems originating from human activity have changed in character over the years, shifting from being local problems, to problems of regional and finally global scale (see Fig. 1.2). This shift in turn calls for a shift from "end-of-pipe" solutions to proactive means to address these new challenges.

In the late twentieth century, the Swedish cancer researcher, Karl-Henrik Robèrt, found traces of manmade synthetic materials in cells. This led Dr. Robèrt to formulate a new planning framework, the natural step (TNS). TNS, unlike most other environmental planning frameworks, such as the "factor four" and "ecological footprint" frameworks, aims to proactively direct society and organizations toward improved sustainability by applying systemic sustainability principles (TNS 2011). The principles have been established by broad scientific consensus and are currently as follows (Robèrt and Broman 2011):

In a sustainable society, nature is not subject to systematically increasing:

- concentrations of substances extracted from the earth's crust
- concentrations of substances produced by society

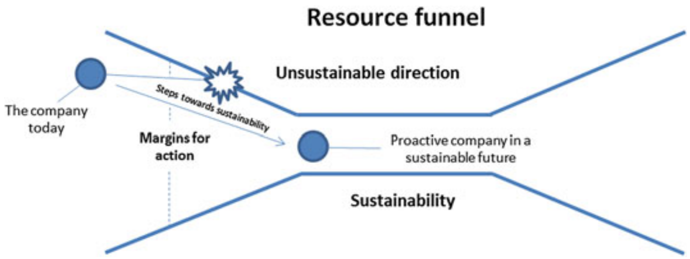

Fig. 1.3 The resource funnel and the steps toward sustainability (Nattrass and Altomare 2001)

- degradation by physical means

and, in that society:

- people are not subject to conditions that systematically undermine their capacity to meet their needs.

Robèrt and his followers in the emerging TNS field have helped apply these principles in business, cities, and regions worldwide (Nattrass and Altomare 2001). What is emphasized by Robèrt is that these principles must be adopted in line with current business activities and global societal trends. If the sustainability principles are adopted too rapidly, industrial organizations risk bankruptcy. However, if industrial organizations direct their operations step-by-step toward improved sustainability, they will reap tremendous economic benefits (see Fig. 1.3). The same benefits will accrue to regions or nations if the principles are adopted wisely.

Given rising energy and material costs, a more sustainable organization may become a sectoral leader. In summary, TNS advocates balanced adjustment in line with the four defined sustainability principles (Nattrass and Altomare 2001). This schema should be kept in mind later in this book in relation to the adoption of industrial energy management practices as well as energy policies and programs.

1.5 Contextualizing Energy Efficiency in Industry

Energy efficiency governance has generally referred to mainstream economic theory ultimately based on Adam Smith’s claim that, for the government to intervene in the market, a so-called market failure must be proven to exist. Regarding energy efficiency, market failures may be categorized as of two major types, i.e., information, asymmetries, and imperfections. This application of mainstream economic theory to government energy policy, based on the assumption of fully rational market actors, together with a history of a major focus on energy supply, has led to what we will call an energy efficiency policy gap, i.e., too few active energy policy programs.

For example, assuming fully rational actors on the market, an unimplemented energy efficiency measure, per definition, must not be a cost-effective one. Alternately, such non-uptake may be explained by barriers to energy efficiency, such as hidden costs, lack of access to capital, or other rational explanations. This rationality paradox implies that, from a governmental perspective, it is very easy to discard energy policy ideas, based on the applied perspective of mainstream economic theory.

Within this discourse[2] or paradigm of energy policy decision-making, one finds only two general contexts in which an industrial company would let energy efficiency attract great attention in the organization: (1) high energy prices force the company to consider every possible means of cutting energy costs to stay competitive; or (2) a global environmental crisis forces individual companies either to immediately shift toward improved energy efficiency, or cease production. The very nature of climate change suggests that such a threat is unlikely: the problem has manifested itself as an increase in various climate-related natural disasters, not as slowly but consistently approaching threat that finally leaves an industrial company with no choice but to "go green". Given that the global environmental crisis is unfolding in this way, it may arguably already be too late to act by improving energy efficiency. Moreover, industrial enterprises are affected differently by increases in energy prices, depending on their energy costs relative to added value. Energy-intensive industrial operations, such as foundries and pulp and paper mills, are much more threatened than are non-energy-intensive industries, such as engineering, if energy prices increase. While the energy cost in relation to added value is only 1–2 % for non-energy-intensive industries such as engineering, it is 515 % for energy-intensive operations such as foundries (SFA 2004) and well over 20 % for energy-intensive processing operations such as pulp and paper mills (SEA 2000).

Regardless of the magnitude of energy costs relative to added value, increased energy costs in an industry negatively affect results and competitiveness, which in turn may lead to lower production and in some cases even cause enterprises to consider relocating abroad (ECON 2003). On the other hand, increased energy efficiency positively and directly affects a company's overall costs, often leading to greater productivity that in turn increases profits (Worrell et al. 2003).

Given that energy efficiency would receive high attention from the government, due to, for example, the issues of security of supply and the threat of climate change energy efficiency face the risk of being neglected, or at least ranked as a lower priority, by individual industrial companies. This is because the energy efficiency perspective of individual companies is based mainly on cost, i.e., it is mainly a monetary perspective, not an environmental or supply security perspective. When energy efficiency in fact receives great attention, it is mostly in energy-intensive industries with high energy costs relative to value added.

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[2] "Discourse" refers to a formalized way of thinking manifested in language, a social boundary defining what can be said about a specific topic.

However, even in such companies, successful energy management practices may not be found in most cases, as will be discussed further in Chap. 6.

Closely related to the energy intensity of a company is the discrepancy between a company's support and production processes. Support processes are processes that support the company's manufacturing of products, while production processes are related to the actual manufacturing of products (see Chap. 2 for further discussion of this).

In capital-intensive, energy-intensive industries such as the paper industry, where, for example, a paper machine may cost several 100 million Euros, a change of production process is not as easily accomplished as is changing the lighting in a warehouse. Moreover, it is among support processes, such as lighting, ventilation, and producing compressed air that one finds the greatest potential for energy savings (EC 2006). Energy audit programs reveal that 60–90 % of the measures implemented by industrial SMEs concern support processes (Thollander et al. 2007; Gruber et al. 2011). Implementing energy-efficient support process measures in non-energy-intensive industries seems easier than implementing energy-efficient production process measures in energy-intensive industries. This is in turn closely related to the discrepancy between operational and strategic actions and to the initial cost of investments. Many energy efficiency measures related to support processes, such as ventilation, space heating, and lighting have a lower initial cost than do similar measures for heavily capital-intensive production processes. The former measures may be implemented at an operational level, while many of the heavily capital-intensive production process-related investments more closely concern strategic activities. Different decision processes are related to the two types of measures, and these processes in turn involve different company divisions and actors, each possessing different types of knowledge, preferences, decision power, etc. The contexts in which product and process measures are embedded differ, a matter to which we will return later in the book.

Referring to the discussion of political economics, it may be argued, with all respect to Adam Smith, that times have changed since Smith founded political economics in the eighteenth century. Markets are now international or global in scope and information technology has enabled a much greater flow of information. Moreover, and perhaps more importantly, Smith, as a social philosopher, was not considering as strict a definition of rationality as is applied today, for example, in the concept of "economic man", i.e., a cost-minimizing, utility (revenue)-maximizing agent. Instead, Smith's view of the individual was fairly altruistic—not least in relation to the more extreme forms of the "quarterly economy" that exist in today's global economy; he argued that it was completely acceptable to earn money, since accumulated capital was reinvested in the company, leading to increased job opportunities in a nation. In fact, he even stated that it would be rational to give away something for the sheer pleasure of seeing someone else become happy (Pålsson Syll 2007).

In summary, the difference between the perspectives of the individual company and of the government reveals that, in a business-as-usual scenario under the current paradigm, large improvements of energy efficiency in the industrial sector

Table 1.1 SME definition (EC 2011)

Enterprise category	Employee headcount	Turnover or	Balance sheet total
Medium-sized	<250	≤EUR 50 million	≤EUR 43 million
Small	<50	≤EUR 10 million	≤EUR 10 million
Micro	<10	≤EUR 2 million	≤EUR 2 million

are unlikely. Only under two conditions will this improvement occur: (1) that of top management commitment in an industrial organization (i.e., so-called industrial energy management) in which energy efficiency becomes of strategic importance; or (2) that of a shift in the discourse or paradigm in which energy policy decisions are being made. These two conditions arguably call for interdisciplinary approaches. To understand energy management and governing of energy in the society we need to understand not only how to lead an organization or a society but also how to implement sustainable values which becomes embedded in the organization and in the society. This is a challenging issue as the previous view of decision-making has been primarily mechanistic where we have had little emphasis on the humans in the organization (Nattrass and Altomare 2001).

In this book, we combine theories prevalent in current scientific discourse, for example, combining barrier theory with sociotechnical studies and transactional analysis (TA), to enhance our understanding of these important issues.

1.6 Industrial Small- and Medium-Sized Enterprises

Industrial SMEs represent more than 99 % of the total aggregated number of companies in most countries. In the EU-25, some 23 million SMEs provide around 75 million jobs (EC 2007). The European Commission states:

> What usually gets lost is that more than 99 % of all European businesses are, in fact, SMEs. … They provide two out of three of the private sector jobs and contribute to more than half of the total value-added created by businesses in the EU. What is even more intriguing is that nine out of ten SMEs are actually micro enterprises with less than ten employees. Hence, the mainstays of Europe's economy are micro firms, each providing work for two persons, on average. This is probably one of the EU's best kept secrets! (EC 2011).

This makes industrial SMEs a sector that, apart from its energy use, is a major economic driver in terms of innovations, GDP growth, investments, employment, and exports. Despite the importance of SMEs in the economy, they have received little research attention with regard to, for example, energy policy activity (Ramirez et al. 2005). This is partly because industrial SMEs constitute a highly diversified sector of companies ranging from low energy-using engineering companies to more energy-intensive manufacturing plants. This fact makes the sector a great challenge when it comes to, for example, energy policy decision-making,

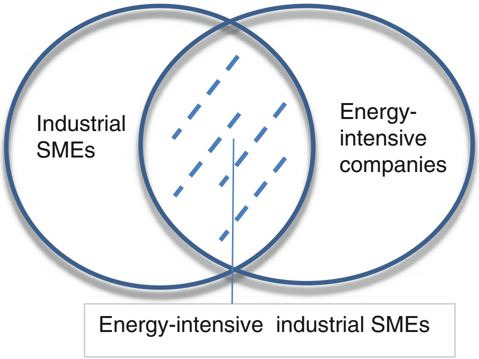

Fig. 1.4 Relationship between energy-intensive companies and SMEs, the shaded area representing energy-intensive SMEs

methods to increase energy efficiency, research, and the promotion of energy management practices. This book defines SMEs as outlined in Table 1.1.

We use the same definition as does the EU Commission, which categorizes SMEs as enterprises employing fewer than 250 people and with annual turnover not exceeding EUR 50 million and/or an annual balance sheet total not exceeding EUR 43 million. Small companies are defined as companies with 10–49 employees while medium-sized companies are categorized as having 50–249 employees.

Regarding energy intensity, the book defines a non-energy-intensive company as one with energy costs in relation to added value of less than 3 %. Figure 1.4 outlines the general relationship between energy-intensive companies and industrial SMEs.

1.7 Contributions

Reanalyzing earlier extensive empirical studies of barriers gives us a broad basis for discussing the “cross-pollination” of the social and engineering sciences, and of how this can enhance our understanding of the improvement of energy efficiency.

We hope to contribute to the existing literature on the energy efficiency gap in four main ways:

- by discussing barriers to energy efficiency as social constructs. The barriers to energy efficiency identified in a company depend on the social context, for example, how energy efficiency is perceived and by whom
- by discussing how various research methods can advance or constrain our approach to barriers
- by reflecting on the discussion of the energy efficiency gap, i.e., address why cost-effective energy measures are not always implemented in industry by

considering how energy management can increase the potential for energy efficiency
- by combining theories from the social and engineering sciences in discussing how barriers may be overcome by applying energy management practices, and how energy policies could be designed to achieve improved energy efficiency.

We will focus on industrial SMEs in our empirical examples, mainly because industrial SMEs face extensive challenges in improving their levels of energy efficiency, compared with large, energy-intensive industrial companies, due to their relative lack of resources and abilities with which to address the issue (Shipley and Elliot 2001). Moreover, little attention has been paid to non-energy-intensive industry and industrial SMEs when it comes to energy policy (Ramirez et al. 2005).

1.8 Organization of the Book

The book begins by introducing energy efficiency in industry as well as the work's overall aim and limitations. The introduction puts the book's theme into context, primarily arguing that new interdisciplinary perspectives are needed when addressing energy efficiency in industry. The book continues in Chap. 2 with overviews of energy use in industry, of technological options for non-energy-intensive companies and industrial SMEs, of technical energy efficiency potential, and of methods, tools, and industrial energy programs for improving energy efficiency. Chapter 3 thoroughly describes the theoretical barriers to energy efficiency and provides a brief overview of the empirical findings. Chapter 3, together with Chap. 2, present the currently prevalent perspective on energy efficiency, which the authors address later in the book using insights from other scientific disciplines. In Chap. 4, we introduce the multilevel model of innovation processes and decision-making in organizations in relation to the constituent institutions and communities of practice. Chapter 5 brings barriers to energy efficiency together with the perspective introduced in Chap. 4. In this chapter, we discuss how barrier theory can be developed by emphasizing the social context in which decisions are embedded and also treat the importance of values and traditions established within, for example, particular sociotechnical regimes. We also discuss how energy use lessons learned in other areas of practice than industry can contribute to our understanding of the barriers to and enablers of energy efficiency. Chapter 6 includes a presentation of energy management and of important aspects related to, in particular, the human aspects of organizations, using TA and previous research to incorporate insights from other fields, such as psychiatry. Chapter 7 examines energy policy as a means to promote improved energy efficiency. In this chapter, we discuss ecological modernization as a way to capture the societal trend to see the economy and ecology in symbiosis, and present factors of importance to energy policy decision-making, such as the need to overcome asymmetric energy policy shocks (AEPSs). Finally, Chap. 8 presents the major conclusions of the book by elaborating on the three energy gaps: the energy efficiency gap, the energy management gap, and the energy policy gap. The conclusions also bring together the previous chapters' insights and discuss the ways and means of the path foward, so that industrial companies, and society, can improve their energy efficiency, reducing greenhouse gas emissions and other negative environmental impacts.

References

Boulding KE (1956) General system theory: the skeleton of science. Manag Sci 2(3):197–208

Bruun H (2001) Teknikstudier på tvären. VEST 14:73–94

Churchman CW (1968) The systems approach. Dell Publishing Co. Inc., New York

Coast E, Hampshire K, Randall S (2007) Disciplining anthropological demography. Demogr Res 16:493–518

EC (European Commission) (2006) Communication from the commission. Action plan for energy efficiency: realizing the potential. COM (2006) 545 final. http://ec.europa.eu/energy/action_plan_energy_efficiency/doc/com_2006_0545_en.pdf

EC (European Commission) (2007) Observatory of European SMEs

EC (European Commission) (2011) European Commission's homepage. http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-observatory/index_en.htm#h2-1

ECON (Centre for economic analysis AB) (2003). Konsekvenser på elpriset av införandet av handel med utsläppsrätter [Impact on price of electricity of the introduction of trading with emission rights]. Ministry of Industry, Employment and Communications, Stockholm

Gielen D, Taylor M (2007) Modelling industrial energy use. The IEA's energy technology perspective. Energy Econ 29:889–912

Greckhamer T, Koro-Ljungberg M, Cilesiz S, Hayes S (2008) Demystifying interdisciplinary qualitative research. Qual Inq 14:307–331

Gruber E, Fleiter T, Mai M, Frahm B-J (2011) Efficiency of an energy audit programme for SMEs in Germany—results of an evaluation study. ECEEE 2011 Summer study

IEA (International Energy Agency) (2007) Key world energy statistics 2007, Paris. http://195.200.115.136/textbase/nppdf/free/2007/key_stats_2007.pdf. Accessed 8 Jan 2008

IPCC (2007) Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. Summary for policymakers. http://www.ipcc.ch/SPM040507.pdf. Accessed 8 Oct 2007

Nattrass B, Altomare M (2001) The natural step for business: wealth, ecology and the evolutionary corporation. New Society Publishers, Gabriola Island

Palm J, Harvey S, Karlsson M, Söderström M (2010) Crossing boundaries in graduate education: experiences from the process of designing and running an interdisciplinary graduate course. Paper presented at Engineering Education in Sustainable Development (EESD), Göteborg, 19–22 September 2010

Pålsson Syll L (2007) De ekonomiska teoriernas historia. Studentlitteratur, Lund

Ramirez CA, Patel M, Blok K (2005) The non-energy intensive manufacturing sector. An energy analysis relating to the Netherlands. Energy 30:749–767

Robèrt K-H, Broman G (2011) Allowing sustainability principles to emerge. Some pedagogical advice by working paper. BTH, Karlskrona

SEA (Swedish Energy Agency) (2000) Energianvändning Inom Industrin [Energy use in industry]. Swedish Energy Agency Publication Department, Eskilstuna

SFA (Swedish Foundry Association) (2004) Specialist support for Scandinavian foundries. Swedish Foundry Association, Jönköping

Shipley A M, Elliot R E (2001) Energy efficiency programs for small and medium sized industry. In: Proceedings of the 2001 ACEEE summer study on energy efficiency in industry, vol 1, pp 183–196

Stern PC, Aronson E (eds) (1984) Energy use: the human dimension. Freeman, New York

Strober MH (2006) Habits of the mind: challenges for multidisciplinary engagement. Soc Epistemology 20:315–331

Thollander P, Rohdin P, Moshfegh B (2012) On the formation of energy policies towards 2020: challenges in the Swedish industrial and building sectors. Energy Policy 42:461–467

Thollander P, Rohdin P, Danestig M (2007) Energy policies for increased industrial energy efficiencyenergy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Policy 35:5774–5783

TNS (The Natural Step) (2011) http://www.naturalstep.org/en/our-story. Accessed 13 Dec 2011

Worrell E, Laitner J, Ruth M, Finman H (2003) Productivity benefits of industrial energy efficiency measures. Energy 28:1081–1098

Chapter 2
Improving Energy Efficiency in Industrial SMEs

Abstract While this book emphasizes the importance of interdisciplinary perspectives of examining improved energy efficiency in industrial companies, industrial sectors, nations, and regions, the importance of technology should not be neglected. This chapter examines technological energy options available to non-energy-intensive companies and industrial SMEs, analyzes the technical potential of energy efficiency, and reviews methods, tools, and industrial energy programs for improved energy efficiency. The chapter should not be seen as a complete examination of all available technological options methods and tools, but as an overview for the reader of the vast number of available technical measures, methods, and tools for improving energy efficiency.

2.1 Introduction

The importance of technology should not be neglected when studying the shift toward improved sustainability in industrial energy systems. Evaluation of energy audit programs reveals that 60–90 % of the energy efficiency measures implemented by industrial SMEs are in support processes (Gruber et al. 2011; Thollander et al. 2007). Many energy efficiency measures related to support processes, such as ventilation, space heating, and lighting cost less than such measures related to heavily capital-intensive production processes. The former measures may be implemented at an operational level, while many heavily capital-intensive production process-related investments more closely concern strategic activities. The implementation of energy efficiency measures for support processes in non-energy-intensive industries is arguably easier, both technically and economically, than implementing energy

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DOI: 10.1007/978-1-4471-4162-4_2,

efficiency measures for production processes in energy-intensive industries. Industrial SMEs thus have great potential to improve their energy efficiency.

This chapter presents an overview of technological options available to non-energy-intensive companies and industrial SMEs. It also analyzes the technical potential for improved energy efficiency, and reviews the methods, tools, and industrial energy programs for improved energy efficiency. The chapter should not be seen as a complete examination of all available technological options, but as an overview for the reader of the vast number of available technical measures for improving energy efficiency.

2.1.1 Unit Process Categorization

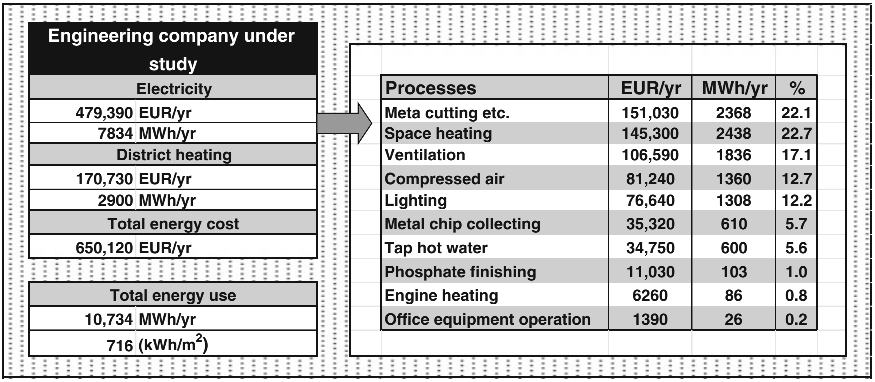
Applying the unit process concept offers a way to divide the energy use of an industry into smaller parts, or units. A single unit process is based on the objective of a given industrial process, for example, mixing materials, cooling, or drying products, producing compressed air, or carrying goods. Unit processes can be considered the smallest components of an industrial energy system. They may be general across industries, allowing comparison of a given process among industries.

Unit processes are defined by the energy service to be performed, being divided into two major categories (Söderström 1996): *production processes*—the processes needed to produce products; and *support processes*—the processes needed to support the production processes but not directly needed for production. As defined by Söderström (1996), the 11 production processes are decomposition, mixing, cutting, joining, coating, forming, heating, melting, drying/concentration, cooling/freezing, and packing, while the 7 support processes are lighting, compressed air, ventilation, pumping, space heating and cooling, hot tap water, and internal transport.

The identified unit processes represent the "building blocks" of energy use, enabling them to be used for comparisons among companies, in both the same and different industries. Furthermore, the categorization of unit processes enables the simulation or optimization modeling of industrial energy use (see, e.g., Söderström 1996; Thollander et al. 2007, 2009).

2.2 Energy Use in Various Industrial Sectors

For non-energy-intensive industrial companies and industrial SMEs, most energy use occurs in the support processes; for energy-intensive companies, however, this may not be the case. Figures 2.1, 2.2 and 2.3 outline the energy use of three types of companies, a non-energy-intensive medium-sized engineering company, an energy-intensive medium-sized foundry, and a large energy-intensive chemical pulp mill (Thollander et al. 2005, 2007; Klugman et al. 2007). Please note that this presentation has not completely followed the unit process categorization.

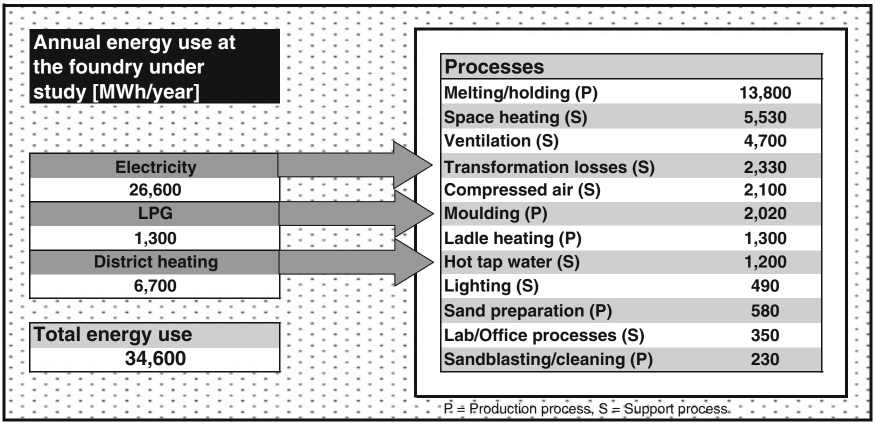


Engineering company under study	
Electricity	
479,390	EUR/yr
7834	MWh/yr
District heating	
170,730	EUR/yr
2900	MWh/yr
Total energy cost	
650,120	EUR/yr

Total energy use	
10,734	MWh/yr
716	(kWh/m^2)

Processes	EUR/yr	MWh/yr	%
Meta cutting etc.	151,030	2368	22.1
Space heating	145,300	2438	22.7
Ventilation	106,590	1836	17.1
Compressed air	81,240	1360	12.7
Lighting	76,640	1308	12.2
Metal chip collecting	35,320	610	5.7
Tap hot water	34,750	600	5.6
Phosphate finishing	11,030	103	1.0
Engine heating	6260	86	0.8
Office equipment operation	1390	26	0.2

Fig. 2.1 Energy use in a medium-sized non-energy-intensive Swedish engineering company (Thollander et al. 2007)



Annual energy use at the foundry under study [MWh/year]
Electricity
26,600
LPG
1,300
District heating
6,700

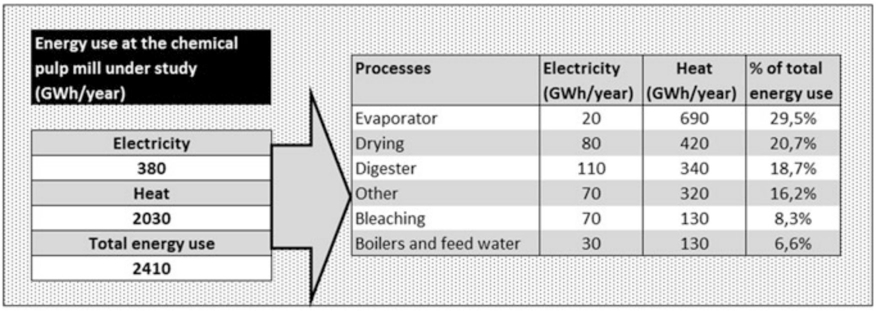
Total energy use
34,600

Processes	
Melting/holding (P)	13,800
Space heating (S)	5,530
Ventilation (S)	4,700
Transformation losses (S)	2,330
Compressed air (S)	2,100
Moulding (P)	2,020
Ladle heating (P)	1,300
Hot tap water (S)	1,200
Lighting (S)	490
Sand preparation (P)	580
Lab/Office processes (S)	350
Sandblasting/cleaning (P)	230

P = Production process, S = Support process.

Fig. 2.2 Energy use in a medium-sized energy-intensive Swedish iron foundry. Published with kind permission of © Elsevier 2005. All Rights Reserved (Previously published in Thollander et al. 2005)

Energy use differs greatly among the various types of industrial companies, as can be seen in Figs. 2.1, 2.2 and 2.3. In the non-energy-intensive medium-sized engineering company, 70 % of the energy is used in support processes, while in the energy-intensive medium-sized iron foundry, about half of the energy is used in these processes. In the large energy-intensive chemical pulp mill, however, only about 15 % of the energy is used in support processes (labeled “Other” in Fig. 2.3). This difference naturally also affects how energy management is carried out, and determines the potential for energy efficiency improvements in various industries.



Energy use at the chemical pulp mill under study (GWh/year)

Electricity
380
Heat
2030
Total energy use
2410

Processes	**Electricity (GWh/year)**	**Heat (GWh/year)**	**% of total energy use**
Evaporator	20	690	29,5%
Drying	80	420	20,7%
Digester	110	340	18,7%
Other	70	320	16,2%
Bleaching	70	130	8,3%
Boilers and feed water	30	130	6,6%

Fig. 2.3 Energy use in a Swedish energy-intensive chemical pulp mill (Klugman et al. 2007)

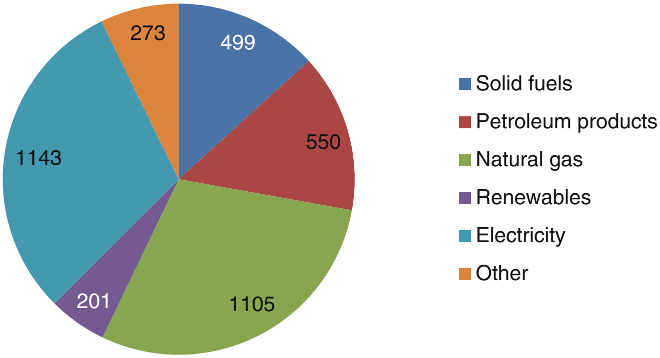


Fig. 2.4 Energy used in industry, EU-27 (TWh/year) (Eurostat 2006)

2.3 Energy Use and Technical Potential for Improved Energy Efficiency in Industrial SMEs

Annually, industry accounts for about 78 % of global coal consumption, 41 % of electricity use, 35 % of natural gas consumption, and 9 % of oil consumption (IEA 2007). Figure 2.4 presents the major carriers of industrial energy used in the EU-27 countries.

Industrial energy use in EU-27, broken down by major energy carrier and industry sector, is presented in Fig. 2.5.

As can be seen in Fig. 2.5, most energy is used in energy-intensive sectors, such as chemicals, iron and steel, and pulp, paper, and print, while non-energy-intensive sectors such as engineering and other industries use much less energy. In addition,

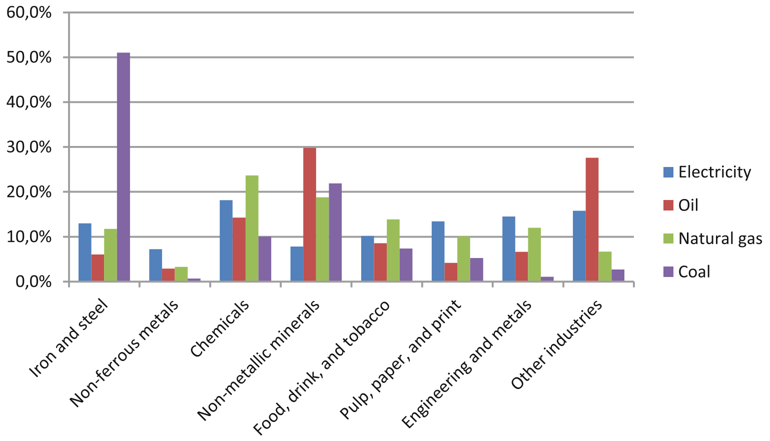


Fig. 2.5 Energy use in industry, EU-27, broken down by energy carrier and industry sector (Eurostat 2006)

Table 2.1 Energy efficiency measures proposed for a medium-sized energy-intensive Swedish iron foundry (Thollander et al. 2005)

Energy efficiency measures	Electricity savings (MWh/year)	LPG savings (MWh/year)	District heating savings (MWh/year)
New induction furnace	2,300	–	–
District heating supplied to municipality	–	–	2,200
Compressed air leak eliminated	1,100	–	–
New sand preparation	780	–	290
Improved ladle heating	–[a]	600	420
Lowering idling losses	1,140	–	–
Load management	–	–	–
Other measures	920	–	1,770
Total (MWh/year)	6,240	600	4,680
Total (%)	23	51	70

[a] Power reduction of 3 MW during peak hours; the energy use is not affected by this measure, but the cost of poweris reduced.

while the energy used in energy-intensive industries is mostly allocated among production processes, most energy used in non-energy-intensive industry and industrial SMEs is used in support processes. This makes the industrial SMEs an easier target for industrial energy programs than large energy-intensive companies.

Tables 2.1 and 2.2 outline the technical energy efficiency measures proposed to be implemented in the two non-energy-intensive and energy-intensive SMEs previously presented in Figs. 2.1 and 2.2.

Table 2.2 Energy audit results for a medium-sized non-energy-intensive Swedish engineering company (Thollander et al. 2007)

Energy efficiency measures	Electricity savings (MWh/year)	District heating savings (MWh/year)
New large-scale ventilation system	–	900
Investment in new lighting	330	–
Elimination of compressed air leaks	700	–
Installation of new windows	–	410
VAV[a] in the shower rooms	40	120
Heat exchange from high temp. oil separator flow	–	140
Heat exchanger on fans	–	120
Other measures	180	10
Total (MWh/year)	1,250	1700
Total (%)	16	59

[a] *VAV* variable air volume.

As can be seen in Tables 2.1 and 2.2, half of the electricity-saving measures proposed for the energy-intensive foundry are found among the support processes, while *all* electricity-saving measures proposed in the non-energy-intensive engineering industry are found among the support processes. In the case of district heating savings, most energy-saving measures are found in the support processes.

The following part presents a more extensive overview of the means to improve energy efficiency of the support processes of industrial energy systems.

2.3.1 Electric Motor Systems

In industry, 68 % of all electricity is used in motorized systems such as pumps, fans, compressors, and mechanical movement; of this, 42 % is used by pumps, fans, and compressors (Waide and Brunner 2011). An electric motor system can be considered at three successively more complete levels (Waide and Brunner 2011):

- the actual electric motor
- the core motor system
- the total motor system

In addition to the actual electric motor, the core motor system includes fans, pumps, wheels, and transmission, and a variable speed drive (VSD). The total motor system consists of the two other levels but also includes supporting pipes, ducts, etc. (Waide and Brunner 2011).

Waide and Brunner (2011) state that while the energy efficiency potential of the actual electric motor is fairly small, that of the core motor system is greater, and that of the total motor system is greater still (Waide and Brunner 2011). Several energy efficiency measures are possible in electric motor systems, such as improved pumping, compressed air, and ventilation systems.

2.3.2 Pumping

Pumping accounts for about 14 % of global industrial electricity use (Waide and Brunner 2011). Means of improving the energy efficiency of pumping include:

- reducing flows through VSDs
- reducing flows through effective time control
- improving gears and transmission.

2.3.3 Compressed Air

Air compression, in which compressors are a major component, accounts for about 17 % of global industrial electricity use (Waide and Brunner 2011). Means of improving the energy efficiency of air compression include:

- reducing air leaks (easy measure with short payback period)
- reducing air pressure from 7 to 6 bars (approximately 7 % energy reduction per bar)
- converting into electric tools where possible
- using VSD compressors
- considering the possibility of using the compressor's cooling output for space heating purposes

2.3.4 Ventilation

Ventilation (fans) accounts for about 11 % of global industrial electricity use (Waide and Brunner 2011). Apart from heat recovery (presented in the next section), means of improving the energy efficiency of ventilation include:

- reducing air flows through VSDs
- reducing air flows through effective time control

2.3.5 Space Heating and Cooling

Heating, including space heating, accounts for about 12 % of global industrial electricity use (Waide and Brunner 2011). Means of improving the energy efficiency of space heating and cooling include:

- recovering heat from hot exhaust air flows
- using ceiling fans (if a displacement ventilation system is not used) reduces energy use by up to 10 %
- shutting down heat circulation pumps in the summer

- using air curtains for shuttle doors
- lowering the indoor temperature during heating season (5 % of heating energy saved per degree lowered)
- insulating roof and walls
- changing windows
- supplying heat and cooling at the right temperature
- insulating pipes, heat exchangers, etc.
- converting from steam into waterborne system if possible
- using heat pumps
- taking advantage of free cooling

2.3.6 Lighting

Lighting uses about 8 % of global industrial electricity use (Waide and Brunner 2011). Means of improving the energy efficiency of lighting include:

- installing more energy-efficient lighting such as T5 fluorescents with high frequency (HF) operation, high-pressure sodium lamps, light-emitting diodes, etc.
- reducing the wattage of lights
- sectioning off the lighting system to enable more effective occupancy control using sensors

2.3.7 Internal Transport

Internal transport (within the industrial site) generally accounts for a fairly small portion of the energy and electricity used in industry. Means of improving the energy efficiency of internal transport include:

- converting from diesel and gasoline vehicles into more energy-efficient ones (e.g., electrically powered)
- maintaining adequate tire pressure
- improving production planning to reduce transport distance
- optimizing storage location to reduce transport distance

2.3.8 Hot Tap Water

Tap water heating generally represents a small portion of the energy and electricity used in industry. Means of improving the energy efficiency of tap water heating include:

- using more energy-efficient shower heads and fittings
- insulating pipes, heat exchangers, etc.

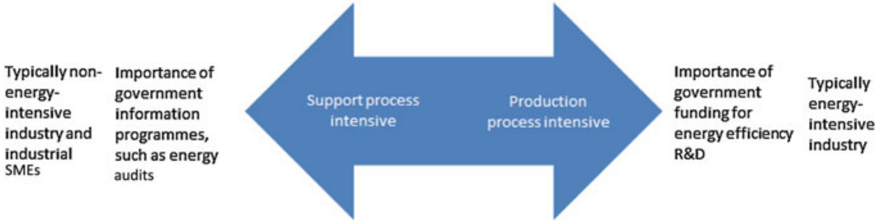


Fig. 2.6 How energy efficiency measures are dependent on whether they apply to a support-process- or production-process-intensive industry

- in colder climates, consider local boilers near source of demand if an overly extensive hot tap water system suffers unnecessary heat loss in summer due to cooling of heated water in long pipe runs

2.4 Energy Efficiency Potentials in Industry

The EU Commission claims that the energy efficiency measures could save up to 25 % of energy used in industry, and argues that most of the improvement measures are found in support processes such as pumping, ventilation, and lighting (EC 2006). While this may apply to non-energy-intensive industry and industrial SMEs, it may not be the case for energy-intensive industry. It is not within the scope of this book to question this stated energy-saving potential, but if the potential for European industry as a whole is 25 %, the potential for energy efficiency in SMEs and non-energy-intensive industrial companies is likely even higher. Moreover, as energy-intensive industry suffers from a higher proportion of production processes than does non-energy-intensive industry, the importance of energy efficiency measures for non-energy-intensive industries and industrial SMEs, from a governmental point of view aiming to reduce environmental impact through improved energy efficiency, is arguably greater than in energy-intensive industries. Figure 2.6 shows how measures promoting improved energy efficiency are dependent on whether they apply to support or production processes.

2.4.1 Importance of a Systems Perspective with Regard to Improved Energy Efficiency

The observations of Waide and Brunner (2011) concerning the energy efficiency potential of electric motors and their systems, as noted above, articulates a central truth regarding industrial energy efficiency. For example, Fig. 2.7 outlines the efficiency of a compressed air system.

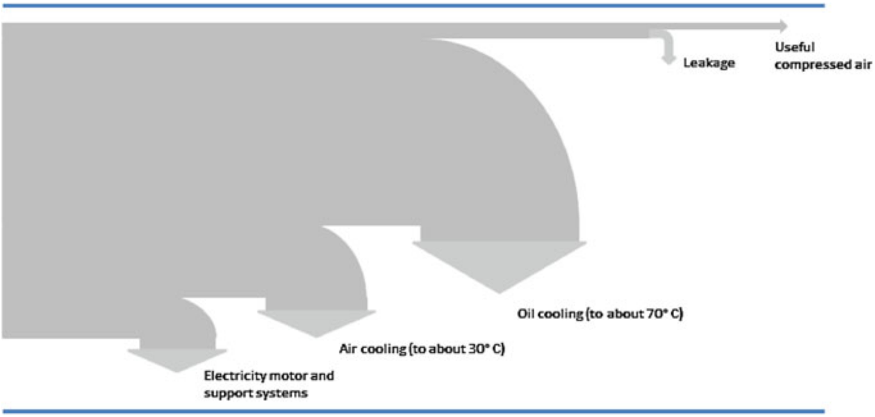


Fig. 2.7 Sankey diagram showing the relationship between electricity supply and the outcome in the form of useful compressed air (Gralén 2002)

A study from Japan, a leading country in energy efficiency and management, stated that:

> Energy efficiency will not be significantly improved simply because energy-saving equipment is installed and renewed. In-plant energy systems are complex, and the optimum operation of these systems will lead to further improvements in energy efficiency (CRIEPI 2011).

It is crucial not to focus exclusively on the actual technology used, but to extend the system boundary and see the technology within the context of its overall system. Take, for example, a company that is told it can reduce its heating cost by installing a heat exchanger on the air compressor; this is indeed true, from a narrow system perspective. Figure 2.7, however, shows that reducing the actual use of compressed air in the factory and reducing air leakage (which may represent 50 % or more of the actual useful air compressor power) would also reduce the cost of compressed air. However, applying a wide system perspective, it is evident that if the heat exchanger investment is treated as the initial investment, the company will, after improving the energy efficiency of the whole system, be left with far too large a heat exchanger or, rarely, may not even need a large central compressed air system at all in the factory, as increased efficiency may allow the company to replace it with a small local air compressor.

A wide system perspective on energy use and efficiency in an industrial energy system can be applied via an energy audit carried out by an external party, for example, as part of an industrial energy program, and this may offer an way of improving overall system efficiency. An energy audit should not, however, be seen as the end of the energy efficiency process, but rather as the first step in forming an in-house energy management program, as further explained in Chap. 6. Next, we will discuss how to form an effective industrial energy efficiency program involving energy audits.

2.5 Energy Audits[1]

One of the most efficient means of deriving energy efficiency measures in an industry, specifically when it comes to measures related to the support processes is the use of an energy audit. The energy auditing method used to derive energy efficiency measures presented below has been used in numerous industries over the last 25 years performed by the Division of Energy Systems, Linköping University, Sweden (Thollander et al. 2005), and other Swedish actors. The method uses a systems approach and has been used for 1–2 day audits up to audits taking several months to accomplish. The method is carried out in six steps:

1. First, a meeting is held with representatives of the industry in question and the conductors of the audit, either by phone or on-site and requirements and delimitations are formulated if needed.
2. Then, an on-site visit (walkthrough) is made where quantitative data are collected through metering etc.
3. The collected data are then compiled into unit processes, which in turn are split into production processes and support processes like lighting, ventilation and compressed air. The data are then analyzed and confirmed.
4. Complementary calculations and, if needed, additional measurements are then made in order to compile a sound analysis of the present energy use.
5. In the fifth step, a meeting is held, by phone or on-site, with representatives of the industry concerned and the conductors of the audit about the proposed energy efficiency measures and the analysis of current energy use.
6. Finally, the energy audit is compiled into a two-part report that includes current energy use and proposed energy efficiency measures.

2.5.1 Effective Industrial Energy Audit Programs

One of the most cited means of promoting industrial energy end-use efficiency and overcoming barriers to achieve such efficiency is to use industrial energy programs. The European climate change commission has concluded that the implementation of energy audit programs and long-term agreements (LTAs) are two of the most important means of reducing CO_2 emissions in industrial processes (Bertoldi 2001). While energy audit programs represent such a means, particularly for non-energy-intensive industrial companies and industrial SMEs, LTA programs are more suitable for energy-intensive industries (Bertoldi 2001). As this book focuses on industrial SMEs, the following section touches on some important aspects of industrial energy programs targeting industrial SMEs. In Chap. 7, energy policies are examined more thoroughly.

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[1] A version of this section was previously published in Thollander et al. (2007) och (2008).

Internationally, government-funded industrial energy programs have been one of the most common means of increasing industrial energy efficiency and overcoming, among other barriers to energy efficiency, that of imperfect information (Hirst and Brown 1990). Information programs may also include educational workshops and training programs for professionals, advertising, and product labeling (Anderson and Newell 2004). General information campaigns on energy efficiency constitute another type of program. While such general campaigns result in increased awareness of the importance of energy efficiency, they seem to result in only a small increase in the adoption of energy efficiency measures (Stern and Aronson 1984).

Industrial energy programs offering audits are one of the most useful policy instruments for overcoming barriers to energy efficiency and providing industry with adequate information about available energy efficiency measures and, in doing so, enabling industry to increase its energy efficiency (Schleich 2004). So far, the non-energy-intensive and SME sectors have often received little attention in energy end-use policies (Ramirez et al. 2005). Energy efficiency programs for non-energy-intensive companies and industrial SMEs are generally of two types: (1) identification of opportunities for technology improvement, generally through energy audits or other technical assistance, and (2) direct financing or other implementation facilitation of identified opportunities; successful programs often employ both these elements together (Shipley and Elliot 2001).

For energy-intensive companies, including energy-intensive SMEs, LTA programs may be a sound option. An LTA—a type of agreement between the authorities and an industry—is claimed to have a great potential and to be among the most effective energy policy instruments by which energy-intensive industry can increase its implementation of economically viable energy efficiency measures in the EU (Bertoldi 1999). Apart from promoting technical energy efficiency measures, LTAs also advocate "soft" issues such as the implementation of energy management routines. One of the most important attributes of an LTA is its flexibility (Bertoldi 2001). One European project has dealt with the design of LTA programs for industrial SMEs, namely, EU LTA Uptake.

2.5.2 Important Aspects of Industrial Energy Audit Programs[2]

As outlined in previous sections, industrial energy audits are one of the most widely used means of providing non-energy-intensive companies and industrial SMEs with information on how to reduce energy costs and increase overall energy efficiency. Studies of various audits have found that the outcome of an energy audit and the program as a whole are dependent on a number of factors.

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[2] A version of this section was previously published in Thollander et al. (2007) and (2008)

Stern and Aronson (1984) emphasize that the *type* of information given is an important determinant of whether or not energy efficiency measures will be implemented. Information must be specific and vivid, i.e., individual energy audits are better than general advice regarding potential cost reductions provided, for example, by information campaigns and seminars (Stern and Aronson 1984). The latter measures, however, should not be underestimated, as they have been shown to increase awareness of the need for energy efficiency and conservation (Stern and Aronson 1984; SEA 2006).

The use of an energy audit is similar to the successful outcome of an information campaign in the U.S.A. While two programs involving extensive advertising in the media achieved little in terms of actual adoption of energy efficiency measures, a third program that sent a booklet to households accompanied by a low volume shower head turned out to be successful (Stern and Aronson 1984). People installed the shower head and then kept on implementing the measures suggested in the booklet.

Research has found that companies with low competence in energy efficiency issues often display more interest in external information than companies with high competence that possess knowledge about how much and where energy is used in their operations and that also have the ability to carry through energy efficiency measures (Edén 1991).

Public-sponsored energy audits are thus valuable when offered to SMEs and non-energy-intensive industries (Schleich 2004). Research into offering energy efficiency subsidies to SMEs, however, is not unambiguous. Gruber and Brand (1991) found that grant funding for energy audits in German SMEs achieved only limited success. Many SMEs were unaware of the funding and many were reluctant to use it, as its future benefits were uncertain, i.e., the costs of the audit (even after the grant) might exceed future potential energy savings at the firm (Gruber and Brand 1991). Consequently, there is a need for sound marketing of such energy audit subsidies to ensure that companies accept the offer. An understanding of the specific energy characteristics of individual companies is also important. Based on such knowledge, the auditor can propose measures related to the specific conditions and the specific company's problems and need of support (Edén 1991). Consequently, sectoral or trade organizations are better out at carrying out such audits, assuming they have the relevant skills, as they are aware of the specific characteristics related to the industrial sector concerned. It should be noted that this might be less important for non-energy-intensive industries, as a large proportion of their energy using processes are related to support and not production processes.

Earlier research into energy audits reveals the importance of creating continuity in ongoing networks (Russell 2006). For companies, this entails frequent contacts and regular energy audits, so they can continue to invest in cost-effective energy efficiency measures in the future. After some time, companies sometimes forget the information given to them and end up investing in inefficient measures. Earlier studies have found that simple methods, such as reminding the companies about simple routines or requesting energy use figures, produce good results in the long term as well (Edén 1991). The need for continuity in the communication process indicates that intermediaries closely related to the particular firms are again better equipped to support industry by providing energy efficiency information than government institutions. The chances of energy information influencing decision-makers also depend on how trustworthy the information presenter is considered by the receiver. If the information receiver lacks trust in the provider, there is a significant risk that the information will be ignored. Different firms may also assign different values to information regarding potential energy efficiency measures.

Effective energy auditing also requires technically skilled auditors with good knowledge of the energy-efficient technologies currently available on the marketplace as well as the theoretical skill needed to make valid calculations (Capeheart and Capeheart 1995).

Furthermore, even if companies have performed energy audits and have information regarding potential energy efficiency measures at their plants, extensive work is often needed for the measures to be implemented. Performing a number of energy audits in the same area has also been found to be more effective than occasional audits, partly because staff at a firm will perceive energy efficiency matters as more concrete when nearby firms are also involved (Persson 1990). Also related to this are findings that “success stories”, i.e., examples of successful energy efficiency investments, may have a large impact on other companies (TemaNord 2003).

When the authorities seek to cooperate with a region’s SMEs, contextual differences must also be taken into account, i.e., the structure of a program that works in one country or region may not be as successful in another, depending on differences in culture, structure, and previous contact with the authorities (von Malmborg 2003). In Sweden, four conditions must be fulfilled if collaboration is to occur and a project is to be effective: organizational capability to participate, a bottom-up perspective with realistic objectives, project competence, and mutual trust (von Malmborg 2003).

Perhaps one of the largest energy programs aimed at industry is that of the American industrial assessment center (IAC). Since 1976, more than 10,000 manufacturing firms have participated in an IAC program that offers energy audits to SME manufacturers. Evaluation of the program demonstrated that more than the half of the recommended measures were adopted and that the main reason for non-adoption was that the measures were economically undesirable. Another large-scale energy efficiency program, which offered energy audits at a 50 % discount between 1991 and 1997, was Australia’s enterprise energy audit program (EEAP), covering about 1,200 firms with an average number of 297 employees. The adoption rate of the approximately six measures proposed per firm was 82 % (Harris et al. 2000). Evaluations of IAC and EEAP both demonstrated that the higher the average cost of a recommended energy efficiency investment, the less likely it was to be implemented (Harris et al. 2000; Anderson and Newell 2004).

The most extensive action targeting the adoption of energy efficiency measures in SME manufacturing industries between 1990 and 2010 in Sweden was Project

Highland. This local energy program included 340 energy audits in six municipalities, of which 139 audits covered manufacturing industries. A total of 359 manufacturing industries with three or more employees are located in this region (SCB 2007). Only about 50 % of the measures that were implemented, or were planned to be implemented, were quantified in terms of their likely costs and benefits.

Outside Sweden, other industrial energy programs such as the Australian EEAP and the program run by IAC in America have adoption rates of approximately 80 % and 50 %, respectively; in Project Highland, however, the adoption rate was only about 40 %, if the planned measures are included. In EEAP, the companies received a subsidy for 50 % of the cost of the audit, while the audits were offered at no cost in both Project Highland and the IAC program. The only partially financed subsidy may explain EEAP's higher adoption rate. EEAP's design would have substantially increased the adoption rate, as only companies that displayed active interest in receiving energy audits participated in the program. Another reason for the high adoption rate in EEAP was that all recommended measures were all quantified and included investment assessments; on average, about six recommendations with investment assessments were presented to each assessed company. Companies participating in Project Highland were offered on average about 13 measures, of which fewer than the half were quantified in terms of saved energy and none included investment assessments. IAC, like EEAP, offered fewer measures—on average about seven individual measures, including investment assessments—resulting in higher adoption rates than those of Project Highland. The inclusion of investment assessments clearly seems to increase the adoption rate, and suggests that such assessments should be included in future programs. Furthermore, future programs should also include quantified energy saving figures to a greater degree than the case in Project Highland. Figure 2.8 presents the adoption rate in Project Highland.

The figure indicates that about 90 % of the implemented measures may in fact be categorized as addressing support processes. In the Swedish LTA program for energy-intensive companies, (PFE (Program for energy efficiency for energy-intensive industry), more than the half of the implemented measures can be categorized as addressing support processes. Figures from the German energy audit program indicate that more than the half of the measures were related to the support processes.

2.6 Realizing the Potential: The Company Perspective

The above sections highlight the importance of using different energy efficiency approaches for energy-intensive versus non-energy-intensive industry. Independent of the energy-intensity of the company, there are two principal means a manufacturing industry can reduce its energy costs:

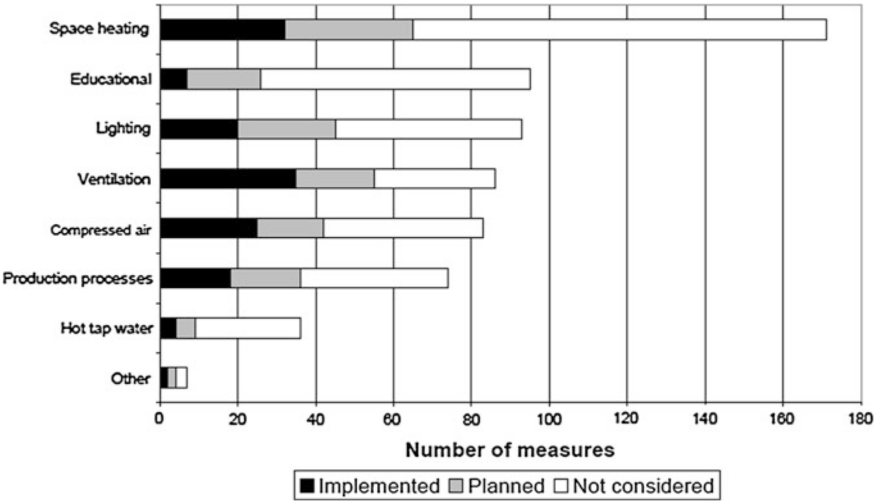

Fig. 2.8 Number of implemented, planned, and not considered measures for the processes for the 47 evaluated firms participating in Project Highland. Published with kind permission of © Elsevier 2007. All Rights Reserved (Previously published in Thollander et al. 2007)

- Focus on obtaining a more cost-effective supply of energy, through negotiating with an energy supplier, investing in self-generated energy, or accessing an external supply of, for example, waste heat
- Focus on more cost-effective use of energy, which should include both technology and management measures

For non-energy-intensive industries and industrial SMEs, the opportunity to invest in self-generated energy or an external supply of, for example, waste heat, is often non-existent. Instead, it is on the use side where the major potential for improved energy efficiency lies; there are four principal means of obtaining improved energy efficiency on the use side, as shown in Table 2.3.

Conducting an energy audit is the important first step in the process of improving energy efficiency. However, and as stated later in this book, an energy audit is merely the first step in successful energy management in an industrial company. What may begin with an audit should preferably be continued by investing in permanent monitoring.

Figure 2.9 shows the level of energy efficiency attained in European industry and how the potential is realized by eliminating barriers to energy efficiency.

The figure shows that by eliminating barriers to energy efficiency, the potential may be realized.

Means to improve industrial energy efficiency and overcome barriers, apart from energy audits, entail the adoption of energy management and energy services. However, there has been little research into energy services related to industry, and the few studies available find only a moderate to low adoption of energy services

Table 2.3 Four principal means of reducing industrial energy costs

Four principal use side means of reducing industrial energy costs	Comment
Energy-efficient technologies	Improved efficiency of technologies using energy is one of the foremost and most common means of increasing energy efficiency in industry
Load management	Reducing power costs by minimizing power loads is a common energy efficiency measure in industry
Change energy carriers	Changing energy carriers, for example, switching from oil to district heating, is another means by which industry can cut costs
Energy-efficient behavior or energy conservation	This is a simple measure involving more efficient behavior on the part of company staff

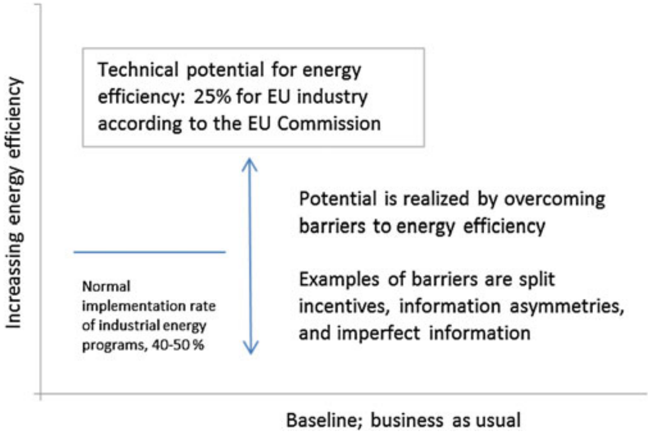

Fig. 2.9 Explaining the energy efficiency gap (Thollander 2011)

in industry (Backlund and Thollander 2011). Energy management and energy services are further elaborated in Chaps. 3 and 6.

2.7 Energy Efficiency: Why Not?

2.7.1 The Rebound Effect

The so-called rebound effect is a commonly cited criticism of energy efficiency (Herring 2006; Saunders 2000; Khazzoom 1980). Cost-effective energy efficiency measures are always positive as energy efficiency strengthens competitiveness through lower production costs and are also positive because energy efficiency will promote a more efficient and prosperous economy. However, it is argued that energy efficiency will not always lead to reduced overall energy use (Herring 2006). The rebound effect may be split into two major categories:

- The direct rebound effect: a price effect where a new technology might increase energy efficiency corresponding to a reduction in the price of energy services that leads to an increased demand for energy (Bentzen 2004).
- The indirect rebound effect: which means that an energy efficiency activity lowers overall energy costs leading to more money left to spend on other goods and services.

The question of importance is not so much whether the rebound effect exists but rather how great the magnitude of such an effect is considered to be. The direct rebound effect for industrial process use was found to be less than 20 % and the indirect rebound effect about half a percent in a study by Greening et al. (2000). In the study it was concluded that: For the energy end-users for which studies are available, we conclude that the range of estimates for the size of the rebound effect is very low to moderate (Greening et al. 2000). In a study by Bentzen (2004) studying the direct rebound effect in US manufacturing industry between 1949 and 1999 it was found that the size of the rebound effect was likely to be less than 24 % for the sector.

2.8 Conclusion

This chapter has demonstrated the vast potential for energy efficiency in industrial SMEs, and noted that the energy efficiency measures that are implemented particularly relate to technical support processes such as ventilation, lighting, pumping, and air compression. The importance of technology should not be neglected in seeking improved sustainability in industry's energy systems. However, it has been emphasized that technology should be addressed using a wide systems perspective, as the major potential lies in the area of the system, not the core technology itself. Evaluations of energy audit programs reveal that 60–90 % of the measures implemented in industrial SMEs concern support processes. To improve energy efficiency, external support, such as energy audits, is often used. This chapter has demonstrated that there are important factors regarding energy audits and energy audit programs that need to be taken into account. When conducting energy audits, it is important that the information given be specific, vivid, and personal and that the company representatives trust the auditor. Intermediaries such as regional energy agencies or sector organizations, i.e., non-government institutions, are more successful at auditing industrial energy use. According to some manufacturing representatives, these intermediaries are more trustworthy, and assuming they have the relevant skills to carry out energy audits, are aware of the specific characteristics of the industrial sectors that they support. If so, this would mean fewer errors in the energy audit reports they produce. It should be

Although the potential is vast, excellent levels of energy efficiency are rarely attained in industrial SMEs. In the next chapter, we will discuss how energy efficiency investments can be inhibited by various barriers to improve energy efficiency. By presenting a theoretical overview of these barriers, as derived from various scientific disciplines, the reader will be made aware of the great challenges to be faced in overcoming these barriers and improving energy efficiency in industrial SMEs.

References

Anderson ST, Newell RG (2004) Information programs for technology adoption: the case of energy-efficiency audits. Resour Energy Econ 26(1):27–50

Backlund S, Thollander P (2011) The energy-service gap: what does it mean? In: Proceedings of the European Council for an energy efficient economy’s summer study, 6–11 June 2011

Bentzen J (2004) Estimating the rebound effect rebound effect in US manufacturing energy consumption. Energy Econ 26:123–134

Bertoldi P (2001) Effective policies and measures in energy efficiency in end-use equipment and industrial processes. In the 2001 workshop on good practices in policies and measurers

Bertoldi P (1999) In: Proceedings of the 1999 SAVE conference “For An Energy Efficient Millennium”, Session III, 1–10

Capeheart BL, Capeheart LC (1995) Improving industrial energy auditenergy audit analyses. In: Proceedings of the 1995 ACEEE summer study on energy efficiency in industry

CRIEPI (Central Research Institute of Electric Power Industry) (2011) Chapter 6 energy management actions in Japanese industries. CRIEPI, Tokyo

EC (European Commission) (2006) Communication from the commission. Action plan for energy efficiency: realizing the potential. COM (2006) 545 final

Edén M (1991) Starta energihushållning i småindustriområden. Hur företagare påverkas av energirådgivning [Starting energy conservation in small industrial areas. How enterprises are affected by energy consulting]. Byggforskningsrådet, Rapport R41:1991, Gävle (in Swedish)

Eurostat (2006) Statistical handbook. Energy yearly statistics 2006

Gralén Klas (2002) Den tryckluftslösa fabriken [the compressed air free factory]. Department of Mechanical Engineering, Linköping University

Greening LA, Greene DL, Difiglio C (2000) Energy efficiency and consumption—the rebound effectrebound effect—a survey. Energy Policy 28:389–401

Gruber E, Brand M (1991) Promoting energy conservation in small and medium-sized companies. Energy Policy 19:279–287

Gruber E, Fleiter T, Mai M, Frahm B-J (2011) Efficiency of an energy audit programme for SMEs in Germany—results of an evaluation study. ECEEE 2011 Summer study

Harris J, Andersson J, Shafron W (2000) Investment in energy efficiency: a survey of Australian firms. Energy Policy 28:867–876

Herring H (2006) Energy efficiency: a critical view. Energy 31:10–20

Hirst E, Brown MA (1990) Closing the efficiency gap: barriers to the efficient use of energy. Resour Conserv Recycl 3(4):267–281

IEA (International Energy Agency) (2007) Key world energy statistics 2007, Paris

Khazzoom DJ (1980) Economic implications of mandated efficiency standards for household appliances. Energy J 1:21–40

Klugman S, Karlsson M, Moshfegh B (2007) A Scandinavian chemical wood pulp mill. Part 1. Energy auditaudit aiming at efficiency measures. Appl Energy 84:326–339

Persson A (1990) Nyttiga lärdomar. Erfarenheter av industriell energirådgivning [Important lessons. Experience from industrial energy consulting]. Statens industriverk, Stockholm (in Swedish)

Ramirez CA, Patel M, Blok K (2005) The non-energy intensive manufacturing sector. An energy analysis relating to the Netherlands. Energy 30:749–767

Russell (2006) Energy management pathfindings: understanding manufacturers' ability and desire to implement energy efficiency. Strateg Plan Energy Environ 25:20–54

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

SCB (2007) Personal communication with staff at SCB. SCB (Statistics Sweden), Örebro

Schleich J (2004) Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany. Int J Energy Technol Policy 2:226–239

SEA (Swedish Energy Agency) (2006) Utvärdering av seminarieserie för tillverkande svenska SMF 2005–2006 [Evaluation of a series of seminars directed toward Swedish manufacturing SMEs 2005–2006]. Swedish Energy Agency, Eskilstuna (in Swedish)

Shipley AM, Elliot RE (2001) Energy efficiency programs for small and medium sized industry. In: Proceedings of the 2001 ACEEE summer study on energy efficiency in industry, vol 1, 183–196

Stern PC, Aronson E (eds) (1984) Energy use: the human dimension. W.H. Freeman and Company, New York

Söderström M (1996) Enhetsprocesser. Ett sätt att strukturera industrins energianvändning. Linköping university

TemaNord (2003) Miljöinformation som styrmedel: Förstudie [Environmental information as a policy instrument] Nordiska Ministerrådet, Rapport 2003:540, Köpenhamn. http://www.norden.org/pub/ebook/2003-540.pdf. Accessed 8 Jan 2008 (in Swedish)

Thollander P, Karlsson M, Söderström M (2005) Reducing industrial energy costs through energy efficiency measures in a liberalized European electricity market: case study of a Swedish iron foundry. Appl Energy 81:115–126

Thollander P, Rohdin P, Danestig M (2007) Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Policy 35:5774–5783

Thollander P, Palm J, Söderström M (2008) Industrial energy auditing—a key to competitive energy-efficient Swedish SMEs Invited publication in energy efficiency research advances. David M Bergmann (ed) 213–238 Nova Publisher

Thollander P, Mardan N, Karlsson M (2009) Optimization as investment decision support in a Swedish medium-sized iron foundry: a move beyond traditional energy auditing. Appl Energy 86:433–440

Thollander P (2011) Energy management. Linköping University (in Swedish)

Waide P, Brunner C (2011) Energy-efficiency policy opportunities for electric motor-driven systems. IEA (International Energy Agency). Energy efficiency, Paris

von Malmborg F (2003) Conditions for regional public-private partnerships for sustainable development: Swedish perspectives. Eur Environ 13:133–149

Chapter 3
Barriers to Energy Efficiency: Theoretical Baseline, Previous Research, and Methodological Approaches

Abstract In this chapter, we will discuss earlier research into the often acknowledged "energy efficiency gap." This concept refers to the assumption that though technologies, methods, and processes exist for reducing energy use in industry, barriers hinder their implementation. To reduce the energy efficiency gap, researchers have defined and analyzed barriers identified in industry. Studies classify these barriers in various ways; here, we will discuss a categorization of these barriers as market failure, nonmarket failure, behavioral, and organizational barriers. This chapter also deals with the major research design approaches used in barrier research and cites examples from studies of barriers. We also believe that structural barriers, unrelated to the site level, as well as energy services must be considered when discussing the energy efficiency gap and how to resolve the gap.

3.1 Introduction

Numerous publications identify the existence of a "gap" between potentially cost-effective energy efficiency measures and the measures actually implemented. This gap is referred to as the "energy efficiency gap" or "energy paradox" (York et al. 1978; Blumstein et al. 1980; Stern and Aronson 1984; Hirst and Brown 1990; Gruber and Brand 1991; Stern 1992; DeCanio 1993; Jaffe and Stavins 1994; Sanstad and Howarth 1994; Weber 1997; Ostertag 1999; Sorrell et al. 2000; Brown 2001; de Groot et al. 2001; Schleich 2004; Sorrell et al. 2004; Schleich and Gruber 2008; Sardianou 2008; Hasanbeigi and Menke 2010; Fleiter et al. 2011;

Part of this chapter was previously published in an earlier version in Thollander et al. (2010a, b).

P. Thollander and J. Palm, *Improving Energy Efficiency in Industrial Energy Systems*,
DOI: 10.1007/978-1-4471-4162-4_3,

Trianni and Cagno 2011). Thus, certain energy efficiency measures may not be implemented, even though they would be financially beneficial. The several reasons for this will be discussed in this chapter.

3.2 Energy Policy Decision Making and Barriers to Energy Efficiency

Historically, energy policy decision making in market economies has often been based on mainstream economic theory, which in turn relies on fundamental assumptions such as the availability of perfect information to both buyers and sellers, zero transaction costs, and complete rationality on the part of market participants. Mainstream economic theory distinguishes among market failures/imperfection, and market barriers. The existence of market failures/imperfections may justify public policy intervention if the intervention passes a cost–benefit analysis. Brown (2001) writes: "the existence of market failures and barriers that inhibit socially optimal levels of investment in energy efficiency is the primary reason for considering public policy interventions. In many instances, feasible low-cost policies can be implemented that either eliminate or compensate for market imperfections and barriers, enabling markets to operate more efficiently to the benefit of society. In other instances, policies may not be feasible; they may not fully eliminate the targeted barrier or imperfection; or they may do so at costs that exceeds the benefits" (Brown 2001).

In other words, barriers to energy efficiency that can be classified as market failures/imperfections may lead to policy adoption, while so-called market barriers—which include any barrier accounting for the energy efficiency gap—cannot justify policy adoption. The classification of barriers clearly has great implications for whether, how, and when a policy should be adopted (Thollander et al. 2010a).

3.3 Market Forces and Market Failures

One criticism of industrial energy policies asserts that technological advances and rising energy prices would cause energy efficiency measures to be implemented, even without government policies. This argument is closely related to mainstream economic politics (e.g., Sutherland 1996), which relies on the market and market restructuring to ensure that energy efficiency improvements are carried out (Jaffe and Stavins 1994). Such theory represents the outgrowth of the ideas of eighteenth-century economist Adam Smith, known as the father of modern economics, who stated that the actions of individuals acting in a decentralized market setting lead to collectively beneficial results. Some of the underlying axioms or ideal conditions postulated by this theory are:

- A complete set of markets with well-defined property rights, such that buyers and sellers can exchange assets freely
- Consumers and producers behave competitively by maximizing benefits and minimizing costs
- Market prices are known by all consumers and firms
- Transaction costs are zero

If any of these axioms fails to hold, a market failure or market imperfection is manifested, which, as previously outlined, may justify public policy intervention. The four broad types of market failures are:

- Incomplete markets
- Imperfect competition
- Imperfect information
- Asymmetric information

Of these four broad types of market failure, information imperfections and asymmetries are of special interest when studying industrial energy end-use efficiency (Sorrell et al. 2000). Sanstad and Howarth (1994) write: “It is not a deep insight to observe that, relative to the theoretical ideal, these market failures are common if not pervasive in the real world” (Sanstad and Howarth 1994). The first two market failures mentioned above, incomplete markets and imperfect competition, are less important when conducting empirical studies of barriers to energy efficiency (e.g., Sorrell et al. 2000), as they cannot explain why cost-effective energy efficiency measures available on the market are not implemented. However, incomplete markets and imperfect competition are not irrelevant to explaining the nonimplementation of energy-efficient technologies (Sorrell et al. 2000). As Sorrell et al. (2000) note, “environmental externalities represent a form of incomplete markets, but do not explain the failure to adopt technologies at current prices. Similarly, monopoly energy suppliers may depart from marginal cost pricing but this again does not explain the gap” (Sorrell et al. 2000).

While declining energy prices have been demonstrated to lead to greater energy use (Trygg and Karlsson 2005), the reverse, i.e., that increasing electricity prices lead to increased energy efficiency, may not be as true in the short run. Bertoldi et al. (2005) claim that “price increases per se are an inadequate approach to inducing energy efficiency” (Bertoldi et al. 2005). In summary, the adoption of cost-effective energy efficiency measures is not solely, according to Bertoldi et al. (2005), based on price mechanisms, such as energy price increases, although they naturally exert an influence.

Moreover, the adoption of the European Energy End-use Efficiency and Energy Services Directive in 2006 and the American Demand Side Management (DSM) regulations in the 1970s indicates that, in current energy service markets, market mechanism solutions alone may not ensure the adoption of energy-efficient technologies without public interference.

In summary, discussion of the energy efficiency gap is based on the assumption that technologies, methods, and processes exist that can reduce energy use in industry, but that barriers hinder their implementation. If industrial actors only acted rationally, it is claimed, this gap would not exist. To explain this gap, various barriers to energy efficiency have been identified, including lacks of information, knowledge, time, and funding. However, these empirical barriers, identified in research, are difficult to classify as market failure or nonmarket-failure barriers.

3.4 The Energy Efficiency Gap: What Does it Mean?

In the often-cited article, “the energy-efficiency gap: what does it mean” by Jaffe and Stavins (1994), the authors outline several levels of “energy efficiency potentials” or “energy efficiency gaps” (see Fig. 3.1).

Jaffe and Stavins (1994) explain that each level in the figure represents a different optimal scenario. The authors’ intention is that the different efficiency gaps should correspond to the distances between the levels and the horizontal axis, the baseline being business as usual. The text between the boxes describes the differences between these scenarios. In addition, the height of each level indicates the relative level of efficiency. Jaffe and Stavins suggest two concepts of economic potential and two of social optimum. They use the general term “economic potential” to describe the degree of energy efficiency that could be achieved if the economic barriers were removed. They first show the “economist’s economic potential” and thereafter the “technologist’s economic potential.” If all barriers, both market and nonmarket, were eliminated, a higher estimated potential could be achieved.

When describing the social optimum, they start by discussing the additional efficiency that could be achieved if the energy prices were “right,” something that would require very costly government programs to remove the relevant barriers. They therefore define a narrower social optimum that, however, does not result in as great efficiency. In this narrow social optimum, only those barriers are retained that can be removed without the costs exceeding the benefits. In the last box of the figure, Jaffe and Stavins place the true social optimum; this optimum takes account of environmental externalities, causing the social optimum to rise again.

In summary, the figure shows that the potential savings realized depend on the view applied: while the “technologist’s potential” is in a sense real, the “economist’s potential” is also real to that person or organization, the difference between the two depending on which theoretical perspective is applied.

The existence of the energy efficiency gap is commonly explained by barriers to energy efficiency; these barriers will now be discussed in greater detail.

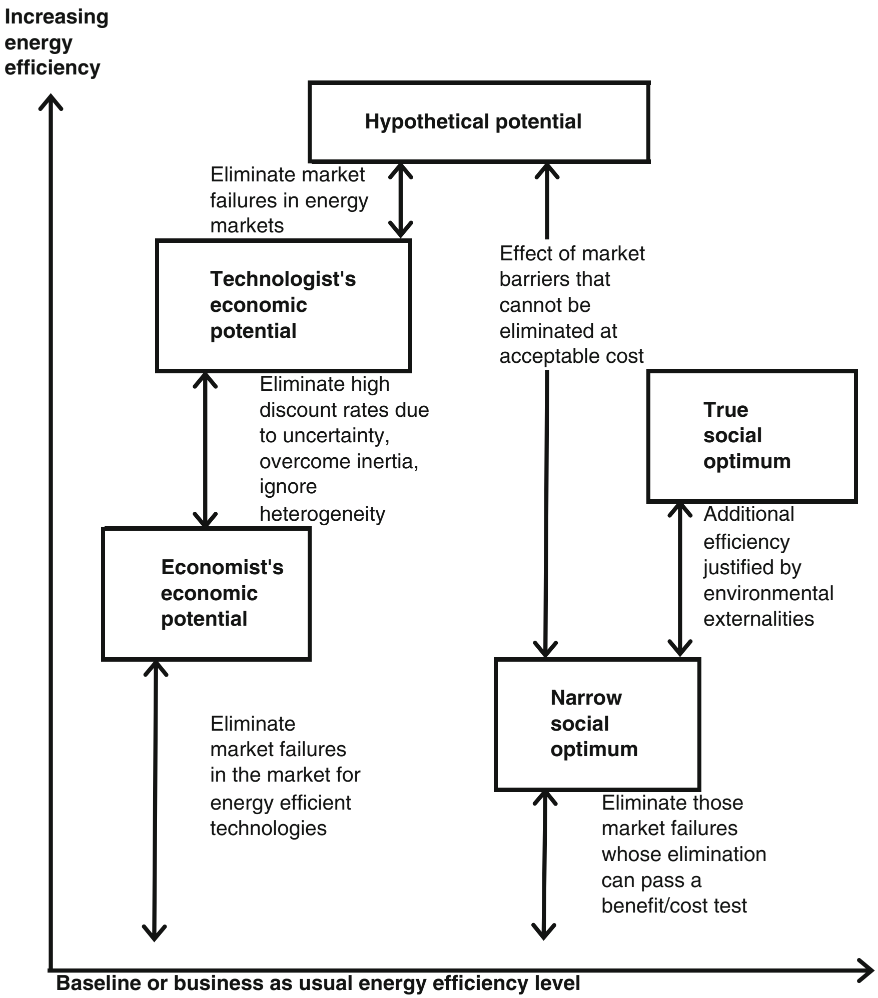

Fig. 3.1 Various levels of energy efficiency potential (Jaffe and Stavins 1994)

3.5 Barriers

Sorrell et al. (2004) define a barrier to energy efficiency as follows: “A postulated mechanism that inhibits investments in technologies that are both energy-efficient and economically efficient” (Sorrell et al. 2004). In other words, though there are various technological means to achieve more energy-efficient industrial activity, various hindrances (barriers) keep these from being implemented.

These barriers are explanatory variables derived from various scientific disciplines, for example, mainstream economics, organizational economics and organizational, and behavioral sciences. In an extensive review, Sorrell et al. (2000)

Table 3.1 Classification of barriers to energy efficiency (based on Sorrell et al. 2004)

Category	Theoretical barriers	Comment
Market failure/market imperfection	Imperfect information	Information imperfections, for example, lack of information, may lead to cost-effective energy efficiency measures not being undertaken
	Adverse selection	If a seller knows more about the energy performance of a technology than the buyer does, the buyer may select goods on the sole basis of price or visible aspects such as color and design
	Principal–agent relationship	Strict monitoring and control by the principal, since he or she cannot observe what the agent is doing, may result in the overlooking of energy efficiency measures
	Split incentives	If a person or department cannot benefit from an energy efficiency investment, the most likely outcome is the nontake-up of the measure
Nonmarket failures/non-market imperfections	Hidden costs	Hidden costs include overhead costs related to the investment, cost of collecting and analysing information, and production disruptions
	Access to capital	Limited access to capital may inhibit cost-effective energy efficiency measures from being implemented
	Risk	Risk aversion may result in cost-effective energy efficiency measures not being undertaken
	Heterogeneity	A technology or measure may be cost-effective in most locations but not in others, leading to excessive potential being claimed for the technology
Behavioral barriers	Form of information	Research has demonstrated that to increase the diffusion and acceptance of information on cost-effective energy efficiency technologies, the information should be specific, vivid, simple, and personal
	Credibility and trust	The source of information must be considered credible and trustworthy by the receiver in order to successfully deliver information about cost-effective energy efficiency technologies
	Values	Energy efficiency improvements are more likely to be of interest if the organization consists of individuals with real ambition
	Inertia	Individuals are often hesitant to change, which may, in turn, result in the overlooking of cost-effective energy efficiency measures
	Bounded rationality	Instead of being made based on, for example, perfect information and complete rationality, decisions are often made in constrained environments that result in limited, or bounded, decisions, i.e., nonoptimal from a fully rational point of view

(continued)

Table 3.1 (continued)

Category	Theoretical barriers	Comment
Organizational	Power	Low status of energy managers may lead to energy issues being assigned a low priority in industrial organizations
	Culture	Over time, organizations may encourage energy efficiency investments by developing a culture characterized by environmental values; for example, the core values of an industrial organization may inhibit or promote energy efficiency

classified the barriers to energy efficiency into four broad categories depending on the scientific discipline from which they were derived. These four broad categories, namely, market failure, nonmarket failure, behavioral, and organizational, are presented in Table 3.1, together with the major barriers derived from each discipline.

In the following section, the barriers outlined in Table 3.1 are explained in greater detail, beginning with barriers derived from economic research, followed by behavioral and organizational theories on why cost-effective energy efficiency measures are sometimes not adopted.

3.6 Market Failures: Economic Barriers

Market failure barriers are barriers that violate the axioms of mainstream economic theory, and that may justify government intervention if the relevant policy or program passes a cost-benefit test. These market failure barriers, i.e., imperfect information, adverse selection, principal–agent relationships, and split incentives, are presented in the following section.

3.6.1 *Imperfect Information*

Research states that consumers are often poorly informed about available energy-efficient technologies. This information imperfection naturally inhibits investments in energy efficiency measures (Sanstad and Howarth 1994). In lack of information—perhaps the strongest form of imperfect information—market actors (i.e., consumers) are not even aware of the available technological options. Another form of imperfect information occurs when information about the energy performance of energy-efficient technologies is unavailable to market actors (i.e., consumers). Yet another form of imperfect information pertains to the accuracy of information; this is found when the information provider is not completely transparent about the product provided. Imperfect information is more likely to occur when products are purchased infrequently; in such cases, performance characteristics are difficult to evaluate either before or soon after the purchase and the rate of technology change is rapid relative to the purchase intervals (Sorrell et al. 2000). This is an unfortunate characteristic of many energy-related investments.

3.6.2 Adverse Selection

Adverse selection is a barrier to energy efficiency that can be classified as a type of asymmetric information. Adverse selection arises when producers of energy-efficient technologies are better informed of the characteristics and performance of the technologies on offer than are potential buyers. The information possessed by the two parties engaged in the transaction is therefore asymmetric. As one of the underlying assumptions of mainstream economic theory is that information is perfect, asymmetric information is known to be a form of market failure. According to, for example, Sanstad and Howarth (1994), adverse selection is extremely common in real-world markets, meaning that inefficient outcomes may be the rule rather than the exception.

3.6.3 Principal–Agent Relationships

A principal–agent relationship arises due to a lack of trust between two parties at different levels of an organization, and may be classified as a type of asymmetric information. The owner of a company, who may not be as well informed of the site-specific criteria regarding energy efficiency investments as the CEO, may in case of lack of trust therefore demand short pay-back rates/high hurdle rates for any such investments in his or her company. This is related to his or her distrust in executive ability to carry out such investments, leading to the neglect of cost-effective energy efficiency investments (DeCanio 1993; Jaffe and Stavins 1994).

3.6.4 Split Incentives

Split incentives constitute a third form of asymmetric information, and these occur when the potential adopter of an investment is not the party who pays the energy bill. If this is the case, information about available cost-effective energy efficiency measures in the hands of the potential adopter may not lead to adoption of the measures. Instead, the measures will only be evaluated if the adopter can recover the investment cost from the party benefitting from the energy savings (Jaffe and Stavins 1994). A division manager in an industrial company, who pays the energy bills for his or her division based on number of employees or per square meter, may have little interest in the organization's overall in-house energy management program. This is because investments leading to lowered energy costs, including investments in energy-efficiency technologies, have no effect on the division manager's own track record, but instead create a heavier financial burden for his or her division. Any savings achieved in this division cannot be allocated to it, hence there is "nothing in it" for the manager (Hirst and Brown 1990).

3.7 Nonmarket Failures: Economic Barriers

Apart from the above market failure barriers related to information asymmetries and imperfections, a number of barriers explaining the "energy efficiency gap" are not categorized as market failures, but as nonmarket-failure barriers or market barriers, according to mainstream economic theory. A nonmarket-failure barrier refers to a situation in which actors, due to the existence of these barriers, decide on a rational basis not to undertake energy efficiency investments. According to Jaffe and Stavins (1994), a market barrier can be defined as any factor that accounts for the "gap," while Brown (2001) defines a market barrier as any barrier that is not based on market failure, but that, nevertheless, contributes to the nonadoption of cost-effective energy-efficient technologies. Barriers that can be categorized as market barriers, for example, hidden costs, limited access to capital, risk and heterogeneity, are outlined in the following section.

3.7.1 Hidden Costs

Hidden costs refer to high costs associated with information seeking; meeting with sellers, writing contracts, etc., that are not included in a narrow investment model that includes only the actual investment costs. If the costs of searching for and acquiring information regarding an investment are excessive compared with the actual investment cost, a fully rational decision will be made not to undertake the investment. Accordingly, a seemingly cost-effective energy efficiency measure may not be cost-effective when hidden costs associated with the investment are included. Hein and Blok (1995) stated that hidden costs in large energy intensive industrial companies ranged from three to eight per cent of their total investment costs. In smaller, nonenergy-intensive firms, such as SMEs, such costs are likely to be even higher.

3.7.2 Limited Access to Capital

Energy-efficient technologies may be more expensive than other technologies. Furthermore, it may be difficult to obtain the additional capital needed in order to invest in such energy-efficient technology. Limited access to capital, quite apart from low liquidity, may arise due to restrictions, sometimes self-imposed, on lending money (Hirst and Brown 1990).

3.7.3 Risk

Risk as a barrier to energy efficiency can be exemplified by a manager who is aware of the capital cost of an energy efficiency investment, but who faces uncertainty when it comes to the long-term energy savings attributable to it. The investment represents risk and thus may not be undertaken (Hirst and Brown 1990). Risk has been found to be of great importance for decision makers (Hirst and Brown 1990).

Stern and Aronson (1984) state that risk, articulated as correct estimates of the net costs of implementing energy efficiency measures, depends on, among other factors, future economic conditions in general and future energy prices, and availability in particular. The history of energy prices tells us that energy prices have fluctuated as long as a market for energy has existed. This uncertainty about future prices makes it difficult for energy users to make “rational” choices about new energy efficiency investments, as the basis for estimating long-term operating costs is so uncertain.

Uncertainty about future energy prices poses a barrier to both the manufacture of and investment in energy-efficiency technologies (Hirst and Brown 1990). Some SMEs may not even be able to reduce uncertainty to a calculated risk, as they lack the time and money to make the estimates needed for that (Stern and Aronson 1984).

3.7.4 Heterogeneity

Heterogeneity is associated with the fact that even if a given technology is cost-effective on average, it will likely not be so for certain industrial companies. This barrier particularly applies to companies specializing in a single type of product, or to technologies with restricted application due to temperature, contamination, or other specific conditions; for example, T5 fluorescent lighting may not be implementable if the ambient temperature is too high or the air is too dirty, while a heat exchanger may not function on an exhaust ventilation flow that contains too much process-related particulate matter. Heterogeneity can be an explanatory variable for the “energy efficiency gap” when modeling the potential, in terms of energy saved per year, of a given technology in a *population* of companies, but is naturally not so relevant when information is gathered from, for example, an energy audit containing site-specific information.

3.8 Behavioral Barriers

Apart from the previously outlined economic barriers to energy efficiency, a number of barriers identified by behavioral research can also explain the "energy efficiency gap" These barriers, i.e., form of information, credibility and trust, values, inertia, and bounded rationality, are presented below.

3.8.1 Form of Information

One barrier to energy efficiency arises when, because of its form, the information provided receives insufficient attention from its recipients. This occurs because people are often not active information seekers, but are instead selective in assimilating information. Research finds that information that is specific in nature, is presented in a vivid and personalized manner, and moreover comes from a person who is similar to the recipient is more likely to be assimilated (Stern and Aronson 1984).

3.8.2 Credibility and Trust

Another factor that can inhibit the implementation of cost-effective energy-efficiency technologies is the perceived credibility of the information provider and, consequently, the recipient's trust in him or her. If an industrial company cannot acquire accurate information about the probable cost of various investment options, it may rely more on the available information that is most credible. An example from the household sector illustrates this point. Pamphlets describing how to save energy when using home air-conditioning systems were mailed to 1,000 households in New York. Half of the households received the information from the local electricity utility and the other half from the state regulatory agency for utilities. The next month, the households that had received the pamphlet from the state agency used about eight per cent less electricity than did those receiving the same pamphlet from the local electricity utility company (Stern and Aronson 1984). Successfully spreading information about energy efficiency clearly depends on how trustworthy the information provider is perceived to be. As regards industry, intermediaries such as sector organizations or consultants may play an important role, as these are often regarded as more trustworthy than are government authorities (Ramirez et al. 2005; Stern and Aronson 1984).

3.8.3 Values

Values such as supporting others, concern for the environment, and moral commitment to energy efficiency influence individuals and groups positively with regard to adopting energy efficiency measures. However, studies from the household sector indicate that norms only have a strong impact on energy efficiency and energy conservation measures that are free of charge (Stern and Aronson 1984). In summary, lack of values related to energy efficiency may inhibit measures from being undertaken.

3.8.4 Inertia

Inertia refers to the fact that individual and organizational behavior is at least partly the outcome of habits and established routines. Accordingly, it may be difficult to promote change in behaviors and habits. Behavioral scientists claim that this is an explanatory variable for the existence of the "energy efficiency gap" (Stern and Aronson 1984). Stern and Aronson (1984) state that individuals strive to reduce uncertainty and change in their environments, and consequently try to avoid or ignore problems. Furthermore, individuals who have recently made important decisions seem to justify those decisions afterwards, evidently trying to convince themselves and others that their decisions were indeed sound. Inertia may help explain the failure of many energy users to take economically justifiable actions to improve energy efficiency, and may also explain why improved energy efficiency often begins with small commitments that later lead to larger steps being taken (Stern and Aronson 1984).

3.8.5 Bounded Rationality

Bounded rationality offers yet another explanation for why cost-effective energy efficiency measures is sometimes not undertaken (Simon 1957). Most types of market failure refer to problems in the economic environment that impede economic efficiency, even when assuming that actors are fully rational. In the case of energy-efficiency-related investment decisions, this assumption formally requires that decision makers solve what may be extremely complex optimization problems to obtain the lowest cost provision of energy services (Sanstad and Howarth 1994). Studies on decision making in organizations identify two major features of organizations that affect the fit of a simple rational view to organizational action (Stern and Aronson 1984; Sanstad and Howarth 1994):

1. An organization is not a single actor but rather an aggregate of individuals with different, and at times conflicting, objectives. The interests of one individual or division may, for example, be in conflict with other departments' or employees' interests.

2. Organizations and individuals, to some extent, do not act on the basis of complete information but rather make decisions by "rule of thumb."

3.9 Organizational Barriers

Apart from barriers identified in economic and behavioral research, barriers in the form of power and culture have been identified in organizational theory. These barriers are presented below.

3.9.1 Power

Insufficient power possessed by the energy controller of an industrial organization may pose a barrier to improving energy efficiency. Energy management practices often do not receive sufficient attention, even in energy-intensive industries, constraining the implementation of energy efficiency measures (Thollander and Ottosson 2010).

3.9.2 Culture

Organizational culture is closely related to the values of the individuals constituting an industrial organization, for example, and may inhibit the adoption of energy-efficiency technologies (Johansson et al. 2011). An organization's culture may be seen as the sum of its constituent individuals' values; the executives' values or the values of other workers with considerable influence may have greater impact on the company's culture than the values of workers lower in the organizational hierarchy (Sorrell et al. 2000).

3.10 Methodology Approaches to Studying Barriers

The methodological approaches for empirically studying the nonadoption of cost-effective energy-efficiency technologies vary, but do have some elements in common. The following sections outline these various methodological approaches.

3.10.1 Various Ways of Categorizing Barriers to Energy Efficiency

Reviewing the research into barriers to energy efficiency reveals the existence of various means of categorizing barriers in empirically based studies of energy efficiency.

When using barriers as a variable explaining why cost-effective investments are not undertaken, a barrier model is constructed. Such models have three features, according to Weber (1997): the objective obstacle, the subject hindered, and the action hindered. The methodological approach used in formulating a barrier model can be expressed in the following composite question: What is an obstacle to whom reaching what in energy conservation? (Weber 1997).

- What is an obstacle….'persons, patterns of behavior, attitudes, preferences, social norms, habits, needs, organizations, cultural patterns, technical standards, regulations, economic interests, financial incentives, etc.
- '…is an obstacle to whom….'consumers, tenants, workers, clerks, managers, voters, politicians, local administration, parties, trade unions, households, firms NGOs (Non Governmental Organizations), etc.
- ….reaching what': buying more efficient equipment, retrofitting, decreasing an energy tax, establishing a public traffic network, improving operating practices, etc.

As described above, Sorrell et al. (2000) distinguish three main categories of barriers to energy efficiency, i.e., market failures, organizational failures, and nonmarket failures, while Weber (1997) categorizes these barriers as institutional, economic, organizational, and behavioral barriers. The barriers to energy efficiency were also categorized by Hirst and Brown (1990), who divide the barriers into two broad categories, structural barriers and behavioral barriers.

We conclude that these barriers can be categorized in various ways and that there is no common theoretical framework on which to rely when studying barriers to the implementation of energy efficiency measures. How we define a problem determines whether and how we can solve it—this is elementary knowledge in all sciences. Clear definitions are the foundation for all innovative thought, and that is why it is important to reflect on how barriers to energy efficiency are categorized and what sort of answers a particular categorization will foster (Thollander et al. 2010a; Palm and Thollander 2010). How these barriers are categorized is a social construct, but it is one that is needed to be able to analyze the problem of energy efficiency gaps. Though necessary, these categorizations can also be problematic if applied without reflection.

3.10.2 Research Design of Studies of Barriers to Energy Efficiency

Another difference among the various studies of barriers to energy efficiency concerns the research design used. Normally, research design consists of an aim or a number of research questions, a method for collecting the relevant data, and finally an analysis.

Independent of the aim and research questions articulated, all of which are of course related to the question of why cost-effective investments are not undertaken, two major research designs are found to be applicable, namely, case studies (e.g., Sorrell et al. 2004) and surveys (e.g., Schleich and Gruber 2008).

These two approaches, to barrier studies, differ when it comes to analyzing the results and collecting the relevant data. Briefly stated, case study researchers favor interviews as the primary means of collecting data, while survey researchers favor the use of questionnaires. In reality, only one applicable case study (Sorrell et al. 2000, 2004) can be said to completely follow the rigid guidelines outlined by Yin (2003). This study, conducted by Sorrell et al. (2000, 2004), included case study protocols and multiple sources of information, including interviews with both top managers and other workers in the studied organization. This type of research design naturally provides highly valid results: the collected data are highly reliable in the cited study, as they come from multiple sources in the case company. The downside of case study research is that it is time-consuming and can normally cover only a few study objects, i.e., cases. This, according to critics of the approach, limits the chances of generalizing the research findings (Bryman 2001).

The other research design, survey research, can lead to a greater opportunity to generalize the research results; as such research normally covers a large number of respondents. Survey studies can also be limited, in that normally only one person per industrial company is asked to participate in the survey; on the other hand, with the exception of Sorrell et al. (2004), research using case study design may also involve only one respondent per studied organization.

3.10.3 Examples from Barrier Studies

Several researchers have empirically examined barriers to energy efficiency, for example, Gruber and Brand (1991), Sorrell et al. (2004), Brown (2001), de Groot et al. 2001, Schleich (2004), Schleich and Gruber (2008), and Sardianou (2008). We will briefly review empirical barriers to energy efficiency identified by Swedish studies (Rohdin and Thollander 2006; Rohdin et al. 2007; Thollander et al. 2007) to demonstrate how such results can be collected and presented.

These studies used questionnaires and interviews. The questionnaires were intended to be completed by energy managers or those in charge of energy issues. The main reason for submitting the questionnaire to the energy managers was that these respondents were able to answer questions generally related to energy efficiency and energy use in the company. These respondents often know about both industrial process and energy-related issues and are often in charge of their companies' energy purchasing and contacts with Swedish authorities.

The questionnaires asked respondents to rank various barriers to energy efficiency. In analyzing these quantifications of the barriers, simplifications were made, as the quantified results capture several perspectives on the issue, not merely presenting a single ranking score. Furthermore, it must also be kept in mind, when drawing conclusions from such studies using questionnaires and in-depth interviews, that respondent answers may include a degree of bias. Personal opinions, for example, may affect a respondent's answers to certain questions. (on the other hand, these people will likely still act according to these opinions). Furthermore, to minimize such biases, respondents were provided with confidentiality in all the reviewed case studies using interviews and questionnaires.

Once again, it is important to note that the cited classifications of barriers to energy efficiency are not entirely accurate. As Weber (1997) states: "it is empirically impossible to find the 'true' reason behind energy-conserving action which has not been taken" (Weber 1997). Like all theoretical frameworks for complex real-world phenomena involving people and organizations, these classifications should be seen as analytical tools. This must be kept in mind when analyzing the empirical findings, as respondent answers often fit into more than one category of theoretical barrier. Table 3.2 presents the results of this review.

Table 3.2 shows the greatest barriers to energy efficiency identified in the reviewed Swedish studies, which examined industries in Oskarshamn, SMEs in the Swedish Highlands, and Swedish foundries. As can be seen, these studies are similar in many ways. For example, technical risks and lack of time are highly ranked in two of the three studies; as a main interest is determining general patterns of barriers to be targeted by policy makers, these barriers could be a focus.

There are also differences among the barriers identified by the companies in the three studies. For example, the industries in Oskarshamn considered the risk of production disruption the greatest barrier to implementing energy-efficient technologies, while this was ranked fourth by the studied Highland SMEs. Among the Highland SMEs, lack of time was deemed the greatest barrier, while the Oskarshamn industries ranked that barrier second and the Swedish foundries ranked it only eleventh. For the Swedish foundries, lack of capital was the largest barrier, while the Oskarshamn industries ranked this barrier ninth and the Highland SMEs ranked it third.

Among the studied Swedish foundries, technical risks, such as potential production disruption, were ranked second, while these were ranked only eleventh by the Highland SMEs. Other priorities were ranked second among the Highland SMEs and Oskarshamn industries, but only fifth by the Swedish foundries. The difficulty and cost of obtaining information about the energy use of purchased equipment was considered as the third greatest barrier by Oskarshamn industries, the fourth greatest barrier by the foundries, and seventh by the Highland SMEs.

After defining and categorizing these barriers, researchers can go on and discuss suggestions for overcoming them. If the major barrier is related to information, then other means will be needed to overcome it than if, for example, lack of capital is the major barrier. If information constitutes the major barrier, then more information about available energy efficiency measures could be a possible solution, and if lack of capital is a greater problem, government subsidies could be an alternative.

How we perceive and define these barriers will lead to different possible means of overcoming them and, ultimately, to different policy recommendations. As these definitions and categorizations are so crucial, it is essential to reflect on and problematize them further.

Table 3.2 Barriers identified in earlier studies of Swedish industry (based on Rohdin and Thollander 2006; Rohdin et al. 2007; Thollander et al. 2007)

	Oskarshamn companies	Swedish foundries	Swedish Highland SMEs
1	Cost of production disruption/inconvenience	Access to capital	Lack of time or other priorities
2	Lack of time or other priorities	Technical risks, such as potential production disruptions	Other capital investment priorities
3	Difficulty/cost of obtaining information on the energy use of purchased equipment	Lack of budget funding	Access to capital
4	Technical risks, such as potential production disruption	Difficulty/cost of obtaining information on the energy use of purchased equipment	Cost of production disruption/inconvenience
5	Other capital investment priorities	Other capital investment priorities	Lack of budget funding
6	Technology is inappropriate for the site	Possible poor performance of equipment	Lack of submetering
7	Lack of staff awareness	Lack of submetering	Difficulty/cost of obtaining information on the energy use of purchased equipment
8	Lack of technical skills	Poor information quality regarding energy efficiency opportunities	Lack of technical skills
9	Access to capital	Cost of identifying opportunities, analyzing cost-effectiveness, and tendering	Low priority given to energy management
10	Poor information quality regarding energy efficiency opportunities	Low priority given to energy management	Lack of staff awareness
11	Possible poor performance of equipment	Lack of time or other priorities	Technical risks, such as potential production disruption
12	Cost of identifying opportunities, analyzing cost-effectiveness, and tendering	Technology is inappropriate for the site	Slim organization

3.11 Barriers Not Fully Explaining the Existence of the “Energy Efficiency gap”

As noted above, the classifications of barriers are not unambiguous, as one real-world phenomenon may be explained by several theoretically derived barriers. Moreover, it should be noted that other barriers, for example, structural or institutional barriers to energy efficiency, do not directly affect the existence of the energy efficiency gap at site level, but nevertheless, if removed, contribute to improved energy efficiency. These barriers are categorized as structural or institutional barriers by Weber (1997), and are presented in the following part of this chapter.

3.11.1 Distortions in Energy Prices

Distortions in energy prices refer to the fact that the prices that consumers pay for fuels or other energy carriers do not fully reflect all the environmental and social costs associated with their production, energy conversion, transportation, and use. These so-called externalities are difficult to estimate, but energy prices would rise significantly if they reflected the full social costs of energy (Hirst and Brown 1990). For industrial organizations, higher energy prices would, in turn, lead to shorter pay-back periods for energy efficiency investments, and plausibly increase the chances of such investments being made.

3.11.2 Various Perspectives on Energy

Energy efficiency is only one of many pressing issues in global and national energy politics. Stern and Aronson (1984) present four views of energy that directly affect energy politics. First, energy is often seen as a commodity, or more accurately, a collection of commodities. Second, energy can be viewed as an ecological resource. A third major view of energy has become increasingly important in recent years: energy as a social necessity. According to this view, consumers have a right to receive energy. The fourth significant view of energy is that it constitutes a strategic material. In this view, the important properties of an energy source include its geographical location, the political stability and orientation of the countries where it is located, whether it is located in an unstable area and the availability of domestic or other reliable substitutes (Stern and Aronson 1984). As far as European energy politics are concerned, there is also a fifth view. The European Union started out as a coal and steel union granting subsidies to the coal and steel industries. The range of views on energy makes energy politics and efficiency intricate matters. Excessively emphasizing a perspective that downplays energy efficiency may lead to a lower priority on, for example, energy efficiency policies and programs.

3.11.3 Government Fiscal and Regulatory Policies

In Sweden, as in other countries, the government has generally provided greater support to the supply than the demand side of the energy system. In Sweden, this can be explained by the 1980 referendum decision to shut down Swedish nuclear power plants in the future and by R&D subsidies for new environmentally sound electricity generation, such as wind turbines and small-scale hydropower plants, while less funding has gone to the demand side to promote energy efficiency (Löfstedt 1993). Increased energy prices, however, could be assumed to increase the attention paid to energy efficiency issues, though, as stated previously, this is not always the case. A variety of government policies, practices, and programs implicitly affect decisions regarding the purchase and operation of energy-using equipment. The low level of government support for demand side measures does not only exist in Sweden. The American authors Hirst and Brown (1990) write: "Unfortunately, these government actions [i.e., supply-side measures] tend to favour increased energy use rather than greater energy efficiency" (Hirst and Brown 1990). In conclusion, lack of energy end-use policies may constitute an institutional barrier to the adoption of energy efficiency measures.

3.11.4 Supply Infrastructure Limitations

Another barrier concerns supply infrastructure limitations, where the availability of new energy-efficient technologies may be limited to particular geographic regions of the country (Hirst and Brown 1990). For example, in regions where district heating is available, it is often more energy efficient than, for example, heat pumps (Gebremedhin 2003), representing an illustrative example of where limitation in the energy supply infrastructure constitutes a barrier to energy efficiency, i.e., in areas where district heating does not exist, the technology can naturally not be adopted.

3.11.5 Codes and Standards

Codes and standards are generally viewed as instruments of change and not as barriers to it. Despite that, the process of setting and revising standards and codes is often slow, cumbersome, and dominated by special interests. Because codes and standards take a long time to adopt and modify, they sometimes specify obsolete technologies, thereby inhibiting innovation (Hirst and Brown 1990). One such example is the European CE (Conformité Européenne) standard for industrial equipment. For example, if a computer numerical control (CNC) machine is equipped with inefficient pneumatics, and the owner of the machine wants to replace the pneumatic devices with Direct Current (DC) motors, the CE standard no longer applies and, consequently, neither does the insurance on the machine.

3.11.6 Structure

Organizational flow-charts arguably represent an old-fashioned way of visualizing organizational structure. Moving away from this conceptualization has prompted the emergence of widely diverse organizational theories, ranging from metaphors of organizations operating like the nervous system (Beer 1981) to the mathematical modeling of firms (Forester 1965). An organization's structure clearly affects its energy efficiency (Cebon 1992). Although it is difficult to state categorically that structure can constitute a barrier to energy efficiency, organizational structure can clearly constrain the range of opportunities for improved efficiency (Sorrell et al. 2000). A study by Cebon (1992) of how organizational structure influenced energy efficiency at two universities found that a centralized university was more successful at implementing a complex building energy management system, while the decentralized university was more successful at installing simple technologies, such as compact fluorescent lighting, involving the active participation of users (Cebon 1992).

3.12 Promoting Energy Efficiency Through Energy Services

Energy services have been outlined as a promising tool to overcome barriers to energy efficiency (EC 2006). An energy service is based on a contractual arrangement which aims to measurably improve energy efficiency through,for example, auditing, maintenance, and financing energy efficiency investments. Companies that offer energy services through *energy performance contract* (EPC) are referred to as *energy service companies* (ESCOs), while companies that offer energy services which is not based on a fixed remuneration are referred to as *energy service providers* (ESP).

ESCOs mainly orient their businesses towards the support processes and thus seem to be suitable when it comes to overcoming barriers to energy efficiency in the nonenergy-intensive manufacturing industry and industrial SMEs.

However, while energy services are an important means to reduce barriers to energy efficiency, it has not been extensively studied (Thollander et al. 2010b). Also, traditional industrial energy efficiency research has emphasized technical matters—such as, for example, the energy efficiency potential from implementing specific technologies (Trygg and Karlsson 2005).

Table 3.3 shows findings from an analysis of energy services using barrier theory.

Apart from the outlined means in Table 3.3, concerning the industry and the ESCO, one may also consider promoting energy services activity by adopting public policy instruments such as risk-free state loans. Such a policy would considerably reduce the risk to both parties from entering into a business agreement. The risk barrier may also need market guidelines and principles to be set up by the government, for example, standardized guidelines for how agreements should be set up. Such guideline would also contribute to lower the hidden cost and credibility and trust barriers and possibly also imperfect and asymmetric information barriers, as both parties would be fully informed of how an agreement should be formulated. Moreover, it is suggested that the National Energy Agencies sets up a separate homepage regarding energy services in industry presenting, among other

Table 3.3 Implications for designing energy services based on the barrier theory (Thollander et al. 2010b)

Perspective	Barrier	Implication for energy services
Economic	Heterogeneity	This barrier may be effectively avoided by having successfully adopted cases to rely upon and skilled ESCO staff
	Hidden costs	Having an ESCO involved in the initial phase of an energy efficiency investment may greatly reduce hidden costs as the ESCO staff are specialists in their field and know where to find information etc
	Access to capital	An ESCO providing third-party financing enables this barrier to be fully eliminated
	Risk	The industry's risk may be considerably reduced by having "specialists" involved, which greatly enhances the investment's stability. The industry's risk of entering into a business agreement with the ESCO and vice versa, however, is not as easily reduced, calling for a complex agreement to be set up which ,in turn, may increase the magnitude of the hidden cost barriers
	Imperfect information	Service opportunities exist where the information for customers/users is imperfect. Providing information of energy use for economically efficient decisions may contribute to service provision. Keeping information on how to increase energy efficiency within a provider may turn out to be a source of services
	Asymmetric information	Building up an agent responsible for both costs and benefits may be a key to introduce energy efficient solutions (split incentives)
		Visualizing and guaranteeing quality of products/services may lead to purchase of better solutions (adverse selection)
		Transferring (and/or translating) the information at the agent level up to the principal level may be effective (Principal-agent relationships)
Behavioral	Bounded rationality	Routines and everyday activities do not support energy efficiency. Establish routines that contribute to "right" decisions being embedded in everyday practices
	Form of information	Different regimes within a company need different kinds of information and information packages that relate to their needs and demands.
	Credibility and trust	The industry's perception of ESCOs needs to be strong as regards their credibility and trust if an energy service is to be carried out
	Values and Inertia	Different value systems can exist in a company. Promote and support value systems that benefit energy efficiency.
Organzation theory	Power	Identify different power arenas in a company to know where to target different kinds of information and measures
	Culture	Embedded knowledge and routines need to be identified to initiate reflection on how to change and improve them

things, successful examples of energy service adoption in industry. A homepage regarding energy services in industry would enable a reduction in magnitude of basically all barriers to energy efficiency in industry outlined in Table 3.3.

Applying an interdisciplinary approach to the adoption of energy services is a unique research approach, and Thollander et al. (2010b) emphasizes that one of the main reasons for the considerable discrepancy between the potential for energy services in industry and their adoption is the existence of various socio-technical regimes in organizations. Moreover, the Thollander et al. (2010b) shows that the ESCO-market would benefit from leaving traditional regimes and moving into nontraditional ones. If the suggested improvements stressed in Table 3.3 were to be successfully adopted, this would lead to improved energy efficiency in industrial SMEs, strengthen the ESCO businesses, contribute to lower manufacturing costs, and increase the industries' competitiveness. From earlier research, knowledge exists of *which* barriers that exists, but the understanding of *how and why* barriers appear in a company needs thus to be deepened. By including an empirical analysis of socio-technical regimes and their negotiations and power relations, future research can contribute to the understanding of the existence of barriers and how they can be resolved. This calls for future empirical studies on the subject involving both ESCOs and manufacturing industry. Chapters 4 and 5 further elaborate the concept of socio-technical regimes.

3.13 Conclusions

It is widely recognized that finding ways to narrow the energy efficiency gap is vital if we are to solve the climate change problem. Defining and analyzing the identified barriers to narrowing this gap are important steps toward finding solutions to this problem. It is equally important to constantly redefine the empirical definitions of the barriers to improving existing solutions and to develop new, creative ways of addressing the efficiency gap.

In this chapter, we have reviewed earlier research into the energy efficiency gap and into the barriers to addressing it; the lessons learned from this are as follows:

- The concept of the energy efficiency gap is based on the assumption that, while there are technologies, methods, and processes that may reduce energy use in an industry, barriers hinder their implementation.
- The hypothetical potential to improve energy efficiency is great if we eliminate market failures and include environmental externalities in our calculations.
- To explain this gap, various barriers to energy efficiency have been identified.
- Defining and categorizing these barriers offer a way to address the energy efficiency gap
- Barriers can be classified in various ways; we presented Sorrell et al.'s (2000) often-cited categorization, in which barriers were divided into market failure, nonmarket failure, behavioral, and organizational categories
- Research into barriers is often empirically based
- The means of categorizing barriers differs among studies

- It is important to reflect on how barriers to energy efficiency are categorized and why
- There are two major research designs: case studies and surveys
- Other, structural barriers, unrelated to the site level, must also be considered
- Improving energy efficiency through energy services is a promising, but not yet fully exploited measure in industry
- The barrier theory can contribute to an enhanced understanding of how to increase the adoption of energy services in industry

In the next two chapters, we will discuss social science perspectives on technological development and link those to a discussion of how these theories can advance our understanding of barriers to energy efficiency. The research tradition in which industrial barriers are discussed and the concept developed has been problematized by sociologist Elisabeth Shove:

> Technical change is a one-way process of technology transfer, and … social obstacles or nontechnical barriers impede technological progress. What is missing is an appreciation of the social contexts of energy saving action and of the socially situated character of technical knowledge. (Shove 1998, p. 1108)

In the next chapter, we will follow up on this and introduce theories that link the social context to technological development. Then, in Chap. 5, we review the barriers and relate them to earlier social science research, to see what lessons can be learned.

References

Bertoldi P, Rezessy S, Bürer MJ (2005) Will emission trading promote end-use energy efficiency and renewable energy projects? In: Proceedings of the 2005 ACEEE summer study on energy efficiency in industry “Cutting High Costs of Energy”, vol 4. American Council for an Energy-Efficient Economy, pp 1–12

Beer S (1981) Brain of the firm: the managerial cybernetics of organization. Wiley, Chichester

Blumstein C, Krieg B, Schipper L, York CM (1980) Overcoming social and institutional barriers to energy conservation. Energy 5:355–371

Brown MA (2001) Market failures and barriers as a basis for clean energy policies. Energy Policy 29:1197–1207

Bryman A (2001) Social research methods. Oxford University Press, Oxford

Cebon PB (1992) Twixt cup and lip: organizational behavior, technical prediction and conservation practice. Energy Policy 20(9):802–814

de Groot H, Verhoef E, Nijkamp P (2001) Energy saving by firms: decision-making, barriers and policies. Energy Econ 23:717–740

DeCanio S (1993) Barriers within firms to energy efficient investments. Energy Policy 9:906–914

EC (European Commission) (2006) Communication from the commission. Action plan for energy efficiency: realizing the potential. COM, 545 final

Fleiter T, Worrell E, Eichhammer W (2011) Barriers to energy efficiency in industrial bottom-up energy demand models—a review. Renew Sustain Energy Rev 15:3099–3111

Forester JW (1965) Industrial dynamics. MIT Press, Cambridge

Gebremedhin A (2003) Regional and industrial co-operation in district heating systems. Linköping studies in science and technology, Dissertation No. 849, Division of Energy Systems, Linköping University, Linköping

Gruber E, Brand M (1991) Promoting energy conservation in small and medium-sized companies. Energy Policy 19:279–287

Hasanbeigi A, Menke C, du Pont P (2010) Barriers to energy efficiency improvement and decision-making behavior in Thai industry. Energy Effic 3:33–52

Hein L, Blok K (1995) Transaction costs of energy efficiency improvement. In: Proceedings of the 1995 ECEEE summer study, Panel 2:1–8

Hirst E, Brown MA (1990) Closing the efficiency gap: barriers to the efficient use of energy. Resour Conserv Recycl 3:267–281

Jaffe AB, Stavins RN (1994) The energy-efficiency gap: what does it mean? Energy Policy 22:60–71

Johansson P-E, Thollander P, Moshfegh B (2011) Towards increased energy efficiency in industry: a manager's perspective. In: Proceedings of the World Renewable Energy Congress 2011, Linköping

Löfstedt RE (1993) Hard habits to break: energy conservation patterns in Sweden. Environment (35):11–15, 33–36

Ostertag K (1999) Transaction costs of raising energy efficiency. In: Proceedings of the 2007 IEA international workshop on technologies to reduce greenhouse gas emissions: engineering-economic analyses of conserved energy and carbon

Palm J, Thollander P (2010) An interdisciplinary perspective on industrial energy efficiency. Appl Energy 87:3255–3261. doi:10.1016/j.apenergy.2010.04.019

Ramirez CA, Patel M, Blok K (2005) The non-energy intensive manufacturing sector. An energy analysis relating to the Netherlands. Energy 30:749–767

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

Rohdin P, Thollander P, Solding P (2007) Barriers to and drivers for energy efficiency in the Swedish foundry industry. Energy Pol 35:672–677

Sanstad A, Howarth R (1994) 'Normal' markets, market imperfectionmarket imperfections and energy efficiency. Energy Policy 22:811–818

Sardianou E (2008) Barriers to industrial energy efficiency investments in Greece. J Clean Prod 16:1416–1423

Schleich J (2004) Do energy audit help reduce barriers to energy efficiency? An empirical analysis for Germany. Int J Energy Technol Policy 2:226–239

Schleich J, Gruber E (2008) Beyond case studies: barriers to energy efficiency in commerce and the services sector. Energy Econ 30:449–464

Shove E (1998) Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. Energy Policy 26:1105–1112

Simon HA (1957) Models of man. Wiley, London

Sorrell S, Schleich J, Scott S, O'Malley E, Trace F, Boede E, Ostertag K, Radgen P (2000) Reducing barriers to energy efficiency in public and private organizations, SPRU's (Science and Technology Policy Research). http://www.sussex.ac.uk/Units/spru/publications/reports/barriers/final.html. Accessed 8 Oct 2007

Sorrell S, O'Malley E, Schleich J, Scott S (2004) The economics of energy efficiency: barriers to cost-effective investment. Edward Elgar, Cheltenham

Stern PC (1992) What psychology knows about energy conservation. Am Psychol 47:1224–1232

Stern PC, Aronson E (eds) (1984) Energy use: the human dimension. Freeman, New York

Sutherland RJ (1996) The economics of energy conservation policy. Energy Policy 24(4): 361–370

Thollander P, Danestig M, Rohdin P (2007) Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Policy 35:5774–5783

Thollander P, Ottosson M (2010) Energy management practices in Swedish energy-intensive industries. J Clean Prod 18(12):1125–1133

Thollander P, Palm J, Rohdin P (2010a) Categorizing barriers to energy efficiency: an interdisciplinary perspective. In: Palm J (ed) Energy efficiency, Sciyo, Croatia. Available at http://www.intechopen.com/books/show/title/energy-efficiency

Thollander P, Palm J, Sakao T (2010b) Energy services in industry—an interdisciplinary approach with engineering- and social science aspects. In: Proceedings of the IPS2 conference, pp 51–56

Trianni A, Cagno E (2011) Dealing with barriers to energy efficiency and SMEs: some empirical evidences. Energy 37(1):494–504

Trygg L, Karlsson B (2005) Industrial DSM in a deregulated European electricity market: a case study of 11 plants in Sweden. Energy Policy 33:1445–1459

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

Yin RK (2003) Case study research: design and method. In: Applied social research methods, 5th edn. Sage, London

York CM, Blumstein C, Krieg B, Schipper L (1978) Bibliography in institutional barriers to energy conservation. Lawrence Berkeley Laboratory and University of California, Berkeley

Chapter 4
Sociotechnical Perspectives on Technological Development

Abstract In this chapter, we introduce sociotechnical perspectives on innovation processes and decision making in organizations in relation to their constituent institutions and communities of practice (CoP). We discuss how an energy system can be seen as a sociotechnical system in which technological and social factors are mutually dependent, coexisting in a seamless web. New ideas that develop and change the system can be treated as innovation processes. In this chapter, we pay special attention to the multi-level model of innovation that seeks to explain transition in sociotechnical systems. To fully understand change in sociotechnical systems, we also introduce institutional theory, which examines the formal and informal rules that influence actors and organizations and are vital parts of a system. We end this chapter by discussing communities of practice theory, which acknowledges that actors act and make decisions in particular contexts, influenced by values and norms established in groups—something also central to the multi-level model.

4.1 Introduction

The aim of this book as a whole is to enhance our understanding of industrial energy efficiency. We do that by combining engineering and social science research approaches. Chapter 3 discussed earlier research into barriers to industrial energy efficiency. In this chapter, we will broaden the barrier perspective by introducing sociotechnical perspectives on innovation processes and decision making in organizations in relation to their constituent institutions and communities of practice.

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4.2 Energy as Sociotechnical Systems

The social sciences have developed an understanding of processes of social and technical change. From the perspective of science and technology studies (STS), energy systems constitute sociotechnical systems. How a system develops depends not only on its technology, but also on its surroundings, including regulations, organizations, and individuals, in which it develop. From a sociotechnical perspective, a sociotechnical system involves a seamless web of mutual dependency between the technology and its surroundings. The technology and its surroundings are so closely intertwined that distinguishing between them is often meaningless, as one cannot study one part without considering the other. The surroundings consist of social, financial, institutional, environmental, and cultural factors and, just as these factors influence the design of the system, so the system influences these factors, directly or indirectly (Hughes 1983, 1986).

The term "sociotechnical" indicates that both the material and social/human parts of a system are central concerns. As such, "sociotechnical" encompasses technical components, individual actors and organizations, legal frameworks, and institutional and political structures.

The process of bringing new ideas or solutions into a sociotechnical system can be described as one of innovation. "Innovation", which refers to renewal or change, generally manifests itself as better or more effective products, processes, technologies, or ideas that are accepted by the market or society.

Innovation processes can be seen as resulting from the interaction between a multitude of actors, distributed over many institutions and locations (Rohracher 2008). Rohracher (2008) notes that innovation processes are becoming more complex and transformation processes more difficult to co-ordinate and govern. There exist, however, "conceptual lenses" that can help us understand and analyze these sociotechnical changes. One such lens entails using an innovation process perspective, which in the 1980s started to interest researchers in the STS field.

4.3 Innovation Processes

In the 1960 and 1970s, most research into innovation treated it as a linear process leading from knowledge to the relatively unproblematic diffusion phase (Aune 2001). An early example of research treating innovation as a nonlinear process is Hägerstrand's (1953) classic thesis. Hägerstrand, however, was an exception, and how end-users adopted new technology was generally not studied. In the 1980s, STS researchers began to take an interest in the innovation process, and started to question this linear approach. They believed that the adoption of new technology was a complex process, and accordingly applied a non-deterministic view of the innovation process. Several slightly different models were developed, the best known of which in relation to innovation are: the social construction of technology

(SCOT), translation, and script models (Pinch and Bijker1987; Latour 1987; Law 1992; Akrich 1992).

The SCOT model puts users at the center of the analysis, and it emphasizes that users play a key role in the innovation process. Successful innovation depends on acceptance from the "relevant social group" that is powerful enough to arrive at "closure", i.e., acceptance of the basic idea of a product. From this perspective, the meaning of a product is negotiated throughout the process, even during the adoption phase. Product development can head in various directions even after the product leaves the design table (Pinch and Bijker 1987). SCOT emphasizes that innovations develop through negotiations between people and technology until satisfactory solutions are attained. Latour (1987) has also emphasized that a support network must be created if an innovation is to be successful. Innovators need support from others, not only to invent new ideas, but also to market them and seek user acceptance. In the 1990s, Akrich (1992) focused on designs as "scripts", by which she meant that innovators try, by means of a product's design, to compel users to use a product in a particular way. Designers try to reduce the available alternatives and make users use a product in the way they had in mind when they designed it. These theories have contributed to our understanding that technology is developed and implemented in a social context, and that we must also understand this context to understand the design and development of technical systems.

It was in this context that the multi-level model of innovation was developed. This model, which enables the researcher to understand and explain transition in sociotechnical systems, will be examined in greater detail in the next section.

4.4 Transition from Multi-Level Perspective

In the 1990s, the multi-level model of innovation was developed for analyzing the stability and dynamics of transitions and historic shifts between dominant modes of the organization and the direction of the sociotechnical systems (Rip and Kemp 1998; Geels 2004). The multi-level model is based on an understanding of the various temporal dimensions of change, ranging from short-term processes at the micro level to long-term changes at the macro level of the sociotechnical landscape (Rohracher 2008).

Innovations—or "radical novelties", as they are called in this theory—are developed in special local orders, "technological niches", where they are sheltered from mainstream competition (Schot and Geels 2008). These could be small market niches or technological niches, where resources are provided by public subsidies. Small networks of actors protect these niches, so social networks are vital when initiating technological innovation. Niches need protection because new technologies initially have a low price/performance ratio (Verbong and Geels 2007). Niches form the micro level (see Fig. 4.1) from which radical novelties emerge. The meso level is the regime level, including routines, knowledge,

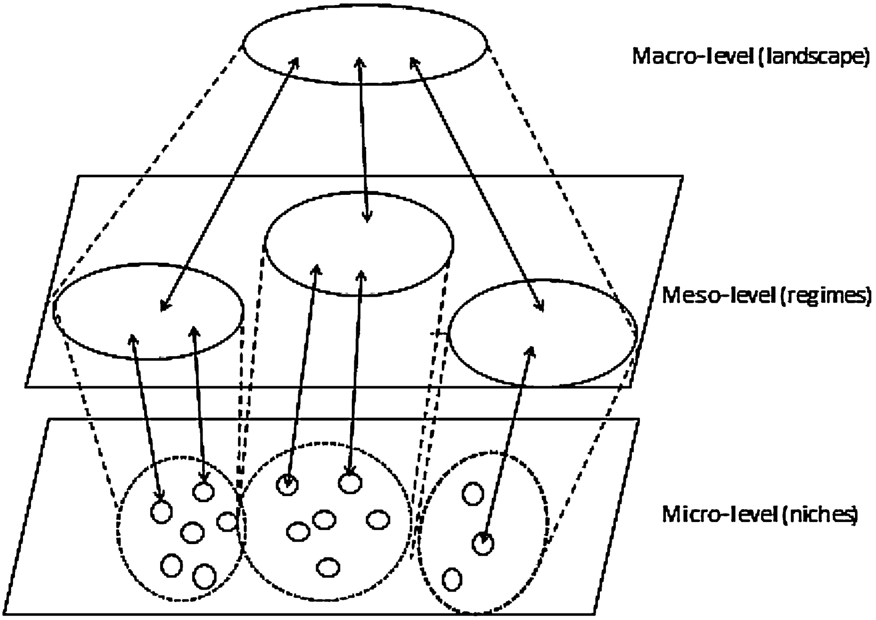

Fig. 4.1 A multi-level model of innovation (Rohracher 2008)

defining problems, etc., embedded in institutions and infrastructures (see section below). The macro level is that of the sociotechnical landscape, which is the level of the environment that changes most slowly, for example, as defined by environmental policy or regulations (Geels and Kemp 2007).

Verbong and Geels (2007) describe the relationship between these three levels, i.e., niches, regimes, and landscape, as constituting a "nested hierarchy". New technologies have problems breaking through because established regimes become so deep-rooted.

4.4.1 Sociotechnical Regimes

Geels (2004) has developed Nelson and Winter's (1982) concept of "technological regime". This term, as originally proposed, refers to the cognitive routines that are shared in a community of engineers and that guide their R&D (Research and development) activities. A technological regime is the rule-set embedded in "engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and people, ways of defining problems; all of them embedded in institutions and infrastructures" (Geels and Kemp 2007, p. 443). This definition is in line with what we discussed in Chap. 3. The concept emphasizes that engineers act in particular social contexts in their organizations, and that the social context can develop differently in the various divisions of a company. In the multi-level perspective, “technological regime” has been broadened into the concept of “sociotechnical regime”. A sociotechnical regime is characterized by the set of rules that guides technical design, as well as the rules that shape market development, rules such as user preferences, and the rules regulating the market (Schot and Geels 2007). The broader sociotechnical regime concept includes interaction with other social groups in society, such as users, policy makers, and social groups, acting together with engineers and firms. The entire surroundings of a given social structure, including applicable regulations and norms, are included. Sociotechnical regimes refer not only to cognitive routines and belief systems in a company or sector, but also to regulative and normative roles. From this perspective, regimes are relatively autonomous, though they can also be interdependent. A sociotechnical regime thus binds together, for example, producers, users, and regulators, who constantly negotiate in networks regarding, for example, new ideas or possible development paths.

The sociotechnical regime concept highlights the fact that actors are embedded in structures that shape their preferences, aims, and strategies. From this perspective, actors also have agency, i.e., have an ability to perform conscious and strategic actions. The model confirms Giddens’ (1979, 1984) concept of the duality of structure, according to which structure can both produce and mediate action. Actors can thus both act upon and restructure these rule systems; regimes can then implement and (re)produce their constituent rules in social activities that take place in local practices. By implementing shared rule systems, the regime actors generate patterns of activity that are similar in various local practices. There may be variation between local practices due to the existence of differences between group members, whose regimes can give rise to somewhat different strategies, resources, problems, and aims. Strategies, aims, etc. are reasonably flexible within a regime, and can change incrementally over time (Geels 2004). In addition, incremental innovations still occur in stable regimes and are important because they can accumulate, resulting in major performance improvements (Geels and Kemp 2007).

A dominant regime can be forced to restructure and invest in new technical directions. For example, changes in the sociotechnical landscape can exert pressure on the regime. Climate change, for example, has forced the energy, industry, and transport sectors to devise new technical strategies. Internal technical problems, changes in user preferences, and negative externalities such as health risks may also trigger action. Competition between firms is another activity that can open up a regime (Geels 2004).

A sociotechnical regime captures the temporal stability of a sociotechnical system; it incorporates the reinforcing technological and institutional structures of specific domains and is characterized by resistance to change (Rohracher 2008). The activities within a regime are coordinated via various rules, both at a regulative level and by means of cognitive and normative rule sets (Geels 2004; Rohracher 2008).

We must understand formal and informal rules if we wish to grasp why actors act in particular ways in particular local orders. Accordingly, we will turn to institutional theory to see how it treats the rules that develop in all organizations.

4.5 Institutions as a Theoretical Concept

Institutions can be both formal (e.g., rules and laws) and informal (e.g., conventions and behavioral norms, such as routines and roles). Institutions make interaction between people possible, but also restrict or constrain how a person can act in a given situation. Informal institutions, for example, are part of an organizational culture or organizational identity.

New institutionalism, or neoinstitutionalism, has developed a sociological view of institutions. Of interest is how institutions interact and how they affect society. New institutionalism considers why so many companies have the same organizational structure, even though they have evolved in different ways, and how institutions shape the behavior of their constituent members.

March and Olsen (1989) believe that there are three basic assumptions conditioning how institutionalism comprehends institutional influence on organizations.

First, peoples' actions are governed by experience-based decision rules. Institutional identity and standard procedures determine what is seen as acceptable behavior, i.e., one acts in a way that is accepted and reasonable (March and Olsen 1995). At the same time, however, "some of the major capabilities of modern institutions come from their effectiveness in substituting rule-bound behavior for individually autonomous behavior" (March and Olsen 1989, p. 24).

The second assumption concerns how institutions influence individual modes of thought. "Institutions are collections of interrelated rules and routines that define appropriate actions in terms of relationships between roles and situations. The process involves determining what the situation is, what role is being fulfilled, and what the obligations of that role in that situation are" (March and Olsen 1989, p. 160). This means, for example, that goals are not exogenously given, but can be discovered during a decision or innovation process.

The third assumption of new institutionalism concerns the historical ineffectiveness of institutions. This means that institutions have a certain degree of autonomy or inertia and cannot be changed easily or quickly. "Extensive adjustment periods may be required (and tolerated) during which diverse, conflicting, and inefficient solutions survive. Institutions develop a character that discourages arbitrary structural changes, and sometimes they change their environments rather than adapt to them" (March and Olsen 1989, p. 55).

Institutions are socially constructed and are shaped by us (Brunsson 1998). Institutions are a set of imaginations and ideas that we share with other people; in that way, they both create conditions for and set restrictions on our actions and interactions. These imaginations are not inherent phenomena, but are developed by people, differing between cultures and changing over time. Imaginations and ideas usually arise in complex, social historical processes and are not shaped by individuals (Brunsson and Hägg 1992).

Although individuals might try to behave rationally, they are not always aware of all the alternatives on the market. They may be unable to collect and process all the relevant information (March 1994), so they focus on a smaller number of alternatives and consequences while ignoring others (see also Chap. 3 and the discussion of bounded rationality). They construct simplified "frames" that help them delineate the situation and come to decisions. Rationality is limited and framing is a device or technique used to simplify reality when one is confronted with complex choices (Simon 1957). The goal is often to achieve a result that is satisfactory, rather than to calculate the expected results and risks and thereafter make the most rational and optimal choice (March 1994).

An institutional perspective lets us see actors as agents who influence and contribute to their surroundings (i.e., actors have agency). Even if institutional theory emphasizes the social context in which actors act (i.e., the context and existing structure), it also recognizes actors' initiative and entrepreneurship.

To explain why actors act in certain ways, we must understand the informal networks that are established in all companies. Actors act and make decisions in certain contexts in which they consciously or unconsciously are influenced by the values and norms established in groups. This is the focus of the literature on the existence of "communities of practice" in companies and their branches.

4.6 Communities of Practice

According to Wenger (1998), an organization is a social construct consisting of various constellations, or communities, of practice. A community of practice (CoP) is a set of people who "share a concern, a set of problems, or a passion about a topic, who deepen their knowledge and expertise in this area by interacting on an ongoing basis" (Wenger et al. 2002, p. 4). It is an informal grouping that is defined by its members and by the shared manner in which they do things (Lave and Wenger 1991; Retna and Ng 2011). Wenger identified certain characteristics of a CoP, which have been compiled by Ash and Roberts (2008):

- sustained mutual relationships—harmonious or conflictual
- shared ways of doing things together
- rapid flow of information and propagation of innovation
- absence of introductory preambles, although conversations and interactions represent continuations of ongoing processes
- very quick setup of problems to be discussed
- substantial overlap in participants' descriptions of who belongs
- members know what others know, what they can do, and how they can contribute to an enterprise
- mutually defining identities

- ability to assess the appropriateness of actions and products
- specific tools, representations, and other artifacts
- local lore, shared stories, inside jokes, and knowing laughter
- jargon and shortcuts to communication as well as ease of producing new ones
- certain styles recognized as signifying membership
- shared discourse reflecting a certain perspective on the world.

CoPs create their own boundaries, which may be—but are not necessarily—the same as the related institutional boundaries. A CoP includes elements such as language, tools, documents, symbols, well-defined roles, and regulations, all of which may be visible; equally important, however, are unspoken norms, embedded understandings, tacit agreements, etc. (Palm and Törnqvist 2008).

Underlying the CoP concept is the recognition that people in the workplace learn not only from formal organized activities, but also through their everyday activities and experience. An employee acquires the most useful know-how from day-to-day activities and by watching and talking with other employees. For most people, learning is a process that usually occurs among and through other people. Knowledge is created and transformed through networks of human interaction (Retna and Ng 2011). In organizations, knowledge transfer through one unit is affected by the experience of another unit (e.g., group, department, and division) (Argote and Ingram 2000). The CoP concept helps us understand the process by which tacit knowledge and knowledge-in-action are transmitted, by stressing the social aspect of this process (Retna and Ng 2011). (The cognitive process is also considered, but we will ignore that perspective here). From this perspective, new learning and knowledge are located in CoPs (Tennant 1997). In a CoP, knowledge is collectively sustained by the members and is embedded in the culture of the community. It is a product of history and is stored in a set of unspoken and more-or-less unconscious principles. To become a member of a CoP, one needs to absorb this unspoken knowledge and learn the informal procedures, such as who are who, what they do, how they live, and their everyday activities. In CoPs, myths, stories, and metaphors are powerful means of preserving sets of meanings. From this perspective, knowledge, activities, and social relationships are interrelated. When interacting with each other, members of a CoP hear and exchange useful tips and anecdotes that they cannot find in an archive, for example (Retna and Ng 2011, p. 43).

In CoPs, people learn and develop their skills by practicing their craft and exchanging ideas about it.

CoPs can be related to the multi-level model's concept of regimes. The sociotechnical regime concept, as described above, implies the existence of various regimes and of connections and mutual dependency between them. In an industrial company, for example, "communities" can be distinguished by their particular features. Actors in any one such group thus share a set of rules or a regime. Because different groups share different rules, one can distinguish various regimes, such as technological regimes, science regimes, financial regimes, and R&D regimes. Those regimes are divided and do not influence each other's work can be both functional and needed. For example, a dominant production regime might have zero defects in production as an overall goal. If it tries to dominate an R&D regime, the result could be devastating, and lead to trial and error not being allowed to confirm or falsify new ideas. This would in turn not favor radical innovation, and business as usual would be a dominant value. As will be discussed in Chap. 6, different regimes also call for different management strategies.

Each regime shares aims, values, problem agendas, professional journals, etc. Rules are linked not just within regimes, but also between them, and regimes influence each other, which is why sociotechnical regime is a better concept to explain these interrelations (cf. Geels 2004).

4.7 Conclusions

In this chapter, we have noted that how energy systems work in a company depends on both the technology and its surroundings. There is mutual dependency between technology and, for example, social, financial, institutional, and cultural factors. When innovations or new ideas are introduced into a system, this does not occur via a linear process; instead, designs and goals can change throughout the process, including in the user phase. When introducing energy efficiency, it is important to consider the financial as well as the cultural aspects of the organization, which is in line with a barrier perspective. Maintaining a holistic view is also essential, to realize that a barrier can change in importance and meaning in relation to other barriers or how processes are designed.

The multi-level model sheds light on the fact that sociotechnical systems change in response to both long-term changes in the landscape and short-term micro-level processes. The sociotechnical regime concept emphasizes that engineers act in a social network, where informal institutions such as routines and norms must be considered when seeking to understand an outcome, for example, why energy efficiency measures are or are not implemented. Institutional theory can help us understand why an actor may seem to be acting irrationally: the behavior may seem rational to the individual in relation to, for example, the way he or she has always done things. Most daily tasks in organizations are performed in accordance with routines and tacit knowledge established over long periods.

Tacit knowledge and the exchange of routines, values, and norms are also central to the CoP concept. CoPs are informal combinations in which members share ideas regarding how to do things and share a discourse, reflecting a certain perspective on phenomena. When seeking to understand energy efficiency in industry, we must consider the sociotechnical character of the systems in question, the needs and dependency of the constituent institutions of the organization, and the existence of sociotechnical regimes and CoPs—all of which determine what measures can and cannot be implemented successfully. When studying barriers to energy efficiency, it is important to reflect on what actor, belonging to what CoP, has actually answered the questions in a survey or interview: a financial manager might well have perceptions, knowledge, values, etc. that differ from those of an energy manager.

When continuing to discuss and analyze barriers to industrial energy efficiency, we will draw on certain concepts and perspectives from this chapter:

- decisions are not made in a vacuum
- decisions are made by actors embedded in structures
- the sociotechnical regime concept emphasizes that decisions are made in particular contexts and are influenced by regulative rules, normative rules, cognitive routines, and belief systems
- by adding elements of CoP theory to the sociotechnical regime concept, we learn that people who share a concern or set of problems deepen their knowledge by ongoing interaction and by the shared way they do things; they also share a certain codified language reflecting a certain perspective on the world
- actors in sociotechnical regimes learn not only from formal organized activities, but also through their everyday activities and experiences.

In the next chapter we discuss the barriers identified in earlier research, contextualizing these by introducing a sociotechnical approach. We also compare earlier research on barriers to energy efficiency in industry by findings in research concerning other practices.

References

Akrich M (1992) The de-scription of technical objects. In: Bijker WE, Law J (eds) Shaping technology/building society. MIT Press, Cambridge

Argote L, Ingram P (2000) Knowledge transfer: a basis for competitive advantage in firms. Organ Behav Hum Decis Proces 82:150–169

Ash A, Roberts J (2008) Knowing in action: beyond communities of practice. Res Policy 37:3 53–369

Aune M (2001) Energy technology and everyday life: the domestication of Ebox in Norwegian households. Paper presented at ECEEE 2001

Brunsson N, Hägg I (1992) Marknadens makt. SNS Förlag, Stockholm

Brunsson N (1998) Politisering och företagisering: institutionell förankring och förvirring i organisationernas värld. In: Lind R, Arvidsson G (eds) Ledning av företag och förvaltningar. SNS Förlag, Stockholm

Geels F (2004) From Sectoral systems of innovation to sociotechnical systems. Insights about dynamics and change from sociology and institutional theory. Res Policy 33:897–920

Geels F, Kemp R (2007) Dynamics in sociotechnical systems: typology of change processes and contrasting case studies. Technol Soc 29:441–455

Giddens A (1979) Central problems in social theory action, structure and contradiction in social analysis. Macmillan, London

Giddens A (1984) The constitution of society. outline of the theory of structuration. Polity publisher, Cambridge

Hughes TP (1983) Networks of power: electrification in western society 1880–1930. Johns Hopkins University Press, Baltimore

Hughes TP (1986) The seamless web: technology, science, etcetera, etcetera. Soc Stud Sci 16:281–292

Hägerstrand T (1953) Innovationsförloppet ur korologisk synpunkt. Lund University, Dissertation

Latour B (1987) Science in action: how to follow scientists and engineers through society. Open University Press, Milton Keynes

Lave J, Wenger E (1991) Situated learning: legitimate peripheral participation. Cambridge University Press, Cambridge

Law J (1992) Notes on the theory of the actor network: ordering, strategy and heterogeneity', published by the Center for Science Studies, Lancaster University. http://www.comp.lancs.ac.uk/sociology/papers/Law-Notes-on-ANT.pdf. Accessed 11 Nov 2011

March JG (1994) A primer on decision making: how decisions happen. The Free Press, New York

March JG, Olsen JP (1989) Rediscovering institutions: the organizational basis of politics. Free Press, New York

March JG, Olsen JP (1995) Democratic governance. The Free Press, New York

Nelson RR, Winter S (1982) An evolutionary theory of economic change. The Belknap Press of Harvard University Press, Cambridge

Palm J, Törnqvist E (2008) Governing the sea rescue service in Sweden: communicating in networks. J Risk Res 11:269–280

Pinch TJ, Bijker WE (1987) The social construction of facts and artifacts: or how the sociology of science and the sociology of technology might benefit each other. In: Bijker WE, Hughes TP, Pinch TJ (eds) The social construction of technological systems, MIT Press, Cambridge

Retna K, Ng P (2011) Communities of practice: dynamics and success factors. Leadersh & Organ Dev J 32:41–59

Rip A, Kemp R (1998) Technological change. In: Rayner S, Malone EL (eds) Human choice and climate change: resources and technology, Batelle Press, Columbus, Ohio

Rohracher R (2008) Energy systems in transition: contributions from social sciences. Int J Environ Technol Manag 9:144–161

Schot J, Geels F (2007) Niches in evolutionary theories of technical change. A critical survey of the literature. J Evol Econ 17:605–622

Schot J, Geels F (2008) Strategic niche management and sustainable innovation journeys: theory, findings, research agenda and policy. Technol Anal Strateg Manag 20:537–554

Simon H (1957) A behavioral model of rational choice, in models of man, social and rational: mathematical essays on rational human behavior in a social setting. Wiley, New York

Tennant M (1997) Psychology and adult learning. Routledge, London

Verbong G, Geels F (2007) The ongoing energy transition: lessons from a sociotechnical multi-level analysis of the Dutch electricity system (1960–2004). Energy Policy 35:1025–1037

Wenger E (1998) Communities of practice. learning, meaning, and identity. Cambridge University Press, Cambridge

Wenger E, McDermott R, Snyder WM (2002) Cultivating communities of practice: a guide to managing knowledge. Harvard Business School Press, Boston

Chapter 5
Barriers to Energy Efficiency from a Sociotechnical Perspective

Abstract In this chapter, we discuss how barrier theory can be developed, by introducing a multi-level perspective focusing on the social context in which decisions are embedded and taking account of the values and traditions established within, for example, sociotechnical regimes. We also discuss how lessons learned regarding energy use in practices other than industry can build our understanding of the barriers to and enablers of energy efficiency. We reexamine the barriers introduced in “Barriers to Energy Efficiency: Theoretical Baseline, Previous Research, and Methodological Approaches” and discuss them in relation to social science theoretical perspectives. Throughout the book, we emphasize that it is important to approach barriers from new perspectives, to arrive at new understandings or questions as to why a particular barrier is perceived as important in a company. We conclude this chapter by presenting a new way of classifying barriers and considering the impact this might have on our approach to the energy efficiency gap.

5.1 Introduction

In Chap. 3, we learned about the identified barriers to energy efficiency in industry. In this chapter, we will discuss how the barrier theory can be developed by introducing a multi-level perspective that focuses on the social context in which decisions are embedded and taking account of the importance of values and traditions established within, for example, sociotechnical regimes. We will also discuss how lessons learned regarding energy use in practices other than industry can build our understanding of barriers to and enablers of energy efficiency in small and medium enterprises. To examine barriers in relation to other theoretical perspectives, however, we will need to arrange the barriers in a new way. We start by discussing information and end by considering the power barrier.

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5.2 Information: Imperfect and Asymmetric Information, Adverse Selection, Form of Information, Credibility, Trust

The first barrier mentioned in Chap. 3 was *imperfect information*, i.e., that people in general are poorly informed about available energy-efficient technologies. Another information barrier arises when the information provider is not completely transparent about the product provided. In the *adverse selection* barrier, producers of energy-efficient technologies are, of course, better informed about the technologies they offer than are potential buyers. In discussing the *form of information* barrier, we said that information should be specific, vivid, simple, and personal to increase its chances of being accepted. *Credibility and trust* refer to the fact that information source must be considered credible and trustworthy by the receiver if the source is to successfully deliver information on cost-effective energy efficiency technologies.

Examining these four barriers gives rise to a special understanding of knowledge and information. We have a sender who gives information to a receiver and the premise of the exchange is that the receiver understands the information in the same manner as does the sender. This sender–receiver model, however, has been greatly criticized for its simplification of knowledge and the process of understanding (Lave and Wenger 1991), the key objection being that knowledge is situated (cf. Stern and Aronson 1984). The concept of knowledge as a package that can be delivered independent of time, space, and the individuals involved signals a rather elitist way of approaching information. Seeing knowledge as a package also supports the idea of knowledge as an objective representation of reality, an idea entailing extensive epistemological problems. In other words, it raises questions concerning what knowledge is and how knowledge is acquired. Berger and Luckmann (1966) claim that reality is interpreted and subjectively meaningful in particular social contexts. According to Lave and Wenger (1991), this means "that there is no activity that is not situated"; accordingly, it is important to "emphasize … comprehensive understanding involving the whole person rather than 'receiving' a body of factual knowledge about the world", as "agent, activity, and the world mutually constitute each other" (p. 33).

Although there is some evidence that it is possible to reduce energy use through information projects (e.g., Henryson et al. 2000), research often regards information provision as a weak form of coercion. Despite this, interest in using information as an instrument has grown and become increasingly common. Vedung (1995) relates this development to policies dealing with the societal movement toward deregulation and privatization. Information provision represents a modern form of intervention that is attractive to policymakers because it can put "emphasis on prevention of wrong or stimulation of the right conduct by offering insights into consequences of behavior" (Bemelmans-Videc et al. 1998).

Studies on energy use in Sweden demonstrate that households are well aware of how to behave in an energy-efficient way. Information campaigns about switching off the lights, lowering indoor temperature, washing clothes in full machine, etc., have reached the households. Household members could repeat such advice, though that did not indicate that they had actually implemented it (Palm 2010, 2011). Today, both sustainable energy-efficient technology and relevant knowledge exist, but the problem is diffusion. Existing knowledge is generally spread through information dissemination campaigns. However, energy efficiency advice is often so general that individuals have difficulties relating to it—it is difficult to grasp what its implementation would actually mean in terms of energy use (Stern and Aronson 1984). That is why it is only when such advice is combined, for example, with the home installation of a meter measuring the actual reduction in energy use, that people realize the practical implications of, for example, advice to systematically turn off lights when not in use. Earlier research has noted that a combination of instruments often produces the best results when it comes to improving energy efficiency (Palm 2010, 2011). A combination of advice and direct feedback, provided, for example, by a meter, exemplifies how information provision can be supported by other measures.

Notably, conducting individual audits and recording individual statistics regarding energy helped the information receiver perceive the information as more relevant (Palm 2010, 2011). Clearly, combining individual audits, energy statistics, and the active involvement of actors in energy efficiency measures is necessary if one wants to reduce energy use.

5.3 Financial Uncertainties: Principal–Agent Relationship, Split Incentives, Limited Access to Capital, Risk

The *principal–agent relationship* highlights that lack of trust between two parties may constitute a type of *information asymmetry* that leads to company owners demanding short payback times for energy efficiency investments. *Split incentives* may arise when the potential adopter of an investment is not the party that pays the energy bill. *Limited access to capital* refers to difficulties in obtaining the additional capital needed to invest in an energy-efficient technology. *Risk* refers to the situation of a manager who is aware of the capital cost of an energy efficiency investment, but who faces uncertainty concerning the long-term energy savings from the investment.

From a company perspective, it is understandably important to make economically rational choices that can be justified to stakeholders. Later, when the choice has already been made and the system installed, it is also vital that the decision be confirmed and accepted by others. What seems rational from a technical or economic perspective, however, may not necessarily appear rational to individual actors. Household research emphasizes that it is difficult to verify the assumption that households make such rational choices concerning energy efficiency investments.

For example, Crosbie and Bakers (2009) have conducted intervention studies of four energy-saving technologies introduced into households. Their studies demonstrate that the benefits the technologies bring to program participants' lifestyles are a stronger motivational factor than the environmental benefits. For example, a less esthetically appealing technology is less likely to be accepted into households.

Jensen (2005) discusses the inertia that makes it difficult to change human behavior and narrow the efficiency gap. Jensen concludes that this inertia may be maintained when energy efficiency measures do not create the symbols of prosperity that some are seeking. People want to maintain appearances before neighbors and friends, so a new car may be more important to them than insulating or installing double- or triple-glazed windows. Ideally, an investment should produce a visible as well as a functional result: "… money is important, but what money can make visible is more important" (Jensen 2005).

Another study, by Lie and Sørensen (1996), demonstrates that when energy-efficient technologies are introduced into households for reasons of improved comfort or esthetic value, their perceived meaning might change over time, these technologies eventually coming to represent values such as energy savings.

From a company perspective, the symbolic values of an investment can be expected to be important as well. Showing that it is at the forefront of technological development can be crucial to a company's positioning in relation to competitors and in the eyes of customers. Some companies have created their own market niches by promoting themselves as green and sustainable.

Stern (2000) discusses the value–belief–norm theory, according to which he categorizes people's values as egoistic, altruistic, and biospheric (i.e., concerned with the biosphere). Later studies have demonstrated that public policies regarding energy saving are most accepted by the public if they incorporate altruistic or biospheric values (De Groot and Steg 2008). Energy efficiency measures that emphasize a company's concern for the environment would, from this perspective, have a better chance of being implemented than if only their economic benefits were emphasized.

5.4 Rationality: Bounded Rationality, Hidden Costs

Bounded rationality relates to the above discussion of rational actors. Bounded rationality emphasizes that an organization is not a single, unitary actor but consists of various individuals with different interests and that organizations and individuals do not act on the basis of complete information. *Hidden costs* refer to the high costs associated with information seeking.

Problems of industrial energy efficiency are multifaceted, one obvious aspect being that energy-efficient technologies do not diffuse satisfactorily. It is clear that, in theory, there is an "efficiency gap" between the technical–economic potential for improved energy efficiency and what is actually implemented. If we acted as rational consumers, this gap would not exist; the fact is that it does exist, so it is time to approach this problem with new tools and new perspectives.

Cohen et al. (1972) discuss decision-making in organizations using the "garbage can" model, treating decision making in organizations as not necessarily rational. They demonstrate that organizational understanding of a problem may be poor, as people enter and exit the organization, complicating the learning process. The organization's "garbage can" constitutes a collection of choices looking for problems, issues, and suitable decision situations to which to attach themselves. In this process, the actors in the organization essentially dump various problems and solutions into a conceptual garbage can; the outcome results from a solution finding an appropriate problem, so the solution represents a mixture of participants, problems, and resources.

This relates to the discussion of the key position of institutions in everyday decision-making. That institutions are difficult to change can be a positive factor, in that they routinize decision-making processes. This means that actors do not need to invent a new procedure every time a decision must be made. The disadvantage is that such institutionalized routine might result in new ideas having a difficult time becoming established in organizations, because actors tend to behave in habitual ways. On the other hand, this institutional inertia protects organizations from the thoughtless implementation of bad ideas.

This supports theories of bounded rationality. Actors cannot make completely informed decisions all the time. We need routines in order to have functional everyday lives and often must make unexamined decisions, for example, regarding how to use technologies that are "black boxes" to us. It would be unworkable if we needed to learn how the electronics of a cell phone worked before we could make a call—to cite a common example. Similarly, we use industrial processes without knowing exactly how they work; consequently, we do not necessarily reflect on how to improve or change the involved technology to improve energy efficiency.

5.5 Heterogeneity

Heterogeneity refers to the fact that even if a given technology is cost-effective on average, it will not necessarily be so for all industrial companies.

Elisabeth Shove (2003) emphasizes the importance of understanding energy use from the perspective of "invisible practices". When it comes to energy systems, users are often not interested in energy per se, but rather in the functions and conveniences that energy can provide. In our homes, energy is required for functions such as preserving and preparing food, supplying heat and light, and maintaining health and sanitation. How the energy is produced and distributed is irrelevant from this point of view: the important thing is discharging those functions. (How energy is produced might, however, be relevant to the environmentally engaged person who emphasizes environmentally friendly energy production).

The ultimate goal must be to introduce ecologically sustainable solutions and integrate them into actors' routines in such a way that they sustain what people consider normal services (Palm and Ellegård 2011).

Shove et al. (1998) point out that the choices people make about what energy-saving technologies to use depend on the institutional, geographical, cultural, and temporal contexts in which these choices are made. For example, "air conditioning in the United States … became an established technology by facilitating a substantial population migration from temperate to comparatively unsettled and hot climates" (Shove et al. 1998).

When exploring energy use, everyday routines and activities constitute a key focus. Everyday activity patterns are where energy is used, for example, when we take the bus to work, surf the Internet, or turn on a light. Our understanding of energy use needs to be framed by all the activities that form the basis of our everyday lives, in which our habits are embedded (Ellegård 2006). Everyday activity patterns and routines are complicated, and flexible work schedules and school hours as well as increased mobility create new activity patterns that have implications for electricity use. Electronic appliances may be used in various ways; for example, multiple appliances can be used simultaneously, such as when someone writes on a computer and watches TV at the same time. Clearly, we demand the services energy provides, not energy per se (Ellegård and Palm 2011). Responsibility for the environment has largely been transferred from the aggregate level of international or national politics (e.g., the ozonosphere and acidification, together with their related action plans) to the world of everyday life. At the same time, we want to have "good" everyday lives. We want to maintain certain standards in our workplaces, and energy efficiency cannot lead to inconvenience when we perform our work tasks. This makes it important to relate energy efficiency measures to existing processes, routines, and habits and to consider what changes are possible, i.e., what employees are prepared to sacrifice to achieve a sustainable workplace. As discussed above, people have other values that go beyond economic incentives, values that should also be taken into account when discussing energy efficiency in industry.

5.6 Values: Inertia and Culture

Values, such as supporting others, concern for the environment, and moral commitment to energy efficiency, can positively influence individuals and groups to adopt energy efficiency measures. Inertia means that individual and organizational behaviors are, at least partly, the outcome of habits and established routines. It may be difficult to change behaviors and habits. Organizational *culture* is closely related to the values of the individuals constituting the industrial organization, and may inhibit the adoption of energy efficiency technologies.

Strong proenvironment attitudes and values (i.e., environmental awareness) are common among many Western citizens, who generally claim to be willing to undertake activities promoting environmental sustainability. However, the challenge is to translate these attitudes and claims into everyday routines and make them part of everyday practices. To take a Swedish example, despite recent increased interest in sustainably produced food, use of such food products remains unchanged at no more than 3 % of total food expenditures (SCB 2006). There is a gap between a stated willingness to live in accordance with environmental awareness and the actions taken.

There are also examples of people actually changing their behaviour. One profound instance in Sweden concerns waste sorting. According to a 2008 study for the Swedish environmental protection agency, 57 % of Swedish citizens had increased their waste sorting activities over the previous 2 years (Söderberg 2008). Clearly, this is one area in which translating norms into behavioral change has been relatively successful. In the case of waste sorting, personal behavioral norms appear pronounced and society's infrastructure supports the activities. Interestingly, the perception that recycling is extensive in other households tends to have positive spillover effects on households. It is stated that a combination of these factors largely explains why norms are more likely to be translated into action in this area than in others (Söderberg 2008).

Guy and Shove (2000) state that people develop knowledge that fits the framework in which they live, energy knowledge being no exception. As noted above, earlier studies have found that environmental concerns are becoming increasingly important as symbolic issues. People want to show others that they are environmentally aware and are thinking about climate problems (Pedersen 2000; Hedrén 2008; Skill 2008; Palm and Tengvard 2011). There is a symbolic aspect to environmentally friendly behavior: by leaving sorted waste in the proper containers at public collection locations or installing a PV panel on the roof, a household can show its neighbors that it actually has a sustainable lifestyle. In relation to the industrial sector, earlier research has demonstrated that companies also want to show their neighbors that they embrace sustainability, doing so by featuring energy efficiency in activities and projects that are visible to neighbors. Improving energy efficiency in industry involves encouraging companies both to engage in particular activities and to assess everyday routines, practices, and processes.

5.7 Power

The last barrier discussed here is insufficient *power* in the hands of the energy controller of an industrial organization.

This barrier relates closely to the discussion in Chap. 4 of regimes, institutions, and CoPs, theoretical perspectives that emphasize the importance of setting decisions in their social contexts. Researchers tend to focus on individual decision-makers as though they made decisions in a vacuum, regardless of their social and institutional context (Shove 1998; Palm and Thollander 2010). At the same time, empirical evidence suggests that decisions concerning how we use energy and implement energy efficiency measures are made in social contexts. Practitioners identify and make energy-related decisions in various networks and contexts:

> What qualifies as a reliable, cost-effective, worthwhile energy saving measure in one sociocultural domain might count for nothing in another (Shove 1998).

The sociotechnical regime and CoP theories both imply that various regimes or practices coexist in organizations through mutual dependency. In a company, various social groups can be distinguished, each with particular features. Actors in these groups share aims, values, problem agendas, professional journals, etc. The rules governing these groups or CoPs are linked not just within each group or CoP but also between them, causing them to exert mutual influence.

According to such a perspective, energy efficiency also depends on the social relationships and discussions, negotiations, and agreements developed in actor networks. One implication of this perspective is that energy-saving measures in one sociocultural domain may be useless in another. What is common practice in one company might be completely inapplicable in another. Experiences, routines, and habits established and negotiated in a particular network will then determine the energy efficiency measures that will be implemented. These negotiated agreements can serve as both facilitators and constraints.

Focusing on social negotiations and agreements helps explain why energy efficiency technologies may be rejected or adopted in one company but not in another. It also directs attention to the fact that technology diffusion is social in character and that it is accordingly relevant to examine the particular energy efficiency discourse in a company, i.e., how employees talk about energy efficiency and how this discourse relates to environmental issues and cost allocations pertaining to energy efficiency measures. It is also relevant to observe which actors' or groups' arguments are held to be true in a company and which are rejected. For example, a company might have a strong financial regime with established rules emphasizing short payoff periods; the energy efficiency regime would need to struggle with these rules to have a longer pay-off period accepted.

5.8 Conclusion

In this chapter, we have discussed how barrier research can benefit from taking account of the results of other social science research. We think that such "cross-pollination" can only strengthen the barrier theory. From this other social science research we can learn that:

- knowledge is situated
- information needs to relate temporally and spatially to the individual taking part in the communication act
- it is difficult to influence people merely by providing information

Table 5.1 A classification of barriers

Category	Theoretical barriers
Technical system	Access to capital
	Heterogeneity
	Hidden costs
	Risk
Technological regime	Imperfect information
	Adverse selection
	Split incentives
	Form of information
Sociotechnical regime	Credibility and trust
	Principal–agent relationship
	Values
	Inertia
	Bounded rationality
	Power
	Culture

- knowledge is not necessarily transformed into particular behaviors merely by providing information
- information should be combined with other measures, such as recording statistics
- rational actors do not exist empirically; instead, rationality must be contextualized
- we cannot always make completely informed choices; this makes institutional routines central to functional everyday life
- it is important to relate energy efficiency to values other than just financial ones
- energy efficiency can have, for example, symbolic value to a company
- energy efficiency measures need to fit into existing everyday activity patterns and routines
- strengthening energy efficiency in industry involves both working with how energy use and efficiency are perceived in the organization and developing structures benefitting certain behaviors
- decisions are made in particular institutional contexts
- an actor's organizational position and social network are important.

Throughout the first five chapters, we have emphasized that is important to approach barriers from new perspectives, using non-traditional analytical tools that can contribute to new understandings or questions as to why particular barriers are perceived as important in particular companies. Analyzing a company's existing culture and networks, that is, understanding the context in which energy efficiency goals and measures are considered, must be done if we are to take industrial energy efficiency a step further (Thollander et al. 2010). A new way to think about barriers would be to divide them according to a sociotechnical perspective, as discussed in Chap. 4 (see Table 5.1).

We have simply related the various barriers to different parts of the system, engendering new insights into the barriers. The point here is not to propose a new model, but to demonstrate that how we contextualize problems and define barriers will determine the solutions and suggested measures. We must use and build on earlier research, but it is also crucial to reflect on how models can influence and in some respects restrict our thinking.

As can be seen in Table 5.1, if the technical system is the focus, different types of barriers will be identified and compared with if the sociotechnical regime is the focus. We can extend this idea, and suppose that if barriers belonging to a particular technological regime are emphasized in a company, then a particular CoP will be addressed with proposed measures. If the emphasized barrier is related more closely to the sociotechnical regime, then other CoPs and barriers, such as corporate culture and established internal values, will be emphasized and problematized. How we perceive and define barriers to energy efficiency will lead to different solutions and, in the end, to different policy recommendations.

We can conclude that energy efficiency problems are multifaceted and should be approached accordingly. Understanding that there are technical, social, and organizational reasons why optimal energy efficiency measures are not being implemented by industrial companies should prompt us to formulate new questions, leading to new and different answers and solutions. How we perceive and define barriers will lead to different proposals for overcoming the barriers and, ultimately, to different policy recommendations. Finding ways to narrow the energy efficiency gap is vital if we are to solve the climate change problem. Defining and redefining the empirically identified barriers is crucial if we are to challenge existing, but suboptimal, solutions and develop new, more creative ways of approaching companies and other actors.

References

Bemelmans-Videc M-L, Rist R, Vedung E (eds) (1998) Carrots, sticks, and sermons: policy instruments and their evaluation. Transaction Publishers, New Brunswick

Berger P, Luckmann T (1966) The social construction of reality. Penguin Books, London

Cohen M, March J, Olsen J (1972) A garbage can model of organizational choice. Adm Sci Q 17:1–25

Crosbie T, Baker K (2009) Energy-efficiency interventions in housing: learning from the inhabitants. Build Res Inf 38:70–79

De Groot J, Steg L (2008) Value orientations to explain beliefs related to environmental significant behavior: how to measure egoistic, altruistic, and biospheric value orientations. Environ Behav 40:330–354

Ellegård K (2006) The power of categorisation in the Study of everyday life. J Occup Sci 13:37–48

Ellegård K, Palm J (2011) Visualizing energy consumption activities as a tool for making everyday life more sustainable. Appl Energy 88:1920–1926

Guy S, Shove E (2000) A sociology of energy, buildings and the environment: constructing knowledge, designing practice. Routledge, London

Hedrén J (2008) Shaping sustainability: is there an unreleased potential in utopian thought? Futures 41:220–225

Henryson J, Håkansson T, Pyrko J (2000) Energy efficiency in buildings through information—Swedish perspective. Energy Policy 28:169–180

Jensen OM (2005) Consumer inertia to energy saving, in ECEEE 2005 summer study. Panel 6:1327–1334

Lave J, Wenger E (1991) Situated learning: legitimate peripheral participation. Cambridge University Press, Cambridge

Lie M, Sørensen KH (1996) Making technology our own? Domesticating technology into everyday life. Scandinavian University Press, Oslo

Palm J (2010) The public-private divide in household behavior. How far into the home can energy guidance reach? Energy Policy 38:2858–2864

Palm J (2011) Energy efficiency in households: policy, implementation and appropriation of technology. Nova Science Publisher, New York

Palm J, Ellegård K (2011) Visualizing energy consumption activities as a tool for developing effective policy. Int J Consumer Stud 35:171–179

Palm J, Tengvard M (2011) Motives for and barriers to household adoption of small-scale production of electricity: examples from Sweden. Sustain: Sci Pract Policy 7:6–15

Palm J, Thollander P (2010) An interdisciplinary perspective on industrial energy efficiency. Appl Energy 87:3255–3261

Pedersen LH (2000) The dynamics of green consumption: a matter of visibility? J Environ Policy Plan 2:193–210

SCB (Statistics Sweden) (2006). Ekologiska livsmedel—ett strategiunderlag för livsmedelsbranschen. Report 2006:13, SCB, Stockholm

Shove E (1998) Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. Energy Policy 1998:1105–1112

Shove E (2003) Comfort, cleanliness and convenience. The social organization of normality. Berg, Oxford

Shove E, Lutzenhiser L, Guy S, Hackett B, Wilhite H (1998) Energy and social systems. In: Rayner S, Malone E (eds) Human choice and climate change. Battelle Press, Columbus, pp 291−326

Skill K (2008) (Re)creating ecological action space: householders' activities for sustainable development in Sweden. Dissertation, Linköping University

Stern PC (2000) Toward a coherent theory of environmentally significant behaviour. J Soc Issues 56:407–424

Stern PC, Aronson E (eds) (1984) Energy use: the human dimension. Freeman, New York

Söderberg P (2008) Hållbara hushåll: Miljöpolitik och ekologisk hållbarhet i vardagen. Report 5899, Swedish Environmental Protection Agency, Stockholm

Thollander P, Palm J, Rohdin P (2010) Categorizing barriers to energy efficiency: an interdisciplinary perspective. In: Palm J (ed) Energy efficiency. Sciyo, Croatia. Available at: http://www.intechopen.com/books/show/title/energy-efficiency

Vedung E (1995) Informativa styrmedel. Report Department Of Political Science, Uppsala University

Chapter 6
Managing Energy Efficiency in Industry: Theory and Practice

Abstract In this chapter, we examine energy management and the need to work strategically on energy in a company. An internal energy management program is a key means by which an industrial company can overcome barriers and improve its energy efficiency. *Energy management* can be defined as the procedures by which a company works strategically on energy, while an *energy management system* is a tool for implementing these procedures; these two concepts are often mixed or used interchangeably. We discuss why industrial companies need to work on energy management while empowering the individuals within their organizations. An industrial company that takes a strategic approach to energy management may reduce its energy use by up to 40 %. Energy management concerns the ability to combine strong leadership with delegated authority as concerns energy issues. Energy management research can be developed by complementing existing questionnaire and interview studies with observational research.

6.1 Introduction

Research into energy efficiency has generally focused on technological and systems improvements, while energy management and organizational means have been relatively neglected. An internal energy management program is perhaps the most important means by which an industrial company can overcome barriers and improve its energy efficiency. International research finds that in-house energy management programs can lead to reductions in energy use of 4–40 % when the savings derive from both technology and management measures (Caffal 1995). Research into energy management has so far been rare (Thollander and Ottosson 2010). Today, there exists a new international energy management standard, International Organization for Standardization (ISO) 50001, as well as the

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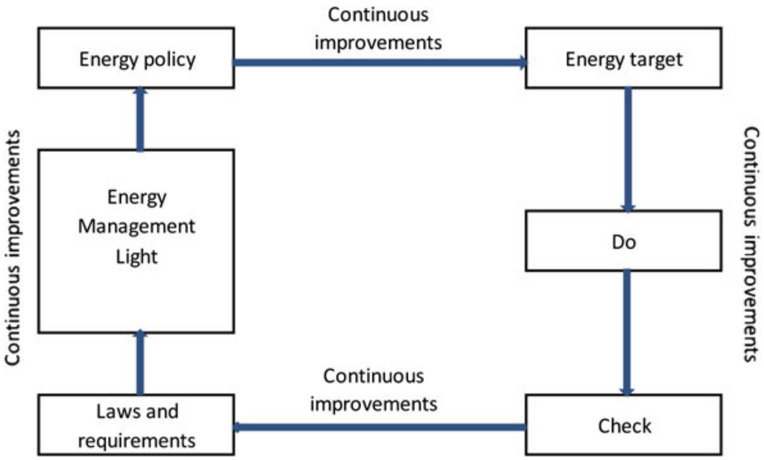

Fig. 6.1 Continuous improvement of the simple energy management system (Hrustic et al. 2011)

European EN 16001 standard. Yet another means to improve energy efficiency is for a company to incorporate its energy work in an environmental management system, if such a system is present. However, without organizational support and more specifically an organizational culture of continuous improvement, any management system becomes ineffective, e.g., Rohdin and Thollander (2006).

Energy management can be defined as the procedures by which a company works strategically on energy, while an *energy management system* is a tool for implementing these procedures; these two concepts are often mixed and used interchangeably. It must be emphasized that an energy management system can only successfully support energy management in a company if adopted properly by the organization.

The energy management system standards, EN 16001 and ISO 50001, were both designed according to the plan–do–check–act (PDCA) cycle (Deming 1986), and are similar to quality and environmental management system standards (ISO 2004). Implementation of standardized energy management systems by industrial SMEs has so far been limited (EC 2007). In an attempt to improve energy efficiency through energy management, simplified management system models have been developed to promote energy management in industrial SMEs; these are inspired by the formal standards but take an easier approach than do full-scale energy management systems (Hrustic et al. 2011). Figure 6.1 presents one such Swedish simplified model, “Energy Management Light”.

As described in Chap. 2, there are two main means by which an organization can reduce its energy cost: one is to focus on the supply side, and the other on the demand side. While energy management naturally concerns both sides, seldom have non-energy-intensive companies and industrial SMEs focused on the supply side. However, as energy prices are increasing as well as awareness of more environmentally adapted electricity production, for example, this situation is likely to change.

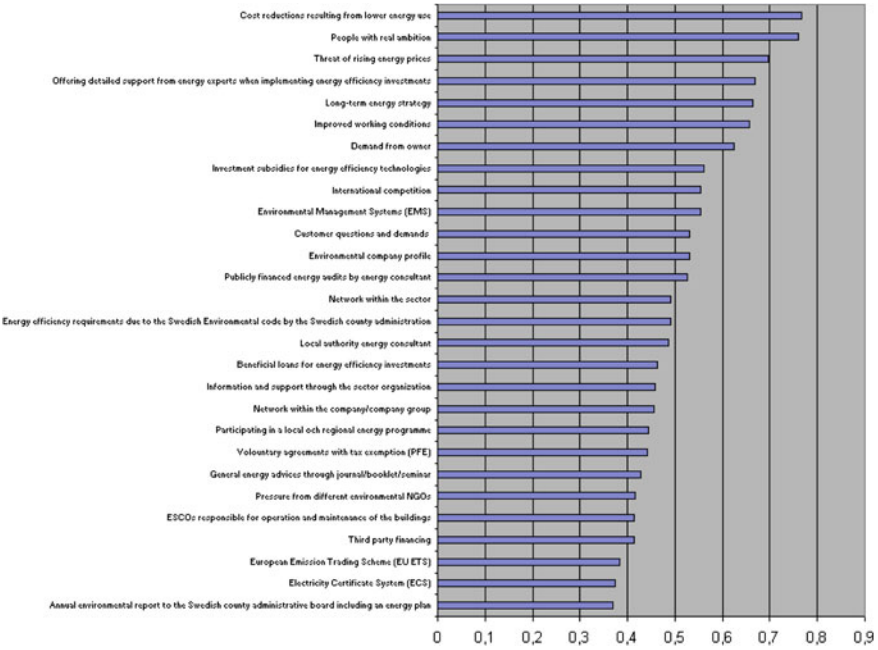

Fig. 6.2 Ranked results of the questionnaire administered to non-energy-intensive SMEs on the driving forces of energy efficiency (Thollander et al. 2009)

6.2 Energy Management in Industry: Previous Research

Previous research has found that two of the highest ranked factors promoting energy efficiency are related to in-house industrial energy management. Companies identified the presence of a committed person with real ambition and the existence of a long-term energy strategy as crucial factors driving energy efficiency improvements (see Figs. 6.2, 6.3, 6.4).

The results of these studies identify a number of similar factors promoting energy efficiency, quite apart from the actual cost reductions resulting from lowered energy use. As mentioned above, two key factors are the presence of a committed person with real ambition and the existence of a long-term energy strategy. Obviously, the industrial respondents who completed the questionnaire ranked the existence of, for example, a committed person extremely highly. In fact, in these sectors, the existence of a committed person is ranked on parity with the actual cost reductions resulting from lowered energy use (see Figs. 6.2, 6.3, 6.4).

Research and experience have demonstrated that industrial companies that strategically adopt energy management practices may, as stated in the introduction, reduce their total energy use by up to 40 % (Caffal 1995). Successful industrial energy management calls for strategic thinking and full support from top management. Strategic approaches vary, but do share some elements, such as the following (Caffal 1995):

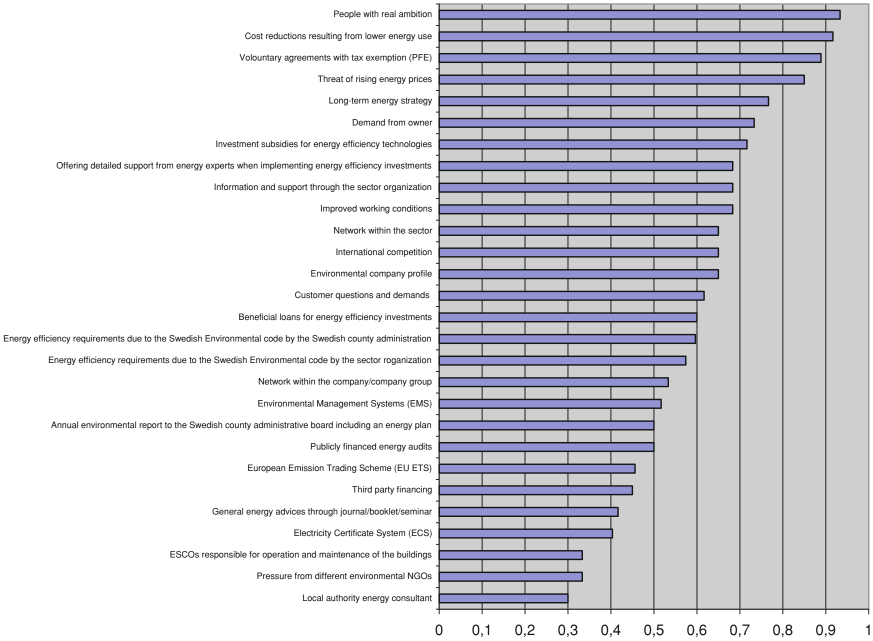

Fig. 6.3 Ranked results of the questionnaire administered to energy-intensive SMEs on the driving forces of energy efficiency (foundries) (Thollander et al. 2009)

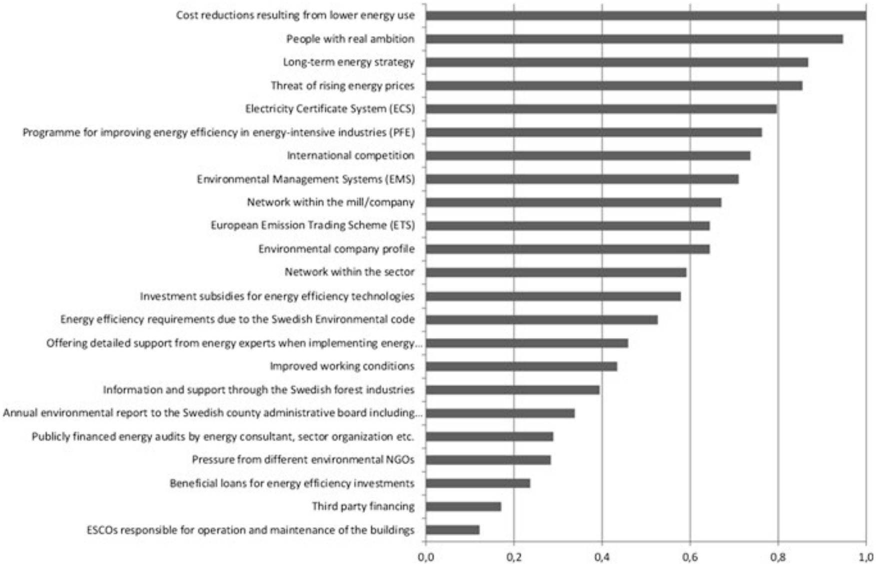

Fig. 6.4 Ranked results of the questionnaire administered to energy-intensive pulp and paper mills (most are not SMEs) on the driving forces of energy efficiency (Thollander and Ottosson 2008)

- an initial energy audit
- senior management support
- energy use monitoring
- recognition that management is as important as technology
- an ongoing and coordinated program for energy-saving projects.

The last item should include:

- a long-term energy-saving scenario
- a factory-wide plan for the medium term
- a detailed plan for the first year
- action to improve energy management, including the establishment of an energy monitoring system.

The program should feature staff motivation and training, and a successful approach to energy management includes both the managerial techniques described above and technical measures appropriate to the site in question (Caffal 1995). It should be noted that there is no "one-size-fits-all" approach to energy management (Christoffersen et al. 2006; Russell 2006). For larger and energy-intensive industries with great incentives to reduce energy costs, full-scale energy management practices could well be justified, while for smaller and less-energy-intensive firms, energy management could be included in the quality or environmental management systems (EMSs) (Caffal 1995). For SMEs with a limited number of staff each handling a broader range of issues, relative to larger companies, energy management is less likely to be prioritized, despite its significant benefits. An interesting EMS approach that could serve as a driver of energy management in SMEs is the so-called Hackefors model, formulated in 1999 in Hackefors, Sweden. In this EMS model, a cluster of SMEs engages an independent company, Altea, to play a central role in running the companies' EMSs on a commercial basis (Altea 2007). This model, which allows an SME to run an EMS despite its limited available resources, has become very popular in Sweden. In 2002, about 24 industrial districts, involving 450 enterprises and 7 industrial groups, were using the model (Ammenberg and Hjelm 2002); by 2006, about 750 firms were using the model (Altea 2007).

The need to evaluate and develop energy management is crucial, and the general field of management research has been criticized, for example, by Boulding (1956), for being too shallow. We will now turn to Boulding and his now classic explanation of system complexity to address this criticism in greater depth.

6.3 Considering the Complexity of a System: A Need for Methodological Change

According to Boulding (1956), systems may be categorized in terms of their complexity. Boulding identifies nine levels of complexity, and claims that social interaction, i.e., interaction between two or more individuals, is by far the most complex system to study. Boulding's (1956) classification of systems is as follows:

1. *Frameworks*—the geography and anatomy of the universe: the patterns of electrons around a nucleus, the pattern of atoms in a molecular formula, the arrangement of atoms in a crystal, the anatomy of the gene, the mapping of the Earth, etc.
2. *Clockworks*—the solar system, simple mechanisms such as the lever and the pulley, and even fairly complicated machines such as steam engines and dynamos
3. *Thermostats*—control mechanisms or cybernetic systems, i.e., systems that maintain a given equilibrium, within limits
4. *Cells*—open systems or self-maintaining structures, i.e., the level at which life begins to differentiate itself from not-life
5. *Plants*—characterized, first, by division of labor with differentiated and mutually dependent parts (e.g., roots, leaves, and seeds) and, second, by a sharp differentiation between genotype and phenotype, associated with the phenomenon of equifinal or "blueprinted" growth
6. *Animals*—characterized by increased mobility, teleological behavior, and self-awareness, with the development of specialized information receptors (e.g., eyes, ears, and other sense organs) leading to an enormous increase in information intake
7. *Human beings*—in addition to all, or nearly all, of the characteristics of animal systems, humans possess self-consciousness, which differs from mere awareness
8. *Social organizations*—the basic unit of such systems is perhaps not the person but the "role", i.e., that part of the person concerned with the organization or situation in question; a social organization might be defined as a set of roles tied together by communication channels
9. *Transcendental systems*—the ultimates, absolutes, and inescapable unknowables that also exhibit systematic structure and relationships.

Management research has been criticized for not moving beyond the lower system levels (Boulding 1956), possibly due to the methods used.

Research into energy management has previously focused on energy management practices, empirical studies having dominated the field. The main data collection methods have been questionnaires and in-depth interviews, as employed by Christoffersen et al. (2006) and Thollander and Ottosson (2010). Earlier studies have defined and analyzed an array of indicators (using questionnaires) or focused on industrial respondents' views and opinions (using interviews). Our aim is to take energy efficiency in industry much farther by relating earlier research to a broader management perspective. In this chapter, we will explore and incorporate managerial responsibilities and concepts in relation to the barriers identified in earlier research. In a previous survey of the relevant literature (Thollander and Ottosson 2010), we found that such research is so far lacking in the academic literature. Such research is greatly needed, both from a business economics perspective, to reduce industrial energy costs, and from a socio-economic perspective, to reduce, for example, the external costs incurred by excessive energy use.

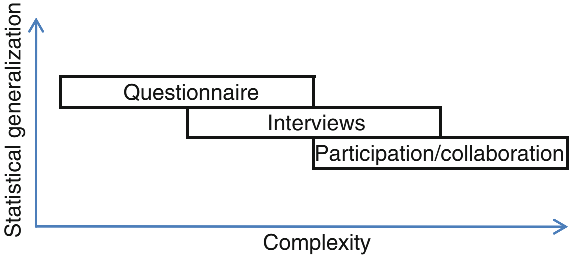

Fig. 6.5 Differences between questionnaires, interviews, and participation/collaboration (inspired by Boulding 1956)

Incorporating a managerial perspective also calls for methods other than questionnaires and interviews. Notably, observations can be used to study behaviors and sequences of events in an authentic context in real time. The method does not rely on either people's memories or ability (or willingness) to retell their experiences in a way that is understandable to outsiders; instead, researchers are present in real time when an activity is performed. Observations can be differentiated by their degree of structuring and collaboration with the people being observed. A more participatory observational approach is action research, a participatory method concerned with developing practical knowledge of routines, practices, behavior, etc. It is described as a reflective process of problem solving in which individuals work as part of a CoP to improve how they approach or solve a problem (Whyte 1991).

Figure 6.5 schematicizes the differences between interviews, questionnaires, and our applied method.

One response to this criticism of management research is to go beyond the more common methodological approaches that use questionnaires and interviews, problematizing the issue in new ways and formulating complementary theories; one such approach was that of Johansson et al. (2011). Participant observation or collaboration limits the ability to generalize from empirical findings compared with the results of questionnaires and interviews, as these methods cover several respondents. Instead, with participant observation, one must generalize findings by emphasizing theory and analytical findings. It is hoped that this approach will enable researchers to explore the more complex levels of (energy) management, enhancing our understanding and engendering better suggestions for the improvement of energy management practices in industry. When reading this chapter, one must bear in mind that the ideas outlined are not proposed as solutions for everyone, but rather as concepts to be considered case by case: "there is no one size fits all" when it comes to energy management (Christoffersen et al. 2006).

We will begin this more nuanced discussion of energy management by considering how transition processes might develop in organizations.

6.4 Transition in Organizations

Returning to Chap. 5 and the discussion of barriers, we saw that an organization creates its own culture, including values such as supporting others, environmental concern, and moral commitment to energy efficiency. This organizational culture is important when trying to influence an organization, because it positively or negatively affects individuals and groups with regard to, for example, adopting energy efficiency measures. This can be illustrated by research conducted among university students.

A study by Aronson and O'Leary (1983) of energy-efficient showering in a university gym revealed that the number of students taking short energy-saving showers increased from 6 (after a sign had been posted encouraging short showers) to 19 % when an *intrusive* sign was used. Moreover, it increased from 19 to 49 % when the researchers used a student as a role model, setting an example by always turning off the water when soaping up whenever someone entered the facility. Finally, the percentage increased from 49 to 67 % when two students were used as role models (Aronson and O'Leary 1983). In summary, lack of values related to energy efficiency may inhibit measures from being undertaken.

When discussing the heterogeneity barrier, we emphasized the importance of understanding routines and activities in the everyday life of a workplace. Energy efficiency measures need to be related to existing processes, routines, and habits and to what extent both the organization and its employees are prepared to made sacrifices in terms of time, comfort, convenience, etc.

To this we can add the influence of the landscape as defined in transition theory (see Chap. 5), where public policy, international agreements, regulations, etc., are also regarded as influencing companies' energy-related decisions. We also saw that decision-making can be more or less rational depending on one's analytical lens, for example, if one views a decision from a financial, environmental, or individual perspective. Taken together, we can sketch a figure outlining transition in organizations with reference to the above mentioned aspects.

In Fig. 6.6, we outline a model of how transition can take form in an organization. There is pressure from either the socio-technical landscape or internal processes that impel change, for example, in energy use. This pressure is captured by a CoP, and if the demands are in line with the community's culture, the process can continue and measures to change behavior and activities will be initiated. This will in turn affect how energy-related practices are performed and whether this will lead to the expected results, for example, reduced energy use; if so, then a positive spiral has been created. This process can take more or less time, depending on whether or not the pressure for change is in line with the values of a dominant CoP, how easy it is to change activities and behavior, whether or not behavioral change leads to consistent change in practices, and, finally, whether or not the results are as expected or whether the process will have to start again.

In this figure, individuals' values and behavior are central to successful transition. An organization's structure determines how open and receptive a company is to the possibility of transition. As well, as we will discuss later, appropriate strategies and active energy management are needed if an organization is to improve its energy efficiency. However, all scenarios involve individual action, hence individuals need sufficient freedom to act and exert agency (Syrett 2007).

Empowering individuals in an organization to work on energy management-related issues is thus central to the energy efficiency transformation of any

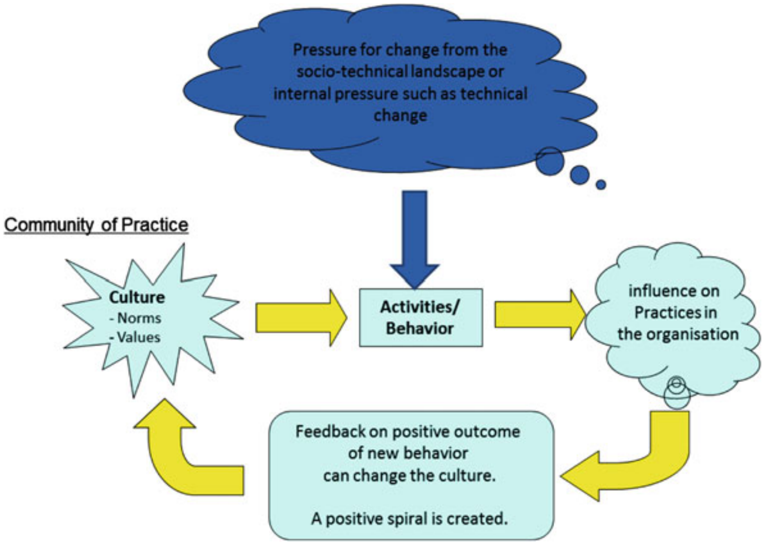

Fig. 6.6 Transitions in organizations (inspired by Johansson et al. 2011)

industrial organization. Inevitably, much depends on a key leader's initiative and sense of responsibility. This finding, like it or not, is far from the economic and engineering view of the organization as a single rational entity, a rational agent. The question is how to empower individuals and transform the organization in the interest of improved energy efficiency? To improve our understanding of energy management in an actor-centric way, we will first turn to transactional analysis (TA), which has its origins in psychiatry.

6.5 Transactional Analysis in Relation to Energy Management

TA, originated by Eric Berne and derived from psychiatric practice, states that interacting individuals assume three major roles. One is the role of an *adult* who is communicating with another *adult*. In TA, such communication is the desired outcome of a well-established relationship between two people. Apart from the *adult* role, one may also take the role of a *parent* or *child*. Using these three roles, four standpoints can be taken: (1) *I'm okay*, *you're okay*; (2) *I'm okay*, *you're not okay*; (3) *I'm not okay*, *you're okay*; and (4) *I'm not okay*, *you're not okay* (Berne 1964).

The *adult* role is one in which the individual makes balanced decisions free of feelings. The *parent* role, on the other hand, may represent an unconscious reaction to how that person was threatened during childhood. Finally, the *child* role is a state in which the individual acts the way she or he did during childhood (Berne 1964).

Naturally, interactions between a parent and a new-born baby differ markedly from interactions with a teenager. While the former represents a *parent* to *child* relationship, the latter should include some characteristics of an *adult* to *adult* relationship.

Arguably, the same schema applies to the education system, including higher education and postgraduate studies. In the first grade, children are taught intensively by the teacher, in a setup involving little freedom and a high degree of teaching material standardization, i.e., a predominantly *parent* to *child* relationship. However, for those who eventually study at the university level, the final part of most graduate or postgraduate programs involves less standardized teaching methods. Instead, there is great freedom and a more *adult* to *adult* relationship between the teacher/supervisor and the student/PhD candidate.

Applying TA to energy management in an industrial organization tells us that that the amount of freedom extended to individuals and the organization by the person in charge needs to be consistent with the individual's and organizations current ability to take responsibility. Moreover, the ability to foster continuous improvement is not static. Instead, it recalls raising a child or the application of progressively different teaching approaches. If a leader is unfamiliar with this schema, she or he might provide insufficiently strict guidelines to the organization (i.e., adopt an *adult* to *adult* approach), potentially leading to neglect of the issue if the individuals and organization are unprepared. Alternately, the leader might provide overly strict guidelines (i.e., adopt a *parent* to *child* approach), fostering an organization that indeed follows the guidelines, but that does not, due to its stasis, encourage or empower individuals to think in new and innovative ways.

Before exploring various strategies for fostering change in the interest of energy efficiency in industrial organizations, we would like to cite yet another example of relevant social science research.

6.5.1 Empowering Means Believing in Individuals

Rosenthal and Jacobson (1966) administered an IQ test to all students, grades one to six, in an American elementary school. After the IQ test was collected and results tabulated, the researchers randomly selected a number of students from this school and told the teachers that these were the top-ranked students in the school, and were expected to greatly improve their learning outcomes. Naturally, not all these selected students had been doing particularly well in their studies.

After 8 months, the researchers approached the local elementary school once again and administered a second IQ test. While one may question the ethics of this research design, the results were surprising. The second IQ test indicated that the randomly selected "top-ranked" students had significantly improved their IQ test results: "For the school as a whole those children from whom the teachers had been led to expect greater intellectual gain showed a significantly greater gain in IQ score than did the control children" (Rosenthal and Jacobson 1966).

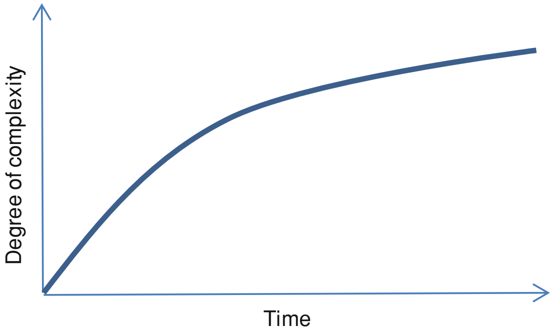

Fig. 6.7 The degree of complexity may vary over time when establishing an in-house energy management program

Why, one might ask? Part of the answer may be that the teachers, after the first IQ test results were tabulated and the purported “high-ranked” students identified, now spent more time and effort fostering these students, because they now believed in their abilities. For some students, this included seeing something yet not visualized, as not all of the claimed high-ranked students in fact met the prerequisites for good performance. These results suggest that believing in one’s employees may represent a basic element of successful energy management practices.

6.6 Establishing Energy Management Within an Organization

TA and the above example together imply that establishing an in-house energy management program is a challenge. Figure 6.7 shows how the complexity of such a program may vary over time.

As shown in Fig. 6.7, an in-house energy management program entails a considerable increase in complexity than when it is initially established. The approach used to initiate the program might greatly affect the organization’s view of the program for a long time. A company often begins to control its energy use by conducting an energy audit, mapping its energy use and possible measures by which to improve energy efficiency, as previously described in detail in Chap. 2.

Next, we will examine the manager’s role more closely in relation to the company’s need to grant agency to its employees.

6.7 Energy Management: The Need to Lead While Delegating Leadership

The adoption of an energy strategy and the restructuring of the energy management practices of an industrial organization naturally restrict the individual’s and organization’s freedom. This challenge should not be underestimated. As previously outlined using TA, a strategy or structure can be communicated in more or less desirable ways. It is more desirable to communicate a new strategy and structure without "forcing" them on individuals and the organization using a *parent* to *child* approach. Instead, people should be informed of the changes before their adoption and enabled to provide their views of the new approach, increasing the chances of the organization accepting the new structure.

When a manager leads change in an organization, he or she can choose one of two main roads or paths, i.e., *method* or *result* governance (Johansson et al. 2011). The difference between these can be described as follows: Location *B* can be reached from location *A* in two ways. The first option is to run along a sandy beach. Although the distance is far, it is traversed relatively quickly. The tracks in the sand, however, are washed rapidly away; soon no one else can be helped by the first person's trailblazing. Instead, each person has to make his or her own way to position *B*. The load to be moved from location *A* to *B* depends on individual capacity and external conditions. In summary, the first path is that of solving the challenge individually.

The second option is to build a road. This will take much more organizational time, resources, and effort, but when the road is finished, more people will be able to travel easily from *A* to *B*. Moreover, people can carry greater loads along the road (Johansson et al. 2011). Improved modes of transport can now be developed so that more cargo than could be carried individually can be moved on each trip. The time needed to complete the shipment may eventually be reduced as well. Moving a load from location *A* to *B* via a road is much less dependent on individual capacity and external conditions. In summary, the second path is that of standardization and continuous improvement, a path that helps those who follow later.

We refer to this second approach as method governance, while the first approach is that of result governance. With the right leadership, result governance often achieves positive results relatively quickly, but these are often not maintained in the longer term. This way of influencing behavior entails letting members of the group seek their own way to achieve the desired results. As the manager does not specify how the results are to be achieved, solutions often rely on individual approaches. Moreover, duplication of these individual solutions is generally impossible, meaning that structural capital does not accumulate in the organization, department, or group. The organizational culture is affected to only a limited extent. There is a great risk that, if the leader loses focus or changes jobs, the good results will not persist (Johansson et al. 2011).

Path number two, which we define as method governance, entails influencing behavior by using good methods and approaches. Behavior modified in such a way provides better results, both economically and in terms of the conditions needed to maintain or improve the work quality and environment. The positive change achieved is likely linked to group dynamics, so the resulting positive spiral creates the opportunity to influence group culture. As method governance emphasizes *how* the work is done, it establishes the conditions for continuous improvement (Johansson et al. 2011).

Elements of this approach that can be improved are the constituent methods, routines, and instructions. Method governance, unlike result governance, builds structural capital and, with the right leadership, long-term improvement in group culture (Johansson et al. 2011).

This also reduces the risk connected with a manager's changing jobs. However, and this must be stressed, bad leadership will always be able to bring down an organization, independent of which governance path is taken.

6.8 Delegating Authority and Taking Risk

Establishing an energy management program and moving an organization in the direction of improved energy efficiency entails a certain degree of risk. For the production manager, who focuses on productivity, shutting down machines outside production hours and replacing old equipment in the production line creates a risk that productivity may decrease during the adoption process. This needs to be taken into account when the person in charge of the program is planning the changes needed. One strategy here is to seek to create stable systems—a machine that is difficult to restart after a shutdown is a typical example of an unstable system.

For the quality manager, who emphasizes zero defects, the replacement of old reliable and proven machines also entails a degree of risk. The person in charge of the energy management program must encourage those in charge of production, quality, maintenance, etc., to accept a certain amount of risk. Risk as a barrier to energy efficiency has been found to be far greater in industries with continuous production processes than in industries with batch production. In the former, equipment malfunction may cost several hundred thousand Euros per hour, while a similar malfunction in an industry with batch production might be resolved much more easily (Thollander and Ottosson 2008).

The CEO of an industrial organization may not be the person responsible for the initiation and design of an energy management program. Delegating that authority is a natural step. However, delegated authority entails a degree of risk, though a different form of risk from those outlined above. If a young, newly employed person is entrusted with designing and operating the energy management program, the organization may see this as indicating that top management is really paying little attention to the issue. This young, inexperienced person might not have sufficient informal power to advocate certain major steps needed to improve energy efficiency.

Similarly, a weak leader might lack the power to establish the needed new values in the organization. This will eventually cause division and delay, even inhibiting the adoption of the in-house energy management program. It is thus crucial that the person in charge of the energy management program at least have an informal leadership position, or have a strong connection with someone on the board of directors.

We will present an example of how leadership delegation can succeed. The CEO of a large multinational company decided to establish an in-house energy management program. After the company had conducted an energy audit, it established a group that met monthly. Although the CEO had delegated the authority to the person in charge of the physical plant [e.g., Heating, ventilation and air conditioning (HVAC), water, and security system] at the company, he demanded that all managers attend the meetings. As the CEO always attended, so did the rest of his staff. The person in charge of the melting division became inspired to start working on energy efficiency on an operational basis. He taught his furnace-operating staff to charge the furnaces immediately after emptying them. Although the processing of the new batch did not always start immediately, with delays of up to several hours, the refractory bricks lining the furnace retained considerable heat, increasing the temperature of the charged room temperature metal by about 100 °C. When the new batch began to be melted, heating did not have to begin from room temperature, but from 100 °C. This simple routine change lowered the electricity consumed by the furnace operation by 10 % or 1600 MWh per year (Thollander et al. 2008). Moreover, the refractory bricks, which normally had to be, renewed every 100–200 melts, now lasted for up to 400 melts before needing renewal. Even without taking into account the tremendous reduction in maintenance costs, the savings from the lowered electricity demand equaled the sum of all undertaken measures suggested by the energy audit. Moreover, this was achieved in the company's absolute core production area, which one would imagine was already highly optimized. In conclusion, through organizational changes, a CEO or a board of directors may be able to empower individuals and mid-level managers to increase efficiency and even revenues.

6.9 The Adoption of an Energy Strategy

As stated previously in this chapter, industry considers the adoption of an energy strategy to be a key driver of improved energy efficiency. Moreover, as we demonstrate below, studies of the matter have found that long-term energy strategies have so far rarely been adopted (Thollander and Ottosson 2008, 2010; Thollander et al. 2009). Two major approaches exist for designing energy management programs, i.e., focusing solely on technology and focusing on purely organizational and behavioral issues. Figure 6.8 shows the adoption levels of various measures proposed in energy audits of industrial SMEs. The figure shows that educational measures were the most rarely adopted. Why, one might ask? We suggest that one answer lies in the non-adoption of in-house energy management programs. In the absence of such a program environment, suggested non-technical measures are largely neglected. Differently stated, few persons in these companies "picked up the baton" and continued to work on energy efficiency improvements.

Independent of whether the chosen approach has a predominantly technical or management/organizational emphasis, an energy strategy is needed; a mixture of the two emphases is, of course, optimal.

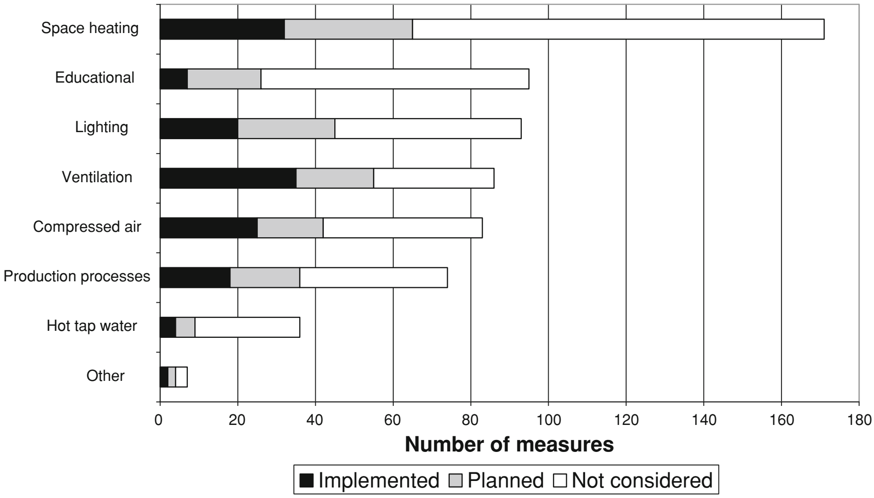

Fig. 6.8 Number of implemented, planned, and neglected measures recommended to the 47 evaluated firms participating in the Swedish energy program project Highland. Published with kind permission of © Elsevier 2007. All Rights Reserved [previously published in Thollander et al. (2007)]

The data presented in Fig. 6.9 capture the level of long-term energy strategy adoption in two energy-intensive industrial sectors.

From Fig. 6.9 we can see that the Swedish pulp and paper industry alone accounts for approximately 2 % of the EU-25's energy use. Surprisingly, about 20 % of Swedish pulp and paper operations lack energy strategies. The results for the Swedish foundry industry are even more surprising, more than 50 % lacking such strategies.

Figure 6.10 shows the adoption of energy strategies by Swedish non-energy-intensive SMEs, compared with the adoption by energy-intensive SMEs. Notably, the adoption of long-term energy strategies in energy-intensive SMEs is low, half of these companies lacking such strategies; the same holds for non-energy-intensive SMEs. This clearly visualizes a vast room for improvement in terms of more successful energy management practices in industrial SMEs.

Figure 6.10 shows that energy strategies are less likely to be adopted by non-energy-intensive SMEs than by energy-intensive SMEs.

The question that remains is whether this low adoption rate is endemic to Swedish industry. Figure 6.11 presents results of a 2012 study of the adoption of energy strategies by European foundries.

The results presented in Fig. 6.11 indicate that nearly half of the European foundries studied lack energy strategies.

In summary, the adoption of long-term energy strategies is not evenly distributed, even within a single industrial sector. It seems likely that whether or not a strategy is adopted depends on intraorganizational factors, not on the company's type of production.

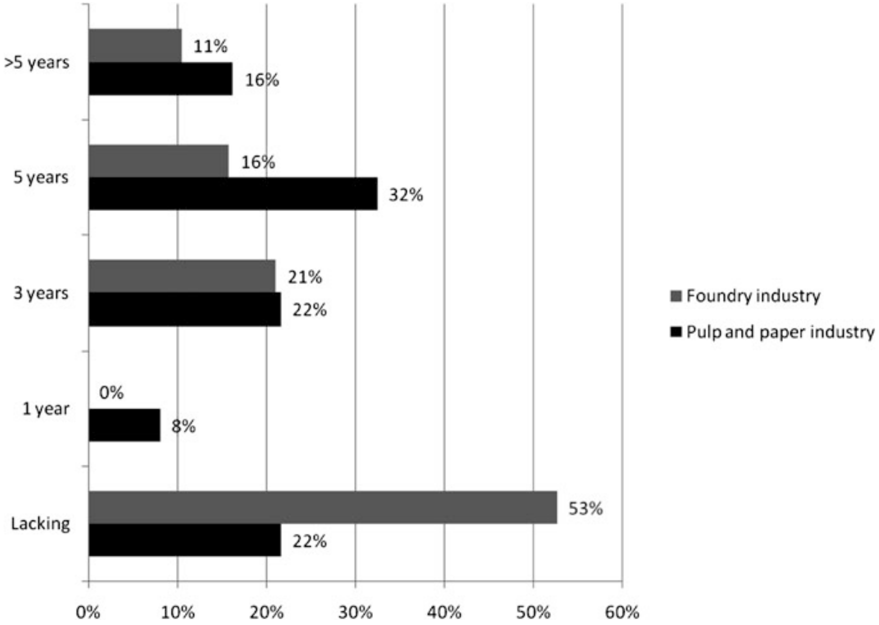

Fig. 6.9 Existence and duration of long-term energy strategies in the Swedish foundry and pulp and paper industries. Published with kind permission of © Elsevier 2010. All Rights Reserved [previously published in Thollander and Ottosson (2010)]

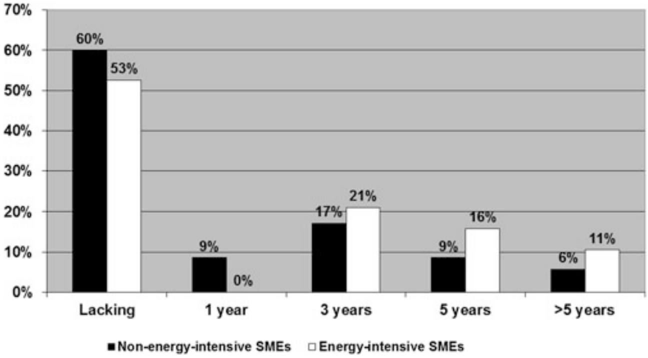

Fig. 6.10 The existence and duration of long-term energy strategies in two studied industries (Thollander et al. 2009; Thollander and Ottosson 2010)

6.10 To Concretize: Success Factors for In-House Energy Management

Based on numerous studies of companies with successful energy management practices, a range of success factors has been identified (Trygg et al. 2011). The following list should not be regarded as exhaustive, but as outlining the most

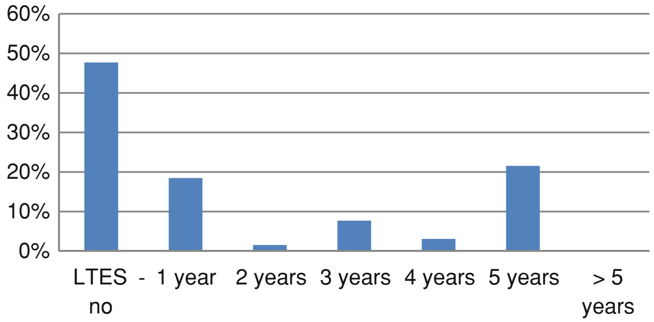

Fig. 6.11 The existence and duration of long-term energy strategies at studied European foundries in Finland, France, Germany, Italy, Poland, Spain, and Sweden (Backlund et al. 2011)

common factors promoting successful energy management practices. It is our conviction that, as it develops, future research will take us much farther in terms of identifying successful energy management practices. Nevertheless, previous research has already identified the following factors as important when it comes to the adoption of in-house energy management programs (Trygg et al. 2011):

1. top management support of the energy management program
2. create a long-term energy strategy with quantified goals for improved energy efficiency over the coming 5–10 years
3. based on the formulated strategy, create two energy plans, covering one-year and multi-year periods, respectively; involved measures should be framed in terms of technology, behavior, conversion, and reduced area to be heated
4. create an energy manager position, i.e., an energy controller; this position does not need to be full time but should be filled by someone with operational responsibility, for example, the production rather than the maintenance manager
5. set aside funding for submetering installations, preferably at the division level, to overcome the split incentive barrier
6. create clear key metrics to enable concrete follow-up of results, for example, of submetering
7. create a floor level position so that one person per shift is responsible for energy
8. provide continuous energy efficiency education to employees
9. visualize the progress of energy management work within the company and its divisions
10. set up an energy competition between divisions.

A properly conducted energy audit is the first step in initiating energy management work. Starting such work without an audit would be like having a company's controller formulate the budget without knowing the previous year's financial balance, and is similarly likely to fail. However, the initial energy audit should preferably lead to the continuous monitoring of the energy use via submetering. Results from the Netherlands and England indicate that implementing in-house energy management programs may be able to improve energy efficiency by up to 40 % (Caffal 1995). The key to such success is said to be combining management practices and traditional energy efficiency measures (Caffal 1995).

6.11 Conclusion

Society faces the great challenge of making industrial energy systems sustainable. This can be accomplished by, for example, increasing manufacturing companies' reflection on their energy use and identifying how it can be reduced. In this chapter, we have examined energy management and the need to combine top–down management leadership with worker empowerment. The lessons learned from this chapter are as follows:

- industrial companies that take a strategic approach by adopting energy management practices may reduce their energy use by up to 40 %
- strong leadership in combination with delegated authority is crucial
- a weak leader might lack the power needed to establish the new values in the organization
- delegated authority entails a degree of risk, for example, if the one with delegated responsibility lacks sufficient informal power to drive the process
- strategic energy management includes empowering individuals in an organization to work on energy management-related issues
- management research has been criticized for not going beyond the lower system levels
- relevant research has so far mainly used questionnaires and interviews
- observation can be used to examine behaviors and events in an authentic context; this would allow management research into energy to address higher system complexity levels
- for cost-effective energy efficiency measures to be implemented, companies need relevant baseline energy information, obtained using energy audits
- energy management requires the creation of ongoing internal networks
- the person responsible for the company's energy use must maintain interest in energy efficiency activities
- result governance is a management method that entails solving problems individually
- method governance is a management method that entails standardization and continuous improvement; this creates a basis for future performance.

Finally, we conclude that an energy audit conducted in-house or by external actors is a necessary first step toward the successful adoption of industrial energy management practices and may play an important role in making industrial energy systems more sustainable. However, the process cannot stop with the audit; ongoing energy management is needed to keep strategic activities moving forward.

We should note that, when it comes to providing energy audits, actors who are already very aware of their energy use display less interest in external information. Consequently, public-sponsored energy audits should initially be offered to SMEs and non-energy-intensive industries in which energy has been less prioritized. This and other policy instruments will be discussed further in the next chapter.

References

Altea (2007) Homepage of Altea AB. Available at http://www.altea.se/ Accessed 14 Dec 2011

Ammenberg J, Hjelm O (2002) The connection between environmental management systems and continual environmental performance improvements. Corporate Environ Strategy 9:183–192

Aronson E, O'Leary M (1983) The relative effectiveness of models and prompts on energy conservation: field experiment in a shower room. J Environ Syst 12:219–224

Backlund S, Thollander P, Giudici L (2011) Foundry bench: a study of barriers to and drivers for energy efficiency in the foundry industry in Finland, France, Germany, Italy, Poland, Spain and Sweden. Linköping University. Available at: www.ep.liu.se

Berne E (1964) Games people play: the basic hand book of transactional analysis. Ballantine Books, New York

Boulding KE (1956) General system theory: the skeleton of science. Manag Sci 2(3):197–208

Caffal (1995) Learning from experiences with energy management in industry. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). Analysis Series 17, Sittard, The Netherlands

Christoffersen LB, Larsen A, Togeby M (2006) Empirical analysis of energy management in Danish industry. J Clean Prod 14(5):516–526

Deming WE (1986) Out of the crisis. MIT Press, Cambridge

EC (European Commission) (2007) Observatory of European SMEs

Hrustic A, Sommarin S, Thollander P, Söderström M (2011) A simplified energy management system towards increased energy efficiency in SMEs. In: Proceedings of the world renewable energy congress 2011, Linköping

ISO (2004) Environmental management systems—requirements with guidance for use. SS-EN ISO 14001:2004, Swedish Standards Institute, Stockholm

Johansson P-E, Thollander P, Moshfegh B (2011) Towards increased energy efficiency in industry: a manager's perspective. In: Proceedings of the world renewable energy congress 2011, Linköping

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

Rosenthal R, Jacobson L (1966) Teachers' expectancies: determinants of pupils' IQ gains. Psychol Rep 19:115–118

Russell (2006) Energy management pathfindings: understanding manufacturers' ability and desire to implement energy efficiency. Strateg Plan Energy Environ 25:20–54

Syrett M (2007) Succesful strategy execution. The Economist Newspaper Ltd., London

Thollander P, Ottosson M (2010) Energy management practices in Swedish energy-intensive industries. J Clean Prod 18:125–133

Thollander P, Solding P, Söderström M (2009) Energy management in industrial SMEs. In: Proceedings of the 5th European conference on economics and management of energy in industry (ECEMEI-5), pp 1–9

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 Effic 1:21–34

Thollander P, Palm J, Söderström M (2008) Industrial energy auditing: a key to competitive energy-efficient Swedish SMEs. Invited publication in energy efficiency research advances. In: David M. Bergmann (ed) Nova Publisher, New York, pp 213–238

Thollander P, Rohdin P, Danestig M (2007) Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Policy 35:5774–5783

Trygg L, Thollander P, Backlund S, Olsson L (2011) Uthålliga energisystem i praktiken: implementering av energieffektivitet inom industrier, Linköping University. Available at www.ep.liu.se

Whyte WF (ed) (1991) Participatory action research. Sage focus editions, vol 123. Sage Publications, Inc. Thousand Oaks, pp 247

Chapter 7
Policies Promoting Improved Energy Efficiency

Abstract In this chapter, we discuss public policy as a way for governments to achieve energy-related targets. Policy seeks to influence people's behavior, so that they will act in accordance with policy maker wishes. We introduce research into public policy and discuss various policy instruments applicable to industrial SMEs. We also introduce the ecological modernization concept that, in policy analysis, captures the belief that economic and ecological values can be combined symbiotically. In this chapter, we discuss the rebound effect. This chapter also describes the EU's energy end-use efficiency and energy services directive (ESD), which came into force in 2006 and addresses several policy areas, as well as the EU emissions trading scheme. We problematize the fact that an EU policy, for example, may influence one part of the EU but not another, and that policy formulation is not the same as policy implementation—energy efficiency policy goals often being much higher than the results achieved. We also review earlier research into energy audit programs and discuss how an industrial energy program should be designed to facilitate program success.

7.1 Introduction

Governments use public policies to achieve energy-related targets, for example, increasing the share of renewable energy sources in the energy mix, improving energy efficiency, and reducing carbon dioxide emissions. National policies to improve energy efficiency can also, for example, seek to reduce oil imports, improve energy reliability, and reduce air pollution. Energy policy has recently been emphasized as a necessary tool for tackling climate change; at the same time, climate change is invoked to justify policy making in the energy sector.

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In this chapter, we will introduce research into public policy and discuss various policy instruments applicable to industrial SMEs. We will discuss the EU's energy end-use efficiency and energy services directive (ESD), which came into force in 2006 and addresses several policy areas. We will also discuss the EU emissions trading scheme as an example of a supply side policy instrument. In this regard, we will also discuss how policy can influence one part of a region while neglecting another, and problematize the fact that policy formulation is not necessarily the same as policy implementation. We will review earlier research into energy audit programs and discuss how an industrial energy program should be designed to promote program success.

We will start with an overview of the theoretical insights arising from the notion of ecological modernization, a trend in society whereby business and ecological concerns are regarded as symbiotically related.

7.2 Ecological Modernization: Ecology and Economy in Symbiosis

Sustainable development depends on an economy's capacity to modernize along ecological lines. Most economies will seek to achieve such modernization as competitively and advantageously as possible. The ecological modernization concept is used in policy analysis to capture the trend whereby societies simultaneously generate business competitiveness and environmental sustainability within the existing liberal market paradigm. One assumption of ecological modernization relates to the environmental readaptation of economic growth and industrial development. The underlying idea is that economic and ecological values can be combined so as to yield win–win outcomes. Environmental productivity represents the productive use of natural resources, such as air, water, and soil that can be sources of future growth and development in the same way as labor and capital productivity can. This entails improved energy and resource efficiency as well as product and process innovations, such as environmental management and clean technologies. The idea is to create win–win situations in which green technological innovation enhances economic profitability while benefitting the environment (Hajer 1995).

Curran (2011) claims that ecological modernization is appealing to many actors: for governments it means low electoral risk, for industry it means only incremental reform, and for society it contains costs and creates opportunities. It is simply an appealing way of marketing sustainable development. Ecological modernization privileges the role of technology and innovations in driving change, in harmony with the concurrent modernization of the political institutions and processes that would steer this change (Mol 1996).

Beck (1999) emphasizes the need for new forms of ecological governance, often referred to as subpolitics or political modernization, in which the environmental movement, community groups, and business take leadership roles in stimulating environmental transformation. Beck claims that we are suffering from institutional lag, as current institutions were developed during the industrial epoch. These institutions emphasize development characterized by consumption, in which we use resources to a maximum degree. Industrial society had a dual organizational and technological focus, to succeed in the challenge of maximizing production. According to Beck (1999), we have left behind the industrial society and now entered the “risk society” era. The problems we face today are not how to maximize production, but how to deal with the problems industrialism has created in the form of climate change, resource scarcity, and pollution. Giddens (2010) also claims that one can view structural change, stagnation, and lack of competition as parts of risk society, and as issues that all societies must address. We have not yet been able to form institutions adapted to the problems of the risk society, but still live with the institutions that worked in the industrial era.

Under ecological modernization, the state can play various roles: as *enabler* of the development of green markets, as the *regulatory medium* that forces companies to recycle waste and reintegrate it into new goods and services, and, notably, as a *dysfunctional institution* incapable of addressing critical local, national, and global environmental problems.

Next, we will delve deeper into the state’s *enabler* and *regulatory medium* roles, i.e., its role as policy maker. Public policy can be defined as the course of action or inaction taken by the state in relation to a specific issue. We will start by looking into policy analysis as a research field.

7.3 Policy Analysis and Policy as Process

From an academic perspective, policy analysis refers not only to the end result, but more broadly to the decision making and analysis of governmental issues.

Policy analysis can be divided into two major fields: analysis *of* policy is analytical and descriptive; analysis *for* policy is prescriptive, and is involved in formulating policies and proposals (Parsson 1995). When analyzing policy processes from a theoretical viewpoint, the object is public decision making, including all stages from initiation to implementation and evaluation. From this process perspective, policy is not so much about single decisions or actions, and policy is assumed to steadily change and develop (Hill 1997; Parsson 1995); accordingly, knowledge is created when actors act in specific situations, so policy cannot be traced back to a single document (Palm 2006).

In developing policies directed toward industry, industrial companies must be given a place in the policy process, something that is not obvious in either theory or practice. Traditionally, the study of policy processes has applied a top–down perspective, in which implementation is regarded as a rational process, structured from above. In theory, implementation is assigned to public administration, which is regarded as a tool of the government and is therefore assumed not to influence implementation. This process is governed by control, direct intervention, and regulation. In the 1970s, Pressman and Wildawsky (1973) developed their bottom–up perspective to serve as a counterbalance. They claimed that the implementation process itself helps formulate policy and solve political problems. According to their perspective, public and private actors participate in policy formulation and policy change, so the process cannot be specified beforehand. Later research into grassroots bureaucrats, i.e., officials such as social workers, teachers, nurses who often influence how policy is put into practice, has demonstrated that both action and decisions influence policy formulation (Lipsky 1980). According to Lipsky's (1980) bottom–up perspective, the focus of policy analysis is grassroots bureaucrats and their freedom of action to shape the final policy outcome. From this perspective, Lundquist (1987) discusses three conditions to be fulfilled in successful implementation: actors must *understand* the decision, they must *be able* to realize it, and, finally, they must have the *will* to realize it. This means that a decision must be clear in order to be understood and that actors must have enough resources (e.g., time, personnel, and economic resources) to implement it.

Traditionally, public policy implementation has not been researched at the company level, attention instead being directed toward how grassroots bureaucrats behave in the implementation phase and how the grassroots level influences policy content and consequences. Earlier policy research focusing on the state and administration stresses that the actors expected to realize policy play crucial roles. Like the professional bureaucrats who implement a policy, companies must also understand relevant public industrial policy, and be willing and have opportunities to implement it.

When discussing policy implementation and companies, policy means or instruments (here used synonymously) will be the focus. When policy instruments are emphasized, it is usually the outcomes that are of interest and how different measurement contribute to a specific outcome. Policy instruments will be discussed next.

7.4 Policy Instruments

One way politicians can steer decisions and actions taken by actors and target groups is by using policy instruments. Policy instruments are intended to influence the direction of actions, to achieve goals, or correct development paths headed in the wrong direction (Schneider and Ingram 1990). How a policy instrument is formulated depends on several considerations, such as assumptions as to how much time is needed to achieve a goal, how much one policy instrument will cost compared with another, public acceptance, and whether massive protests can be expected from stakeholders. The choice of policy instrument and how implementation measures are formed, as well as how the target group is defined, are decisive for the effectiveness of any strategy to improve industrial energy efficiency.

Policy instruments are intended to influence people's behavior, to induce them to act in ways they would not in the absence of the policy, and to ensure that these actions are in accordance with policy maker's wishes. The most powerful policy instruments are regulations and prohibitions that force people to abstain from a particular behavior or measure. These mandatory instruments are efficient at interfering with practice and hence are often implemented. The problem is that such instruments are blunt and not very flexible. They are implemented in the same way regardless of context; this can have unforeseen effects, as reality is often much more complex than policy makers can predict (Schneider and Ingram 1990).

Incentives are market-based policy instruments whereby the policy maker tries to influence the game so that one type of behavior will be more profitable than another. These include taxes and fees to increase the costs of certain products or behaviors, and subsidies to lower the costs of others. These policy instruments are fairly easy to administer. However, people do not always behave as rationally as policy makers expect. Incentives also offer a way to manipulate the market, which can obliquely drive competition (Schneider and Ingram 1990).

Capacity tools are policy instruments that encourage people to adopt certain behaviors; examples of such instruments are education and information provision. Symbolic tools are policy instruments that appeal to people's attitudes and values, attempting to enhance or alter these so that they facilitate desired changes (Schneider and Ingram 1990).

Today's energy policy has its origins in the oil crises of the 1970s. In the 1990s, energy policy increasingly came to be about the environment and the possibility of restructuring the energy system to promote increased resilience. In addition to taxes and subsidies directed toward reducing environmental impact, various standards have been formulated, justified on environmental grounds (Palm 2004, 2006).

Policy instruments in the energy area attempt to influence processes in a way that leads to more efficient or careful use of resources, bringing about more ecologically sustainable behavior (Palm 2010). The instruments promoting such development vary in form and have been referred to using various terms in earlier research. Bemelmans-Videc et al. (1998) discuss such policy instruments in terms of "carrots", "sticks", and "sermons". Sticks include regulations that the addressee is forced to follow. Carrots are economic instruments that make an action either cheaper or more expensive. Sermons, finally, are information-dissemination instruments that attempt to influence the addressee by persuasion or presenting facts on a subject. The most effective way to influence energy use, though, is to combine these three types of instruments.

Lindén et al. (2006) take a slightly different way, identifying four categories of policy instruments: information, economic, administrative, and physical improvement instruments. Information instruments represent various aspects of knowledge mediation, such as written information, labeling, and advertisements. With these policy instruments, change in behavior takes time to register. In relation to SMEs, one problem is knowing whom to target with information. As discussed in Chaps. 3 and 5 on barriers, SMEs do not always have anyone specifically responsible for energy issues, and it can be unclear who in the company should be approached. Economic instruments include taxing, pricing, subsidies, and the like. According to Lindén et al. (2006), economic instruments catalyze future change: they motivate actors to monitor and plan their behavior in an efficient way. Administrative instruments such as CO_2 emission limits, prohibitions, and legislated regulations have immediate effects, punishing deviant behavior with negative sanctions such as fines. Finally, physical improvement instruments, such as the provision of energy meters, provide immediate feedback so as to inculcate new patterns of behavior. All four types of instruments are intended to externally motivate actors to change routines and behavior.

How effective are these instruments in practice? Neij and Öfverholm (2002) review the impact of various policy instruments, arguing that the effects of taxes and targeted price increases have rarely been evaluated. The main contribution of R&D has been to improve stakeholder competence, while, for example, building codes, in addition to improving knowledge, have also increased awareness of energy issues. Regarding subsidies and loans, their effects have mainly been felt in relation to technology diffusion, but high costs and problems with free-riders, i.e., those who would have invested in promoted technologies regardless of the subsidies, are problematic. Neij and Öfverholm (2002) also note that energy labeling has influenced the supply of, for example, energy-efficient refrigerators and freezers. Technology procurement has often been conducted in combination with other policy instruments, leading to improved technology, improved stakeholder knowledge, and the successful entry of new technologies into the market. Overall, Neij and Öfverholm (2002) conclude that the most effective means of control is to combine policy instruments, for example, technology procurement, information, and education; they have little to say, however, about information and education.

Measurements to get companies economize with energy may also result in a rebound effect, which counterpoise the expected beneficial effects. That will be discussed further next.

7.5 The Rebound Effect[1]

The so-called rebound effect is a commonly cited criticism of energy efficiency (Herring 2006; Saunders 2000; Khazzoom 1980). Cost-effective energy efficiency measures are always positive as energy efficiency strengthens competitiveness through lower production costs and are also positive because energy efficiency will promote a more efficient and prosperous economy. However, it is argued to not always lead to reduced overall energy use (Herring 2006). The main idea with the rebound effect is that measurements to get companies to economize with energy can result in energy saving but it can also result in a rebound effect, which refers to behavioral response to the introduction of new technologies or measures that offset the expected beneficial effects (Berkhout et al. 2000; Sorrell et al. 2009).

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[1] Based on Thollander (2008).

The rebound effect may be split into two major categories:

- The direct rebound effect: a price effect where a new technology might increase energy efficiency corresponding to a reduction in the price of energy services that lead to an increased demand for energy (Bentzen 2004).
- The indirect rebound effect: which means that an energy efficiency activity lowers overall energy costs leading to more money left to spend on other goods and services.

The question of importance is not so much whether the rebound effect exists but rather how great the magnitude of such an effect is considered to be. The direct rebound effect for industrial process use was found to be less than 20 % and the indirect rebound effect about half a percent in a study by Greening et al. (2000). In the study it was concluded that: For the energy end-users for which studies are available, we conclude that the range of estimates for the size of the rebound effect is very low to moderate (Greening et al. 2000). In a study by Bentzen (2004) studying the direct rebound effect in US manufacturing industry between 1949 and 1999 it was found that the size of the rebound effect was likely to be less than 24 % for the sector.

With the rebound effect in mind, we will now discuss examples of policy development in the energy area, starting with policy making in the EU.

7.6 The Energy End-Use Efficiency and Energy Services Directive[2]

The liberalization of the EU energy sector began with a 1996 directive aimed at developing an internal market for electricity. Parallel to this, the EU also addressed energy efficiency and issues concerning security of energy supply.

The ESD was tabled by the Prodi Commission in 2003. The aim was to increase energy savings when energy was sold to end-users, including industry, households, and the public sector.

The ESD, which came into force in 2006, proposes a 9 % reduction in energy use in each Member State, to be achieved by the ninth year of application of the directive (EC 2006). The ESD addresses several policy areas and energy efficiency services, such as the availability of energy auditing to small- and medium-sized industrial customers. It also highlights the availability of energy efficiency funds to all market actors and promotes energy audits and financial incentives promoting the adoption of energy efficiency measures and energy services. The ESD aims to enhance the cost-effective improvement of energy end-use efficiency in Member States by:

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[2] Bases on Palm and Thollander (2010).

> (a) providing the necessary indicative targets as well as mechanisms, incentives and institutional, financial and legal frameworks to remove existing market barriers and imperfections (market failures) that impede the efficient end-use of energy and (b) creating the conditions for the development and promotion of a market for energy services and for the delivery of other energy efficiency improvement measures to final consumers. (EC 2006).

Companies participating in the EU European Trading Scheme (EU ETS) are, however, not covered by the Directive (EC 2006).

In this way, the EU is going a step further than traditional economic policies based on mainstream economic theory, as the Directive's aim is to eliminate both market imperfections and market barriers (EC 2006). The ESD promotes, among other things, efforts to find feasible energy end-use policy initiatives directed toward SMEs in a national context:

> In order to enable final consumers to make better informed decisions as regards their individual energy use, they should be provided with a reasonable amount of information thereon and with other relevant information, such as information on available energy efficiency improvement measures. (EC 2006).

The Directive includes obligations applying to national public authorities regarding energy savings and energy-efficient procurement, and measures to promote energy efficiency and energy services. It has been left to each Member State to design and adopt national energy efficiency action plans (NEEAPs) to fulfill the terms of the ESD.

One criticism of energy policies and programs is that technological advances and rising energy prices will cause energy efficiency measures to be implemented in any case, even without government intervention (Geller and Attali 2005). Yet another argument is that factors opposing the implementation of energy-efficient technologies do not represent market failure or market imperfection barriers but simply market barriers (Sutherland 1996). These arguments refer to mainstream economic policy, which relies greatly on the market and its self-regulatory mechanisms in seeking to improve energy efficiency (Jaffe and Stavins 1994). This means that, for public intervention to be implemented, the factors inhibiting the adoption of energy efficiency technologies must be categorized as market failures or market imperfections, of which there are four broad types: incomplete markets, imperfect competition, imperfect information, and information asymmetry.

Via the ESD, the EU has given the Member States specific goals and a framework in which to work; it is then up to the Member States to concretize these goals and develop their own national processes and priorities. This will lead to differences between Member States in terms of the program content, actors included, and time needed for various measures.

Next, we explore how EU policy can affect different parts of the EU in different ways.

7.7 Asymmetric Energy Policy Shocks (AEPSs)[3]

An asymmetric shock in a monetary union refers to the occurrence of effects in one part of the union that do not occur in another. Thollander et al. (2012) introduced the term "AEPSs", defined as the strong effects of an energy policy in one part of a region or sector while other regions and sectors remain less affected. The sections below briefly introduce this concept in relation to some of the key challenges related to the Member States and EU energy policy development and formulation needed to achieve the EU 2020 primary energy target.

The EU 2020 primary energy target states that the EU is to reduce energy intensity by 3.3 % per year, and that the major industrial energy efficiency potential, stated by the Commission to be 25 %, is found in the support processes such as ventilation and lighting (EC 2006). However, while this is the case in EU industry as a whole, in regions with a large proportion of energy-intensive process industry, this fails to fully hold, for example, in Sweden, where 75 % of industrial energy is used in energy-intensive industry. The different proportions of energy-intensive industry in EU Member States lead to implementation asymmetry regarding the EU 2020 primary energy target, an example of an AEPS.

Yet another AEPS related to the EU 2020 primary energy target is the diversity of renewable energy sources (RESs) used in EU Member States. While the amount of renewable energy used by the EU economy as a whole represents a small portion of the aggregated energy end-use, this is not the case in all Member States. In Sweden, for example, RESs accounted for 39.8 % of the energy mix in 2005 and, according to the 2020 RES target, this proportion should reach 49 % in 2020. In relation to achieving a 3.3 % annual reduction in energy intensity, Member States such as Sweden, which make great use of renewable energy, naturally form part of a pattern of implementation asymmetry.

The Swedish industrial sector, for example, has already undertaken large-scale conversions from fossil fuels to RESs. Naturally, this restricts the sector's ability to implement further RES-related conversion measures, representing yet another example of implementation asymmetry. Moreover, energy end-use efficiency measures will include RESs in the Swedish case, negatively affecting the possibility that Sweden will meet the EU 2020 primary energy target.

Yet another example of an AEPS is that of the Swedish pulp and paper industry (PPI). The Swedish PPI accounts for half of Swedish industrial energy use, which makes this sector important if aiming to achieve a more efficient use of biomass. This is in direct contradiction to the target of increasing the use of RES in Sweden from 39.8 % of all energy in 2005 to 49 % in 2020.

In relation to AEPSs, a third challenge is research into technological development. Utterback (1996) states that technological development often passes through several phases before transitioning into a phase involving strong competition among a few large market actors. Research into technological

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[3] A version of the following section was previously published in Thollander et al. (2012).

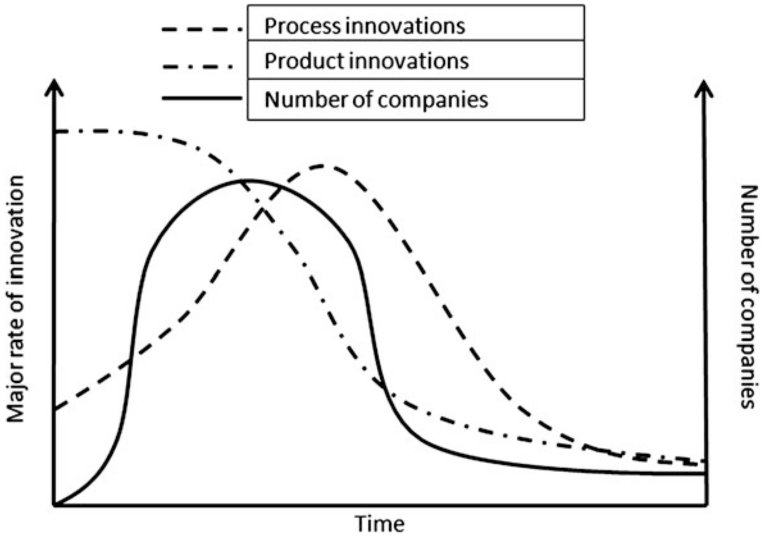

Fig. 7.1 Technological development (based on Utterback 1996)

development finds that development occurs in steps. When a new technology is first invented and reaches the market, this follows a pattern in which major product-related technical innovations are made first; as the product and market develop, innovations are also made in relation to the production process. The initial phase of technological development is characterized by a large number of entrepreneurial SMEs. As the product and market become more mature, the number of major innovations in the product and process gradually decrease (see Fig. 7.1).

During this mature phase, most manufacturers are, for competitive reasons, forced to leave the market, which is characterized by large manufacturers with very cost-effective manufacturing processes.

In relation to the EU 2020 primary energy target, it is obvious that there are limited opportunities to achieve substantial energy savings in a sector that has already reached this mature phase. This is because, over the years, actors with limited success at reducing costs—energy efficiency definitely being a major cost-reduction area in energy-intensive industries—have already been forced to leave the market. Research into the Swedish PPI has found that: “respondents feel that their industry has gone through—and is still going through—a globalization and consolidation phase that has led to tougher competition, which in turn exposes the companies to constant pressure to improve their cost-effectiveness” (Sandberg 2004; Möllersten 2002). Moreover, research states that major energy cost increases affecting Swedish industry have led to the shutdown of certain PPI actors (Thollander and Ottosson 2010).

In conclusion, actors still on the market in mature industries can to some extent already be seen as efficient in terms of, for example, energy use. Moreover, these mature industries, for example, energy-intensive industries such as PPI or iron and steel, often produce less added value than do other less mature industries.

7.7.1 Implications of AEPSs in Relation to Energy End-Use Policy Cost-Effectiveness

In relation to the three outlined AEPSs, the cost-effectiveness of various energy end-use policies indicates the risk that individual Member States will face if AEPSs occur. Research into the cost-effectiveness of the two current major industrial energy end-use policies in place in Sweden indicates a cost-effectiveness of 200–400 kWh/EUR for the Swedish energy audit program directed toward SMEs and non-energy-intensive industries (Thollander and Dotzauer 2010), i.e., industries in which the major energy efficiency opportunities are found in the support processes such as ventilation and lighting, as stated by the EC (2006). However, the cost-effectiveness of the Swedish LTA program, PFE, directed toward electricity-intensive industry, is around 10 kWh/EUR (Thollander and Rohdin 2010). This comparison of the cost-effectiveness of existing Swedish energy policies targeting energy-intensive and non-energy-intensive industry indicates that AEPSs will in fact pose a key challenge to some Member States, a challenge the EU will have to resolve. In the case of Sweden, meeting the EU 2020 primary energy target will be considerably more costly due to the occurrence of AEPSs.

In summary, EU Member States with (1) a large proportion of energy-intensive industry, (2) a large proportion of mature industrial sectors, and (3) extensive use of RESs in the energy mix will have to take a more costly approach to achieving the EU 2020 primary energy target due to the existence of AEPSs. AEPSs are also likely to affect Member States with a large need for space heating or cooling.

We will next discuss policy implementation, emphasizing implementation structures and implementation successes and failures.

7.8 Policy Implementation Through Energy Networks

Hjern and Porter (1981) describe how, when policy is to be implemented, actors form implementation networks to achieve the desired results. Such implementation structures represent a kind of infrastructure that, from a bottom-up perspective, facilitates the activities needed for successful policy implementation. In this way, policy makers do not need to organize policy implementation; instead, other actors exploit the framework the regulators try to create through institutional change. In this way, clusters are formed to co-ordinate policy implementation activities.

An important aspect of changing social direction is the facilitation of new networks of actors who are striving to create new, workable ideas. This requires the mobilization of various actors who co-ordinate their resources to create something new, yet to be developed. This calls for a development process in which actors together drive a process by which institutions, technology, and new solutions develop that foster long-term change in societal attitudes. In political science, this shift to a networked society in which policy making is done in networks consisting of private and public actors is called governance. Policy making in most Western states is today arguably characterized by a process of opening up government to broader governance partnerships and network-oriented decision making involving intricate interplay among public, private, and non-profit organizations. The role of local government then changes, and local government becomes just one of many players (Pierre and Peters 2000). Governance structures have developed in response to the state's increased need to mobilize actors (and their resources) outside their formal contexts, in order to formulate and implement public policy (Wihlborg and Palm 2008).

Business activity also arises from this new trend toward co-operation in networks. Porter (1990) emphasizes that clusters of co-operating companies create both efficiency and competitive advantages for member companies. Another way to achieve energy reduction within companies is to use supply side policy instruments such as emission trading schemes. How these have been used within the EU will be discussed next.

7.9 Energy Efficiency Related to the EU ETS[4]

Growing concern for increased global warming resulting from the use of fossil fuels has led to the implementation of a number of supply side policy instruments, e.g., the EU ETS using EU allowances (EUAs).

The EU ETS works on the cap and trade principle. This means there is a cap, or limit, on the total amount of certain greenhouse gases that can be emitted by the factories, power plants, and other installations in the system. Within this cap, companies receive emission allowances which they can sell to or buy from one another as needed. The limit on the total number of allowances available ensures that they have a value.

At the end of each year each company must yield enough allowances to cover all its emissions, otherwise heavy fines are imposed. If a company reduces its emissions, it can keep the spare allowances to cover its future needs or else sell them to another company. The idea is that the flexibility that trading brings will ensure that emissions are cut where it costs least to do so. The number of allowances is reduced over time so that total emissions fall. In 2020 emissions will be 21 % lower than in 2005 if the system works as expected.

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[4] Based on Thollander (2008), and Thollander and Gustafson (2011).

The introduction of the EU ETS within parts of the European economy began on 1 January 2005 and continued through 2007. The European Union's emission trading includes only a limited number of actors, mostly energy supply and energy-intensive demand side companies.[5] All Member States of the Union must participate.

The concept was evaluated after the first period and a new period began for 2008–2012. During the first (2005–2007) and second (2008–2012) phases of the EU ETS, each Member State set the size of the cap for EUAs available for companies under its jurisdiction in a so-called National Allocation Plan. From 2013, the energy and climate package will no longer include such national emission budgets. Instead, the total cap for the third phase (2013–2020) is scheduled to be set centrally and will include a linear decrease of 1.74 % annually. With the EU ETS, the carbon dioxide emission level within the European Union is fixed within parts of the economy.

One other type of criticism regarding energy efficiency and the EU ETS is closely related to the rebound effect. It concerns that energy efficiency actions related to electricity and district heating, resulting from for example the implementation of industrial energy efficiency measures, will not necessarily result in lower carbon dioxide emissions within an ETS period. Put in another way, it is argued that a more efficient use of energy will not always result in lower emissions of carbon dioxide. In fact, in SCC (2008) is has been confirmed that energy efficiency within an EU ETS period will not reduce the carbon dioxide emissions (SCC 2008):

> Lowering the electricity demand in Sweden gives rise to reduced production in coal fired power plants and thus lowers the electricity production in other European countries. This reduction, however, takes place within the EU ETS. Electricity efficiency (as well as the use of district heating) has, therefore, in the short run—within an EU ETS period—no effect on the emissions within the EU ETS. However, prices within the EU ETS are under pressure and it will be possible to lower the emissions level at a lower cost, compared with if no energy efficiency actions had taken place. The prerequisites for lowering the cap and by doing so lowering the emissions from production plants on the continent, are therefore enhanced, Efficiency activities thus affect, in a long-term perspective, the possibilities to lower the emissions. (SCC 2008).

On the other hand, lower use of energy within the EU ETS will cause EUAs to be set free. According to mainstream economic theory, when these are sold on the EU ETS market, this will force prices of EUAs down and demand will consequently increase. From an energy efficiency point of view, the EU ETS is leading to increased energy prices, which, again according to mainstream economic theory, will mean that more cost-efficient energy efficiency measures will be implemented. However, as previously stated, these measures will not necessarily lead to reduced emissions of carbon dioxide (SCC 2008). Reduced emissions are currently

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[5] The types of utilities concerned during the 2005-2007 period, include plants with an installed capacity above 20 MW, a mineral oil refinery, coke plants, and companies producing and refining iron, steel, glass and glass fiber, cement, pulp and paper.

achieved through a political decision to lower the carbon dioxide emission level or through a demand change, caused for example by higher prices for EUAs. The EU ETS may be one of the most important environmental policy instruments for reducing the threat of increased global warming, but, as outlined above, their areas of improvement, e.g., in order to achieve faster carbon dioxide emission reductions. In order to improve the EU ETS, an extensive review of the scheme has been undertaken to spot significant areas of improvement of the policy (EC 2011). However, the previously outlined limitation that undertaken energy end-use efficiency measures regarding electricity and district heating will not necessarily result in lower carbon dioxide emissions during a trading period have not explicitly been stated in that review (EC 2011).

7.9.1 A Means to Merge Energy End-Use Policy Programs and the EU ETS[6]

The criticism that the EU ETS leads to zero carbon dioxide emissions effects for energy efficiency programs such as, e.g., industrial energy audit programs in the short run, has by Thollander and Gustafsson (2011) been suggested to be faced by a means merging energy policy programs and the EU ETS.

The proposed energy policy concept means that the EU should centrally withdraw (buy) EUAs from the EU ETS, equivalent to the energy saved in undertaken energy end-use measures directly after measures have been adopted. The idea is presented Fig. 7.2. The proposed concept is argued to result in faster reductions of carbon dioxide emissions, even within an EU ETS period, as the number of available EUAs is lowered continuously when demand side actors invest in energy-efficient technologies. The carbon dioxide emission cap is thus not solely lowered intermittently, using a top-down approach, as is currently the case, i.e., is lowered in between two EU ETS periods or as will occur in the third phase, each year (Thollander and Gustafsson 2011).

The most prominent advantage of the proposed policy concept is faster carbon dioxide emission reductions, even during an EU ETS period, as the number of available EUAs is withdrawn continuously when demand-side actors invest in energy efficient technologies. In fact, the concept may reduce EU carbon dioxide emission figures substantially within an EU ETS period. For an illustration of this, see the shaded areas in Fig. 7.2.

The cap between period X1 and X2 is lowered with i + j. The achievement with the proposed concept is simply a faster feedback to the system. Assuming, as in Fig. 7.2 that 50 % of the energy end-use measures implemented during a trading period (the gray shaded area) are possible to include within the proposed policy concept, this means that the area [(X1 * i)/2] representing carbon dioxide emission

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[6] Based on Thollander (2008), and Thollander and Gustafsson (2011)

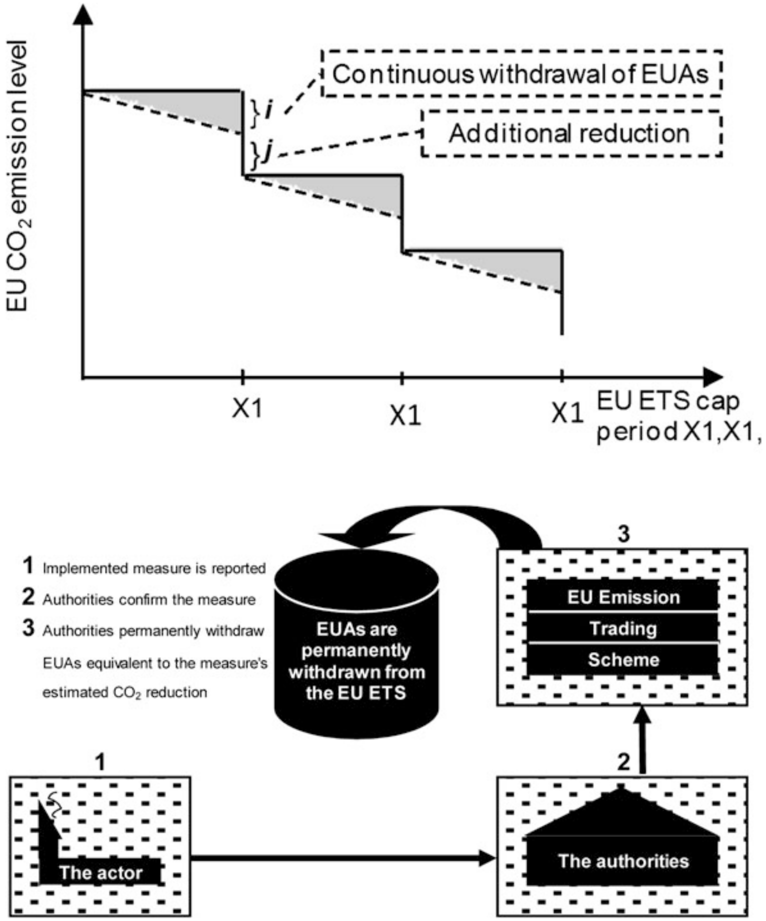

Fig. 7.2 The policy proposals and its effect on European carbon dioxide emissions, i.e., the effect when combining the EU ETS and, for example, measures from policies launched as a result of the ESD. The shaded area represents actual reductions in carbon dioxide emissions using a combined bottom-up and top-down approach. Published with kind permission of © Nova 2011. All rights reserved [Previously published in Thollander and Gustafson (2011), Nova]

are reduced during the trading period X1. In absolute figures, for period X1, assuming that energy end-use measures are possible to quantify in terms of carbon dioxide emission and that EUAs are withdrawn instantly after a measure has been reported, the EU will cut carbon dioxide emission with 25 % [(X1 * i)/2]/([X1 * (i + j)]).

Thus, the effect of the proposed concept in terms of carbon dioxide emission reductions could be expressed as the number of possible measures divided by two, e.g., assuming that only 10 % of the energy end-use efficiency measures are possible to include, using the same calculation as above, 5 % more efficient carbon dioxide emission reductions are achieved.

Next we will discuss another problem in relation to the goal to reduce energy use to reduce greenhouse gas emissions and that is that not all cost-effective energy-efficient measures are implemented.

7.10 Energy Efficiency *Potential* Not Equivalent to Actual Outcome[7]

The scientific literature on energy efficiency *potential* versus the actual outcomes of energy programs is scarce. By highlighting the energy efficiency potentials of new energy-efficient technologies, researchers sometimes imply that energy efficiency *potential* is equivalent to the actual level of implementation. The world's largest industrial energy program, covering more than 10,000 industrial companies and run by the American industrial assessment centre (IAC), has an implementation rate of 50 %, i.e., half of the measures proposed in energy audits are in fact implemented (Corbett et al. 2009; Anderson and Newell 2004). Evaluation of Sweden's largest industrial program finds an implementation rate of 22 % of proposed measures implemented, 44 % if planned measures are included (Thollander et al. 2007), while the Australian EEAP has an implementation rate of 82 % (Harris et al. 2000). However, the Australian results were not based on the full energy efficiency potential; instead, a few selected technology investments (on average, six proposed measures per firm) were more thoroughly investigated. Improving energy efficiency by 20 %, versus a stated potential for European industry of about 25 % according to the EC (2006), would call for an 80 % adoption level of proposed measures. So far, research has found that such a level is very seldom reached in an energy program, and an 80 % adoption level has, to the authors' knowledge, never been reached in any European energy program targeting the industrial sector. This accentuates the urgent need for new innovative policy approaches to address this challenge.

7.11 Designing Energy Policies Differently for Different Sectors[8]

It is a great challenge to formulate different policies for different sectors (Ramirez et al. 2005). If this is not done, energy policies may end up being designed uniformly, independent of the sector targeted. This challenge has been explored by

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[7] A version of the following section was previously published in Thollander et al. (2012).

[8] The following section represents a development of Thollander et al. (2012).

research into barriers to energy efficiency, which reveals that the barriers differ between sectors. One such example is energy audits and energy networks. Energy audits, according to the European Commission and the ESD (EC 2006), are a major means of increasing energy efficiency in European SMEs. However, an energy audit program targeting the energy-intensive process industry may not be the optimal policy of choice; this is partly due to the considerable time needed for data collection, and partly because a time-constrained auditor may be unable to do full justice to the complexity of the industry's energy systems. These two factors may make a policy favoring energy audits not very cost-effective: an energy audit program targeting energy-intensive industry may be less cost-effective than a similar program targeting industrial SMEs, as demonstrated by, for example, Thollander and Rohdin (2010).

Energy network policies, a type of information policy that has become more common in a number of local, regional, or sector-specific Swedish programs, have achieved considerable success in energy-intensive industry. In energy networks in this sector, energy controllers, experts in their field, meet and share their positive and negative experience of various technological options. However, energy networks in non-energy-intensive sectors, such as industrial SMEs, are likely to fail, as either nobody is specifically responsible for energy controlling in such firms, or because the person in charge lacks the necessary time or knowledge (Shipley and Elliot 2001). In summary, information assimilation difficulties among industrial SMEs constitute a major barrier, not lack of information per se (e.g., Schleich and Gruber 2008; Thollander et al. 2007; Shipley and Elliot 2001). Evaluation of energy information programs targeting households has revealed that information programs can increase knowledge of the negative environmental effects of individual energy use (Stern and Aronson 1984). However, changes in actual behavior or investment patterns were found to be lacking (Palm 2010). This suggests that energy information programs, including energy networks, targeting low energy-using sectors could well fail.

There are technical, social, and organizational reasons why optimal energy efficiency measures are not being implemented by industrial companies, and simply acknowledging that fact would have positive consequences for policy development. Common policy instruments such as taxation and subsidies could arguably be combined with information and discussion across established professions and sectors. For example, creating actor networks crossing established sector boundaries would challenge established norms and routines. Moreover, by realizing the importance of the social construction of technological development and of the spread of energy-efficient technologies, other policy instruments would become relevant, such as networks promoting energy services and energy efficiency. In such a scenario, purely economic incentives would perhaps prove not to be the most efficient policy instruments, which might instead be workshops, seminars, energy clusters, or other open networks in which established norms, routines, and tacit knowledge are highlighted and challenged.

7.12 Policy Instruments in Relation to Barriers[9]

In sectors in which technical risks, such as the risk of production disruptions and the associated costs, are considered major barriers, we need thorough studies of energy efficiency issues before appropriate measures can be justified. In the foundry industry, for example, one such instrument found to be successful is the MIND method (method for analysis of industrial energy systems), in which various investment options can be optimized (Thollander et al. 2008). Other such instruments include various investment decision support tools, such as manufacturing simulation (e.g., Solding and Thollander 2006), which can reduce energy use in production processes by up to 10 %.

Another type of barrier, the possibility of poorly performing new equipment, is considered somewhat important in the energy-intensive foundry industry, though this barrier was found to be less important in earlier studies of non-energy-intensive manufacturers and SMEs. In sectors in which this barrier is of greater importance, plausible policy measures would include practical research into various energy efficiency measures and examples of successfully implemented measures in various industries.

Lack of time and other priorities are often cited as major barriers (except in foundries). As regards SMEs and non-energy-intensive manufacturers, this clearly indicates a need for simplicity when it comes to adopting energy end-use policies. While larger energy-intensive companies have the resources to join, for example, LTA programs, non-energy-intensive manufacturers, industrial SMEs in particular, do not have the time to invest in such activities; moreover, they have insufficient time to apply to various investment funds. One policy instrument that has been used in the Netherlands, and that is proposed in the ESD, is that of investment funds. The fact that lack of access to capital is a major barrier indicates that this might be a sound policy. However, application of the policy in Dutch industry indicated a free-rider effect of at least 85 % (Farla and Blok 1995). Among German SMEs, providing a subsidy for energy audits did not prove to be successful. Swedish experience from the 1970s indicates similar results: only about 10 % of Swedish companies accessed such investment funds (Persson 1990). Interestingly, the results of the barrier studies presented here seem to indicate why energy is not prioritized by non-energy-intensive manufacturers, especially not by SMEs. Although investment funding is offered, it is unlikely to be successful in companies in which lack of time and other priorities are major barriers, i.e., in non-energy-intensive industries. In contrast, such a measure would likely succeed in an industry in which lack of time and other priorities are not major barriers. Such companies will likely have the time to complete the forms and apply for such funds. LTAs may thus be a good way to target energy-intensive manufacturers and energy-intensive SMEs with such funding policy measures. Results for the

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[9] The following section is based on Thollander (2008).

Swedish PPI regarding driving forces indicate that the current LTA, the Swedish PFE, is much appreciated (Thollander and Ottosson 2008).

As regards non-energy-intensive manufacturers and SMEs, a plausible policy measure found to be successful in both Sweden (Thollander et al. 2005) and elsewhere (Anderson and Newell 2004) is to offer energy audits free of charge. Earlier empirical studies indicate that such an approach is also useful in lowering barriers such as lack of budget funding and other capital investment priorities.

Results from Germany indicate that energy audits do lower the barriers to energy efficiency (Schleich 2004). The question that remains is who should carry out such audits of non-energy-intensive sectors and SMEs. Using actors considered trustworthy is key, which indicates that sector organizations, in cases where they are considered trustworthy, would be appropriate candidates. However, regional energy agencies could also be used. Notably, both the ESD and reports on Swedish NEEAPs state that it is crucial that the authorities act as role models (EC 2006).

Next, we will use results of earlier studies of energy audit programs to consider how industrial energy programs should be designed to maximize the chances of program success.

7.13 Structuring an Energy Audit Program for Industrial SMEs[10]

In designing an industrial energy program, several elements need to be considered, such as program goal formulation, implementation instruments, key players, and administrative structure (Väisänen 2003). For an overview of these elements (please see Fig. 7.3).

Appropriate goals are crucial for program success (Väisänen 2003). Program goal formulation should take account of, for example, target sectors, estimated free-rider coefficients, total energy audit volumes, and likely program effects (Väisänen 2003). In the context of such programs, the legislative framework, subsidy policy, and promotion and marketing measures are among the implementation instruments. As regards key players, four are of importance (Väisänen 2003): administrator, operating agent, auditor, and client. The administrator, usually a government department, is the one initiating the program, while the operating agent is responsible for managing the program and is accountable to the administrator (Väisänen 2003). The auditor in turn conducts the energy audit and has the closest contact with the client. Either the auditor or the client usually reports the results of the energy audit to the operating agent (Väisänen 2003).

The cost-effectiveness of a program is dependent on the size of the subsidy (Väisänen 2003). Too small a subsidy will mean that only those companies that

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[10] Based on Thollander and Dotzauer (2010).

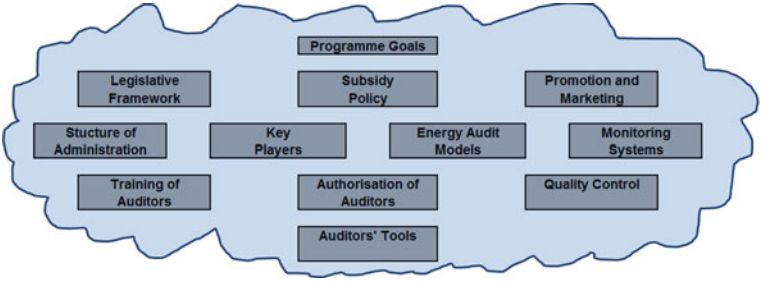

Fig. 7.3 Twelve important elements in the design of an energy audit program (Väisänen 2003)

would have conducted an energy audit in any case will participate. Too high a subsidy, in contrast, reduces the cost-effectiveness of the program. Company interest is also dependent on the relative size of the subsidy, a 100 % subsidy creating the risk of low participating company interest in the energy audit results. If the program is voluntary, marketing should be central (Väisänen 2003).

An industrial energy audit program demands more resources in the initiation phase than during the actual operation, so that the longer the program duration, the greater its cost-effectiveness (Väisänen 2003). A longer term scenario should therefore be considered for industrial energy programs than, for example, for energy policies involving solely an investment subsidy for energy efficiency technologies (Väisänen 2003). The next section outlines the proposed design of the Swedish energy audit program, including a brief look at the underlying logic of the proposed program.

7.13.1 Fully or Partly Subsidized Energy Audits

The degree of subsidy varies between programs and countries. The world's largest energy audit program—the American IAC program—offers industrial SMEs energy audits free of charge without any agreements (Anderson and Newell 2004). The Finnish program offers a subsidy of 40 % of the energy audit cost, while the Norwegian program offered energy audits free of charge, but with some requirements to be met in terms of energy management practices (Väisänen 2003; Christensen and Aamodt-Espegren 2002). From a public finance perspective, it is more effective to offer partly subsidized audits, as this enhances program cost-effectiveness, i.e., more kWh are saved per public Euro invested. From the energy auditor's perspective, partial subsidization is also beneficial, as it will likely increase the attention paid to audit results by the involved companies. Moreover, partial subsidy means that only genuinely interested companies will likely join the program. This is perhaps the largest disadvantage of such a design: companies that lack the time (the largest barrier among the industrial SMEs evaluated in the

Swedish Project Highland) and that have not articulated a desire for such an audit might not participate; moreover, such companies may not be particularly interested in actually implementing measures identified in the energy audits even if they did participate. How to design such partially subsidized programs is difficult to determine, especially given that international comparisons indicate that subsidies differ greatly between programs. As the EU's industrial energy program is intended to lower overall energy use, and because the ESD states that energy audits play a central role in this, as many companies as possible should be induced to join the program. In other words, it seems desirable to offer partly subsidized energy audits. The Finnish program, found to be the most cost-effective in an evaluation of 42 European energy programs (Väisänen 2003; Christensen and Aamodt-Espegren 2002), initially offered energy audits with a 50 % subsidy, declining to 40 % as the program matured. The new Swedish energy audit program offers a 50 % subsidy as well (Thollander and Dotzauer 2010).

7.13.2 Scope of Energy Audits

The cost-effectiveness of an energy audit depends on both the size of the subsidy and whether the audit includes investment assessments. The Swedish energy program, Project Highland, was the largest Swedish energy program since 1990 in terms of participating companies. This program involved so-called "walk-through" audits, not including investment assessments. Comparing this with the world's largest energy audit program targeting industrial SMEs, the American IAC program, in which some 14,000 energy audits *including investment assessments* have been made since the 1990s, indicates that the proportion of implemented measures was higher in the IAC program (Corbett et al. 2009). Around 50 % of recommended measures were implemented in the IAC program and 20 % in Project Highland. Notably, the Project Highland figure does not include planned measures; if these are included, the figure rises to about 40 %. In the Australian enterprise energy audit program (EEAP), which offered energy audits including investment assessment with a 50 % subsidy, around 80 % of the recommended measures were implemented (Harris et al. 2000). As regards the average number of proposed measures per participant in the energy audit reports, Project Highland proposed 13 each, compared with the IAC's and EEAP's seven.

Although including investment assessments of the measures identified in the energy audits may increase the number of implemented measures, doing so may be excessively costly (for the energy auditor), possibly lowering the program's cost-effectiveness. Including investment assessments in the form of straight pay-off periods for each measure, however, is simpler and should not greatly increase costs. Audits within an industrial energy program should therefore include simple investment assessments in the form of straight pay-off periods. Moreover, the administrative agent should present general figures for common energy efficiency measures; this would support the energy auditors in the important task of estimating pay-off periods while reducing the audit cost, thus increasing program cost-effectiveness.

7.13.3 Coverage of the Industrial Sector: A Swedish Example

A Swedish Government Bill in 2008 proposed that companies using 500 MWh per year or more of energy should be targeted in an industrial energy audit program. At an estimated energy cost of EUR 40 per MWh, this means that companies using 500 MWh annually have energy costs of at least EUR 20,000 per year. Evaluation of the Project Highland energy program indicated that bare-minimum "walk-through" energy audits took one auditor about two working days. At a cost per consultant of around EUR 100 per hour, this represents around EU 1,500 per audit, excluding metering and travel expenses. Including all costs, the total cost of EUR 2,000 per audit seemed reasonable, as it represented only about 10 % of the smallest company's annual energy costs. Using this criterion and an estimated energy cost of EUR 40 per MWh, companies using 5,000 MWh per year would gain an effective subsidy of approximately EUR 20,000 or more (representing 10 % of the company's energy expense). This can be considered excessive, because the costs of auditing larger SMEs may not increase exponentially. Consider that the average energy use of Project Highland participants was about 4,000 MWh/year, and that auditing these cost an average of approximately EUR 1,500 per firm. This indicates that energy auditors should be able to audit industries up to approximately that size in terms of energy use in about 2 days. The proposed energy audit subsidy was thus set to a minimum of EUR 1,000, half of the estimated cost of a two-day audit, excluding the cost of program administration. As the program's target sector comprised industrial SMEs, an upper limit of EUR 3,000 per audit was suggested, excluding the cost of program administration. This cost ceiling is arguably somewhat arbitrary and was not based on field research as no such research could be found. The ceiling instead represents an attempt to minimize the free-rider effect and maximize program cost-effectiveness. If no limit was set, then larger participating companies would use too much of the program budget, even though they are not the program's target sector. Moreover, these companies likely have sufficient resources to conduct audits even without subsidies.

7.13.4 A Energy Audit program Versus an LTA program

Studies of industry's view of various energy policies find that industrial SMEs are not interested in full-scale LTA programs such as PFE (Thollander et al. 2009). Previous research into barriers to energy efficiency in Sweden, outlined in Chap. 3, and previous international studies of energy programs targeting industrial SMEs (e.g., Shipley and Elliot 2001) suggest that this is due to severe limits of time, resources, etc. While a larger company may have specific staff working only on energy efficiency and energy management, SMEs lack such personnel resources (Shipley and Elliot 2001). However, based on research into energy management and its potential, as outlined in Chap. 6, it seems reasonable to include certain LTA elements in industrial energy programs targeting industrial SMEs. Based on earlier research into key energy management factors (e.g., Caffal 1995), energy programs targeting industrial SMEs should incorporate the following requirements included in LTAs:

- companies should report energy audit results, including annual energy use
- companies should present the potential energy efficiency measures identified in the energy audits, including the overall energy efficiency potential
- companies should present a simple energy plan detailing planned measures, including when implementation is expected; mandatory implementation of these measures is not required
- for a certain period after receiving subsidies, companies should annually report the measures implemented or not implemented.

7.13.5 Choice of Operating Agent and Local Authority Involvement

As regards the operating agent, there are several main actors to choose from in the Swedish case: county administrative boards (CABs), the Swedish Energy Agency, and regional energy agencies. Letting a CAB operate an energy audit program may lead to uncertain results, as the board would then have the dual role of both promoting energy efficiency (through the program) and enforcing national environmental laws and regulations. CABs, however, would be able to compel industries to conduct energy audits, thereby increasing the number of participating companies. For a CAB to be a credible program operating agent, it would be crucial that CAB enforcement efforts not be stricter than mandated by program requirements.

Regional energy agencies would also be questionable operating agent candidates, as these agencies, at least in Sweden, have little experience of industrial issues.

The Swedish Energy Agency may well be the best choice for operating agent, as it possesses competence in industrial energy efficiency but does not act as an enforcer.

Regional energy agencies could be responsible for collecting the energy audit reports and for the annual evaluation of the audits. They would be appropriate for this role for three reasons. First, this would enable a regional overview of program implementation, which is crucial for evaluating regional climate goals. Second, this would allow participating firms to direct questions about the audits toward an objective actor. This could well increase the level of program participation as well as the implementation of identified measures. Third, this would spur the establishment of regional networks. Inspired by the Norwegian program, the regional energy agencies could also be responsible for the training and accreditation of the energy auditors, if it is determined that this is needed.

Based on the design of the Swedish program, Project Highland, it might be appropriate that publicly sponsored energy consultants attached to the relevant local authority, if such exist in a county or region, be responsible for marketing the energy audit program. According to some companies involved in Project Highland, the project was perceived as “the best” the municipality had ever run to support their businesses. Involving the local authority’s energy consultants in marketing such programs would arguably help anchor them locally (Persson 1990).

7.14 Evaluating Energy Audit Programs

In order to gain knowledge about the outcome of an energy program, energy program evaluation is an important research discipline. Evaluation of energy programs consists of two phases: information gathering and analysis (Väisänen 2003). For an energy program evaluation, typical questions that may be of interest are (Väisänen 2003):

- Program interest in terms of applications received and the amount of audits undertaken.
- The impact of the program in terms of energy actually saved and the quality of these units.
- The amount of public money spent per kWh saved.
- The environmental impacts.
- The target groups’ opinion of the program.

The data collected is thus dependent on the issues that are chosen for consideration (Väisänen 2003).

Evaluating energy programs is difficult, as it involves a large number of plausible causalities (Vedung 1998). For example, Larsen and Jensen (1999) stated that the evaluation of energy programs faces the risk of being overly optimistic or, due to free-rider effects, even given a false-positive result. This is due to the fact that measures proposed by the program may wrongly be attributed to the program when in reality they would have been implemented anyway (Larsen and Jensen 1999).

A questionnaire is a common means of collecting figures when evaluating energy programs for energy actually saved (Väisänen 2003). Other methods include interviews and actual metering. Sometimes, evaluations include a minor part of the population being remetered. In other words, some companies receive a second round of energy metering, so the effect of the program can be quantitatively derived (Väisänen 2003). One distinguishing difference between ex-ante and ex-post evaluations is that the latter includes an evaluation made after the program or activity has ended, and the former includes an evaluation made before the program or activity has ended (Thollander and Dotzauer 2010).

Evaluating energy programs may be done using impact evaluation using Eq. 7.1 (Vine 2010):

$$\begin{aligned}\text{Net Energy Savings} = {} & \text{Gross Energy Savings} \\ & - \text{Savings not caused by program} \\ & + \text{Additional Savings} + \text{Non} - \text{Participant Spillover}\end{aligned} \tag{7.1}$$

where Net Energy Savings are the impact from the program, Gross Energy Savings are the savings achieved not taking into account free-riders, additional savings, and Participant Spillover. Savings not caused by the program is commonly referred to as the free-rider effect. Additional Savings are the savings the participants earned apart from the actual reported savings. Non-Participant Spillover are the savings from actors outside of the program, which was accomplished by nonparticipants when they heard of the program and its results (Vine 2010).

As stated above, if the research includes an evaluation of an energy program in terms of applications received and amount of audits undertaken, and even the impact of the program with regard to energy actually saved, the method may be applied. Too often, however, energy programs tend to never be evaluated. This is occasionally related to the fact that when the budget is set for the program, evaluations many years down the road are not always included. In essence it is forgotten.

Evaluating an energy program is of great importance for energy policy decision makers. If programs are not evaluated, energy policy decision makers have little left but to qualitatively assume the outcome of a future policy. One example of this was the local energy program Project Highland, which until 2011 was the largest Swedish program in the last 20 years and involved 340 companies. A part of the program was evaluated ex-post in 2006 (Thollander et al. 2007). The evaluation showed the cost-effectiveness of providing low-cost energy audits to small- and medium-sized enterprises (Thollander et al. 2007). Later on, the ex-post evaluation was an important input when the Swedish government decided to launch a national energy program offering energy audits to small- and medium-sized enterprises (c.f. EEC 2008a, b).

7.14.1 Alternative Evaluation Methods

One alternative to energy program evaluation is econometric studies[11] on energy end-use and on, for example, energy intensity and decomposition analysis. Such studies, which apply a top-down approach, may be suitable in order to find the

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[11] Econometric studies use economic theory using statistical approaches.

program impact at a national level. However, these methods may be difficult to use if one is to evaluate one single program. As there are other factors affecting energy use apart from an energy program, including energy prices and other energy policies, a bottom-up energy program evaluation is often the only means to achieve a figure that reflects the outcome of the program.

7.15 Conclusion

Public policy is used by governments to achieve energy and environmental targets and, as discussed in this chapter, to address climate change. Ecologically sustainable measures, to be sustainable in all senses of the term, must be economically sustainable as well. In policy analysis, ecological modernization captures the idea that economic and ecological values can complement each other. Finding measures by which to “green” society in economically feasible ways permeates more or less all theoretical and empirical models today. In this chapter, we have introduced some of these measures, and the lessons learned from them are:

- Ecological modernization privileges the role of green technology and innovation in driving change
- research examines both the end result of public policy and analyses the whole decision-making process from policy initiation to implementation and evaluation
- when policy instruments are emphasized, it is usually the end results that are in focus
- policy instruments are intended to influence people’s behavior, to make them act in accordance with policy maker’s wishes
- policy instruments include regulations, incentives, information, taxation, subsidies, and provision of energy meters
- the most effective means of control is to combine policy instruments
- it can be difficult to know whom to target with an energy policy instrument at SMEs, as they may not have anyone responsible for energy issues
- the rebound effect refers to behavioral response to the introduction of new technologies or measures that offset the expected beneficial effects
- liberalization of the EU energy sector began with the 1996 directive, the energy end-use efficiency and ESD
- the ESD promoted the development of an internal electricity market together with energy efficiency and supply security
- the ESD left it to each Member State to design and adopt NEEAPs in order to meet ESD targets
- EU ETSEU ETS works on the cap and trade principle. There is a cap or limit, on the total amount of certain greenhouse gases that can be emitted by a factory. Within this cap companies receive emission allowance which they can sell or buy.

- the cost-effectiveness of EU energy end-use policies differs between Member States
- an AEPS occurs when an energy policy has a strong effect in one part of a region or sector and a weaker effect in another
- the existence of AEPSs makes it costly for some Member States to achieve the EU 2020 primary energy target
- when policy is implemented, actors create implementation structures in the form of networks or clusters to co-ordinate activities
- when changing direction, it is important to facilitate new networks of actors with new ideas
- the energy efficiency potential of a new energy-efficient technology may not be completely realized in implementation
- it is not unusual for half or fewer of the measures proposed in energy audits to be implemented
- energy audits can increase SME energy efficiency
- SME energy networks are likely to fail because nobody is specifically responsible for energy in such firms
- designing an industrial energy program includes program goal formulation, choosing implementation instruments, identifying key players, and setting up the administrative structure
- the cost-effectiveness of an energy audit depends on both the size of the subsidy and whether the energy audit includes investment assessments
- an energy program design should include the company report on timeframe, results, and measures
- the auditors do not necessarily have to be public actors; using energy consultants would in the long run build greater energy audit competence in a country

References

Anderson ST, Newell RG (2004) Information programs for technology adoption: the case of energy-efficiency audits. Resour Energy Econ 26(1):27–50

Beck U (1999) World risk society. Polity Press, Cambridge

Bemelmans-Videc M-L, Rist R, Vedung E (eds) (1998) Carrots, sticks, and sermons: policy instruments and their evaluation. Transaction Publishers, New Brunswick

Bentzen J (2004) Estimating the rebound effect in US manufacturing energy consumption. Energy Econ 26:123–134

Berkhout P, Muskens J, Velthuijsen J (2000) Defining the rebound effect. Energy Policy 28: 425–432

Caffal (1995) Learning from experiences with energy management in industry. Centre for the analysis and dissemination of demonstrated energy technologies (CADDET). Analysis series 17. Sittard, The Netherlands

Christensen W, Aamodt-Espegren K (2002) AUDIT II topic report: monitoring and evaluation. http://www.motiva.fi/en/projects_and_campaigns/save_ii_-projects. Accessed 22 March 2010

Corbett C, Muthulingam S, Benartzi S, Oppenheim B (2009) Adoption of profitable energy efficiency related process improvements in small and medium sized enterprises. In: Proceedings of the 5th European conference on economics and management of energy in industry (ECEMEI-5)

Curran G (2011) Modernising climate policy in Australia: climate narratives and the undoing of a Prime Minister. Environ Plan C: Gov Policy 29:1004–1017

EC (European Commission) (2006) Communication from the commission. Action plan for energy efficiency: realizing the potential. COM (2006) 545 final

EC (European Commission) (2011) The homepage of the European Commission http://ec.europa.eu/environment/climat/emission/review_en.htm

EEC (Energy Efficiency Committee) (2008a) Ett energieffektivare Sverige [A more energy efficient Sweden]. SOU (Statens offentliga utredningar), 2008:25, Stockholm (in Swedish)

EEC (Energy Efficiency Committee) (2008b) Vägen till ett energieffektivare Sverige [The road to a more energy efficient Sweden]. SOU, 2008:110, Stockholm (in Swedish)

Farla JCM, Block K (1995) Energy conservation investment behaviour of firms: analysis of investments in energy efficiency in the Netherlands in the 1980's. Paper presented at the ACEEE 1995 summer study

Geller H, Attali S (2005) The experience with energy efficiency policies and programmes in IEA countries: learning from the critics. International Energy Agency, Paris

Giddens A (2010) En skenande värld. Hur globaliseringen är på väg att förändra våra liv, SNS Förlagj

Greening LA, Greene DL, Difiglio C (2000) Energy efficiency and consumption—the rebound effect—a survey. Energy Policy 28:389–401

Hajer M (1995) The politics of environmental discourse: ecological modernization and the policy process. Oxford University Press, Oxford

Harris J, Andersson J, Shafron W (2000) Investment in energy efficiency: a survey of Australian firms. Energy Policy 28:867–876

Herring H (2006) Energy efficiency—a critical view. Energy 31:10–20

Hill M (1997) The policy process in the modern state. Prentice Hall/Harvester Wheatsheaf, London

Hjern B, Porter D (1981) Implementation structures: a new unit for administrative analysis. Organ Stud 3:211–237

Jaffe AB, Stavins RN (1994) The energy efficiency gap: what does it mean? Energy Policy 22:60–71

Khazzoom DJ (1980) Economic implications of mandated efficiency standards for household appliances. Energy J 1:21–40

Larsen A, Jensen M (1999) Evaluations of energy audits and the regulator. Energy Policy 27:557–564

Lindén A-L, Carlsson-Kanyama A, Eriksson B (2006) Efficient and inefficient aspects of residential energy behavior. What are the policy instruments of change. Energy Policy 34:1918–1927

Lipsky M (1980) Street-level bureaucracy. Russel Sage, New York

Lundquist L (1987) Implementation steering. An actor-structure approach, Studentlitteratur

Mol APJ (1996) Ecological modernisation and institutional reflexivity: environmental reform in the late modern age. Environ Polit 5:302–323

Möllersten K (2002) Opportunities for CO_2 reductions and CO_2-lean energy systems in pulp and paper mills. Dissertations ISSN 1104-3466, Royal Institute of Technology, Stockholm

Neij L, Öfverholm E (2002) Teknikens bidrag till effektivare energianvändning. In: Boverket. Energimyndigheten. Naturvårdsverket (eds) Effektivare energi i bostäder. Swedish Energy Agency, Eskilstuna

Palm J (2004) Makten över energin: policyprocesser i två kommuner 1977–2001. Dissertation, Linköping University

Palm J (2006) Development of sustainable energy systems in Swedish municipalities: a matter of path dependency and power relations. Local Environ 11:445–457

Palm J (2010) The public-private divide in household behavior. How far into the home can energy guidance reach? Energy Policy 38:2858–2864

Palm J, Thollander P (2010) An interdisciplinary perspective on industrial energy efficiency. Appl Energy 87:3255–3261. doi:10.1016/j.apenergy.2010.04.019

Parsson W (1995) Public policy. An Introduction to the theory and practice of policy analysis. Edward Elgar Publishing Limited, Cheltenham

Persson A (1990) Nyttiga lärdomar. Erfarenheter av industriell energirådgivning [Important lessons. Experience from industrial energy consulting]. Statens industriverk, Stockholm (in Swedish)

Pierre J, Peters G (2000) Governance. Politics and the State, Macmillan

Porter ME (1990) The competitive advantage of nations. Free Press, New York

Pressman JL, Wildawsky A (1973) Implementation: how great expectations in Washington are dashed in Oakland. University of California Press, London

Ramirez CA, Patel M, Blok K (2005) The non-energy intensive manufacturing sector. An energy analysis relating to the Netherlands. Energy 30:749–767

Sandberg P (2004) Optimisation and co-operative perspectives on industrial energy systems. Dissertation, Linköping University

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

SCC (Swedish Climate Committee) (2008) Svensk klimatpolitik [Swedish Climate Policy]. SOU (Official reports of the Swedish Government) 2008:24, Stockholm (in Swedish)

Schleich J (2004) Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany. Int J Energy Technol Policy 2:226–239

Schleich J, Gruber E (2008) Beyond case studies: barriers to energy efficiency in commerce and the services sector. Energy Econ 30:449–464

Schneider A, Ingram H (1990) Behavioral assumptions of policy tools. J Polit 52:510–529

Shipley AM, Elliot RE (2001) Energy efficiency programs for small and medium sized industry. In: Proceedings of the 2001 ACEEE summer study on energy efficiency in industry, vol 1, pp 183–196

Solding P, Thollander P (2006) Increased energy efficiency in a Swedish iron foundry through use of discrete event simulation. Paper presented at the 2006 Winter Simulation Conference (WSC), 1971–1975

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

Stern PC, Aronson E (eds) (1984) Energy use: the human dimension. W. H. Freeman and Company, New York

Sutherland RJ (1996) The economics of energy conservation policy. Energy Policy 24:361–370

Thollander P, Karlsson M, Söderström M (2005) Reducing industrial energy costs through energy efficiency measures in a liberalized European electricity market: case study of a Swedish iron foundry. Appl Energy 81:115–126

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

Thollander P, Söderström M, Solding P (2009) Energy management in industrial SMEs. In: Proceedings of the 5th European conference on economics and management of energy in industry (ECEMEI-5)

Thollander P, Rohdin P, Danestig M (2007) Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Policy 35:5774–5783

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 1:21–34

Thollander P, Palm J, Söderström M (2008) Industrial energy auditing: a key to competitive energy-efficient Swedish SMEs. In: Bergmann DM (ed) Energy efficiency research advances. Nova Publisher, New York

Thollander P, Dotzauer E (2010) An energy efficiency program for Swedish industrial small- and medium-sized enterprises. J Clean Prod 18:1339–1346

Thollander P, Ottosson M (2010) Energy management practices in Swedish energy-intensive industries. J Clean Prod 18:125–133

Thollander P, Rohdin P (2010) Cost-effectiveness of energy programs involving energy audits: results from Sweden. In Proceedings of the international energy program evaluation conference (IEPEC) 2010, Paris

Thollander P, Gustafsson SI (2011) Combining the EU ETSEU ETS and EU energy end-use policies: a policy proposal achieving faster EU CO2 emission reductions. Int J Energy Environ Econ 19:717–724

Thollander P, Rohdin P, Moshfegh B (2012) On the formation of energy policies towards 2020: challenges in the Swedish industrial and building sectors. Energy Policy 42:461–467

Utterback JM (1996) Mastering the dynamics of innovation. Harvard Business School Press, Harvard

Vedung E (1998) Utvärdering i politik och förvaltning. (Evaluation in policy and administration). Studentlitteratur, Lund (in Swedish)

Vine (ed) (2010) Workshop on energy program evaluation at the 2010 international energy program evaluation conference, Paris, 9–10 June

Väisänen H (co-ordinator) (2003) Guidebook for energy audit programme developers. http://www.motiva.fi/en/projects_and_campaigns/save_ii_-projects. Accessed 22 March 2010

Wihlborg E, Palm J (2008) Who is governing what? Governing local technical systems an issue of accountability. Local Gov Stud 34:349–362

Chapter 8
Concluding Discussion: Elaborating on the Energy Efficiency Gap

Abstract In this concluding chapter, we summarize and discuss our main findings, and suggest possible ways forward when it comes to narrowing the energy efficiency gap. We elaborate on the book's findings in terms of three system levels, i.e., technology, management, and policy. This examination outlines the need to extend the classical view of the energy efficiency gap, which sees it as a solely technological matter, and introduces two new terms, the energy management gap and the energy policy gap. The energy management gap refers to the need to address energy strategically in a company to improve energy efficiency. The energy policy gap refers to the lack of energy policy specifically targeting industrial SMEs, partly because it is difficult to formulate policy for such a diverse group. Narrowing the energy policy gap calls for strict policy making together with government strategies to decentralize power and devolve responsibility to industry.

8.1 Introduction

A major part of the scientific community agrees that increased global warming, largely due to anthropogenic carbon dioxide emissions resulting from the use of fossil fuels, poses a major threat to the environment. As industry, together with transportation, is the highest energy-using sector in the world, a shift toward increased energy efficiency in industry is essential to reduce carbon dioxide emissions.

According to IPCC (2007), improving industrial energy efficiency is one of the most important ways to reduce the threat of increased global warming. Industrial SMEs represent more than 99 % of the total aggregated number of industrial companies in most countries. In the EU, SMEs provide two out of three private-sector jobs and account for more than half of the total value added created by

P. Thollander and J. Palm, *Improving Energy Efficiency in Industrial Energy Systems*, DOI: 10.1007/978-1-4471-4162-4_8,

businesses (EC 2011). This makes SMEs major economic drivers in terms of innovations, GDP growth, investments, employment, and exports. Despite the importance of SMEs to the economy, they have received little attention in terms of, for example, energy policy making or research (Ramirez et al. 2005). One reason for this neglect is that industrial SMEs are highly diverse, ranging from low energy-using engineering companies to more energy-intensive manufacturing plants. This diversity makes the sector a great challenge when it comes to, for example, energy policy decision making, methods to increase energy efficiency, research, and the promotion of energy management practices.

A large survey of EU companies found that 63 % of SMEs lack even simple rules or devices for saving energy, while only 29 % have introduced any measures to save energy and resources in their operations. Furthermore, only 4 % of SMEs in the EU have environmental management systems in place; for larger companies, this proportion is 19 %. Regarding attitudes toward energy savings, 70 % of SMEs in the EU with fewer than 10 employees, 57 % with fewer than 50 employees, and 44 % with fewer than 250 employees stated that they did not care about the issue; 30 % of large companies expressed the same indifference (EC 2007).

It is therefore vital to find both public- and private-sector organizational strategies to improve energy efficiency in the SME sector. Such a transformation is urgently needed, and must be addressed by a combination of measures, such as effective policies, the elimination of energy efficiency barriers, sound energy management practices, employee empowerment, and changes in routines, behavior, and attitudes.

The energy debate has tended to emphasize energy supply. Moreover, the outcome of this debate, regarding both energy supply and end-use, is dependent on two factors: the perspective addressed and the system boundary defined. These factors greatly affect the outcome of any discussion of energy systems and ultimately define what a person, organization, or society considers the right or wrong thing to do.

System theoretician Charles Churchman (1968) has stated that a systems approach begins when one looks at the world through another's eyes. In this book, we have therefore emphasized a broadened systems perspective on industrial energy efficiency.

Understanding industrial energy use and efficiency calls for the application of a range of perspectives, theories, and methods (Palm and Thollander 2010). This necessity leads us to the interdisciplinary approach we have applied to industrial energy systems and energy efficiency in industry. We have combined perspectives from social science and engineering to consider, both empirically and theoretically, how such an energy transformation of industry can be fostered.

Taking an interdisciplinary approach entails acknowledging that the interaction of a range of knowledge areas or perspectives is needed to solve certain problems. In this sense, we have moved within and across the boundaries of various disciplines and assessed what we can learn and integrate in our discussions from each of them. We have started a much-needed process of "cross-pollinating" multiple perspectives and provided an example of how this can be done in examining industrial energy efficiency. We hope this effort will inspire others to extend such

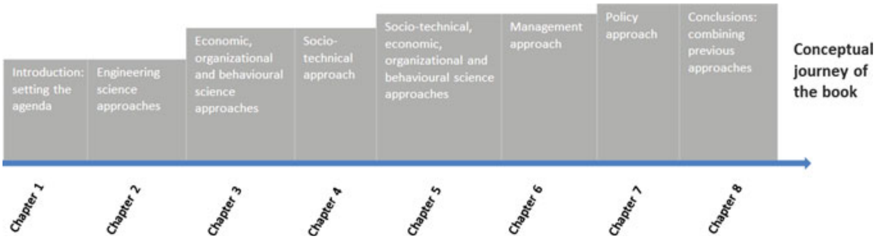

Fig. 8.1 Conceptual journey of the book and the perspectives addressed

interdisciplinary analysis, integrating more fields when examining the energy gaps discussed below. Figure 8.1 outlines the conceptual journey taken in this book.

In this chapter, we summarize and discuss our main findings and consider possible ways forward. We elaborate on the book's findings in terms of three system levels, i.e., technology, management, and policy. In industrial SMEs, these refer to the technical system level (i.e., technology level), the technical and organizational levels (i.e., energy management level), and the sociotechnical level, including the surrounding policy environment (i.e., energy policy level). We outline the need to extend the classical view of the energy efficiency gap only relating to the theoretical level, and introduce two new terms, the energy management gap and the energy policy gap, which are explained later in this chapter. Figure 8.2 visualizes these three system levels.

8.2 The Energy Efficiency Gap in a Social Science Context

In Chap. 2, we examined technological options by which non-energy-intensive companies and SMEs could improve energy efficiency. Evaluation of energy audit programs reveals that industrial SMEs tend mainly to implement energy efficiency measures addressing the support processes. Many of the measures addressing support processes such as ventilation, space heating, and lighting have a lower initial cost than do measures addressing heavily capital-intensive production processes. We then examined relatively "hands-on" methods and tools for improving energy efficiency. There is great potential for energy efficiency improvement: in-house energy management programs can reduce company energy use by 4–40 % (Caffal 1995). For non-energy-intensive industries and industrial SMEs, it is most cost-effective to focus on the user side, where the major potential for improved energy efficiency is located. Such user-side measures include improving the efficiency of energy-using technologies, minimizing power loads, changing energy carriers, and introducing more efficient staff behavior. For cost-effective energy efficiency measures to be implemented, companies need to obtain relevant information on their energy use, and one successful way to do this is to conduct an energy audit. An energy audit maps a company's energy use and

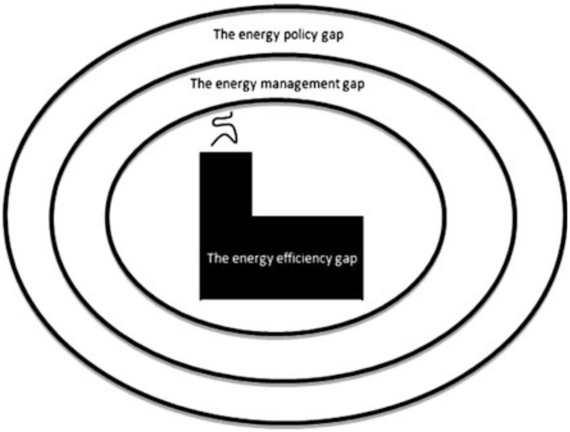

Fig. 8.2 The energy efficiency, energy management, and energy policy gaps and their relationships

suggests measures leading to improved energy efficiency in the audited company. As a policy instrument, it is obvious that *general* informations is fairly ineffective in terms of influencing behavior. Energy audits, however, include targeted, customized information that has proven to be much more effective when it comes to changing actual behavior.

The potential for improved energy efficiency in European industry is great—25 %, according to the European Commission—but many barriers must be overcome before that potential can be realized. One way to approach this energy efficiency gap is to define and categorize these barriers to energy efficiency, something done differently in different studies. In Chap. 3, we used Sorrell et al.'s (2000) often cited categorization of barriers as market failure, non-market failure, behavioural, and organizational barriers. These barriers have often been identified empirically, and researchers have interviewed industry representatives or sent out questionnaires to gather the needed data. As reiterated throughout the book, one must reflect on how and why energy efficiency barriers are categorized in particular ways, to uncover barriers that may have been overlooked. Accordingly, we have highlighted structural barriers, unrelated to the site level, as often overlooked by research. We need to explore and overcome these structural barriers as well, and understand that a broader systems perspective that encompasses structural barriers may sometimes be needed. Apart from *distortions in energy prices*, *supply infrastructure limitations*, and *codes and standards*, the major structural barriers addressed here are *different (interdisciplinary) perspectives on energy*, *government fiscal and regulatory policies*, and *organizational structure*.

Defining and analyzing the identified barriers are important steps in finding ways to narrow the energy efficiency gap. One must constantly redefine existing empirically defined barriers, to challenge existing solutions and develop new, creative ways of addressing the efficiency gap.

To develop barrier research in a new direction, we introduced a sociotechnical perspective on innovation processes and decision making in organizations, in relation to their constituent institutions and communities of practice (CoPs). It is illuminating to perceive energy systems as sociotechnical systems in which there is mutual dependency between technological and social factors coexisting in a seamless web. How energy systems work in an industrial SME depends not only on technology, but also on the systems' surroundings, which includes the organization, industrial sector, policy mix, and society. The introduction of innovations or new ideas into a system does not occur via a linear process; instead, design and goals can change throughout a process, even during the user phase. When studying energy efficiency it is important to maintain a holistic view or, as Churchman (1968) would say, a systems perspective.

The multi-level model introduced in Chap. 4 emphasizes that sociotechnical systems can give rise to both long-term changes in the landscape and short-term processes at the micro level. Engineers also act within sociotechnical regimes, i.e., social networks, in which informal institutions such as routines and norms must be considered when attempting to understand an outcome, for example, why energy efficiency measures are or are not implemented. Decisions are never made in a vacuum, but by actors embedded in structures. When people in industry make decisions they are influenced by regulative rules, normative rules, cognitive routines, and belief systems.

The literature treats these formal and informal "rules" as institutions. Institutions can explain why an actor may seem to be acting irrationally. A seemingly irrational behavior may reveal its hidden rationality if established routines or embedded values is taken into consideration when analyzing it. Taking account of tacit knowledge when discussing barriers to energy efficiency can also be useful. In a CoP, tacit knowledge and the exchange of routines, values, and norms are central factors forming the group and holding it together. CoPs are informal groupings in which members share a way of doing things and also share a discourse, reflecting a certain perspective on phenomena. A dominant CoP can be very powerful in a company and can itself constitute a barrier to or enabler of improved energy efficiency. Actors learn from both formal organized activities and through their everyday activities and experiences.

Bearing this in mind, we can begin to consider how barrier theory can be elaborated by including, for example, the perspective that decisions are embedded in and dependent on sociotechnical regimes. In Chap. 5, we demonstrated that not only is knowledge situated in everyday practices, but also that information needs to be related to the individual taking part in the communication act. It is difficult to influence people by providing them with general information: to capture attention and exert an impact, information must be adapted to peoples' experiences, values, and knowledge. In addition, it is not established that information, translated into personal knowledge, will necessarily be transformed into behavior. Hence, information needs to be combined with other instruments, such as practical actions in which one tries to do an activity and not just talk about it.

This line of argument differs from the previously more mechanistic view of decision makers (e.g., engineers and economists) as fully rational. For too long, simply inputting a signal into a system, for example, providing general information to a CEO on how to reduce energy use in his or her industrial SME, has been viewed as an adequate means to reduce energy efficiency information gaps. This book, which is based on the previous research of, for example, Boulding (1956) and Stern and Aronson (1984), underlines the importance of taking a broader systems perspective that also takes account of the individual aspects of decision making and behavior.

We also need to accept that it is impossible to make fully informed choices all the time, and that much of what we do depends on routines. It is not really rational to seek full information about every task involved in our daily work. Accordingly, it is important to fit energy efficiency measures into existing routines in a company, or to establish new routines that can advance energy efficiency. To successfully improve energy efficiency in industry, one must develop a structure that both benefits certain behaviors and molds how energy use and efficiency are perceived throughout the organization.

Throughout this book we have emphasized approaching barriers to energy efficiency from new directions, applying new perspectives, using novel analytical tools that cast new light on questions such as why a particular barrier is stressed in a company. In Chap. 5, for example, we categorized these barriers in a new way, to see whether this would foster new insight and problematize the dominant barriers in a company. The point was to demonstrate that how we contextualize a problem and define a barrier leads to different solutions and suggested measures. Defining and redefining empirically identified barriers is therefore important if we are to challenge existing solutions and develop new, creative ways of looking at companies and other actors.

We then went on, in Chap. 6 to discuss the need for energy management in companies, exploring the human aspects of management, while in Chap. 7 we addressed the role of energy policy and programs in narrowing the energy efficiency gap. We will now continue this discussion of energy management and develop the idea of what we call an energy management gap.

8.3 The Energy Management Gap

Industrial energy management is perhaps the most important factor in overcoming barriers to energy efficiency and closing the energy efficiency gap. Energy management has been little emphasized in research or policy touching on industrial SMEs, and is accordingly underdeveloped in research and practice. Companies need to address energy strategically to reduce the energy efficiency gap. Industrial companies that take a strategic approach by adopting energy management practices may reduce their total energy use by up to 40 % (Caffal 1995).

The tricky part of energy management is that companies must combine top–down management support with worker empowerment. Strong leadership is key, but so is delegating authority to employees.

A weak leader will lack the power needed to establish new ideas, routines, and values in a company. A strong leader, on the other hand, can be a dynamic driving force of an organization. However, if lack of trust means that employees are given insufficient authority to put new ideas into practice, results will be disappointing. There are various management methods; among these we discussed *result governance*, a method that involves solving problems individually, while *method governance* entails standardization and continuous improvement. Method governance will benefit an organization in the long term, it builds support structures for the future. Result governance, on the other hand, has a shorter term focus: it extinguishes the fires burning now, but leaves no indelible positive traces.

How successful ideas and values become established in companies, however, is not so well documented, possibly because interviews and questionnaires have generally been used in earlier research. Combining these methods with observational approaches would foster better knowledge of these issues. Observational methods would also deepen our understanding of energy management in general and introduce a more complex system analysis.

It is also important to create continuity in the energy efficiency work. This can in some companies be done by developing an ongoing network or an in-house energy management group where actors continuously meet to discuss these issues. In the majority of industrial SMEs, however, such networks are today likely to fail as the organizations lacks the capacity to establish these fundamental ideas. This calls for future research in this field on how to overcome this challenge. Another important factor has been to have an appointed person responsible for the company's energy use to maintain interest in energy efficiency activities.

We can conclude that energy audits, conducted in-house or by external actors, represent the first step toward the successful adoption of industrial energy management practices, thereby playing a key role in making industrial energy systems more sustainable. The process cannot stop with the audit, and energy management is important as it can keep strategic activities ongoing. In summary, to address the great challenge of improving sustainability in industrial energy systems, we need to focus not only on technical energy efficiency (i.e., the energy efficiency gap), but also take account of energy management. Doing so will greatly extend the potential for improved energy efficiency. Figure 8.3 visualizes what we refer to as the energy management gap.

As can be seen in Fig. 8.2, the potential for energy efficiency is in fact much greater than has been identified in previous research into the energy efficiency gap and barriers inhibiting the adoption of more energy-efficient technologies. Energy services, as emphasized by the European Commission (e.g., EC 2006), will only help us realize about half of the technical energy efficiency potential, i.e., half of the energy efficiency gap will remain even if energy services are fully developed (for empirical evidence, see Backlund et al. 2011). What is needed to fully close the technical energy efficiency gap is the adoption of energy management practices. Total energy efficiency potential can be enhanced beyond the merely technical energy efficiency potential, for example, by means of improved usage routines for energy-using equipment and employee energy conservation. When

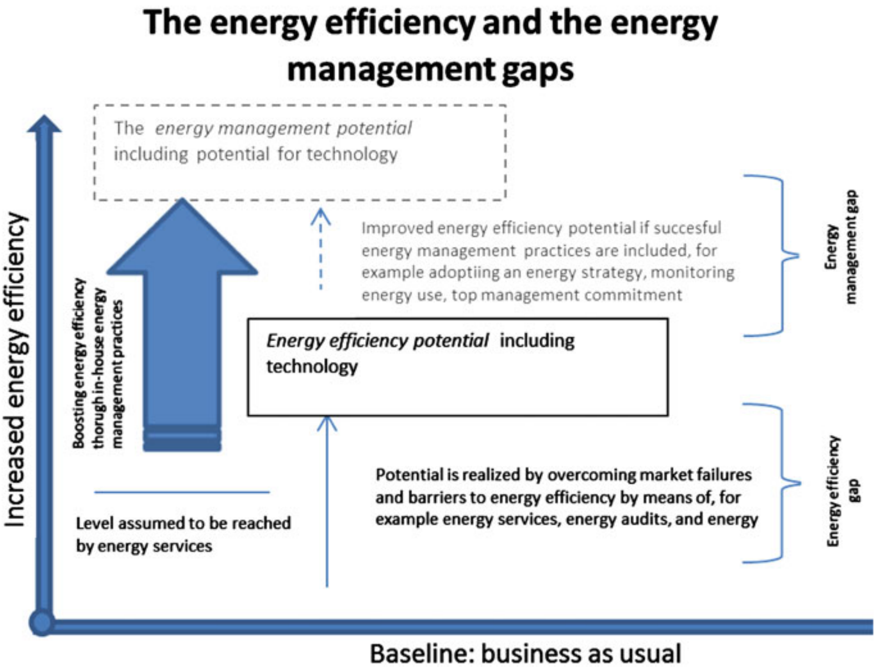

Fig. 8.3 The energy efficiency and energy management gap

energy management practices are included in the mix as well, the total energy efficiency potential becomes greater still.

It is important to note that the potential for improved energy efficiency through the adoption of energy management practices differs widely due to type of production (e.g., batch or continuous), energy intensity (related to, e.g., degree of energy use for production processes compared with support processes), degree of automation in the production, previous emphasis on energy efficiency in the organization, etc. A heavy automatized production facility in an energy-intensive process industry, e.g., with large energy use in the production process, may be stated to have an extended energy efficiency potential of only 1–2 % higher than the technical energy efficiency potential, if energy management practices are adopted. On the contrary the extended energy efficiency potential in a non-energy-intensive facility with a large energy use in the support process may be twice as high as the stated technical energy efficiency potential of 25 % according to EC (2006). This high extended energy efficiency potential is further supported by Waide and Brunner (2011) who stated that while the energy efficiency potential for the actual electric motor is fairly small, the potential for the core motor system is good, while the energy efficiency potential for the total motor system is large (Waide and Brunner 2011).

For enhanced energy efficiency potential to be realized, policy makers must include energy management in policies. Can policy options help improve energy management practices and promote the adoption of energy efficiency measures, boosting energy efficiency and taking us toward improved sustainability? Insights from the book regarding the efficacy of policy instruments are discussed in the next section referring to the energy policy gap.

8.4 The Energy Policy Gap

Industrial SMEs have been paid little attention in policy (Ramirez et al. 2005), largely because of their great diversity: numerous production processes, sectors, and organizational types are all included in the broad SME definition. To overcome barriers to energy efficiency and promote improved energy management practices, well-designed energy polices arguably play a key role.

In Chap. 6, on energy management, we introduced the transactional analysis (TA) approach to improve our understanding of the relationship between executives and employees (Berne 1964). We would like to close the discussion by suggesting that TA might also help us to better understand and greatly improve the promotion of energy efficiency through policy means. According to TA, the goal of any interaction is to forge a mature *adult* to *adult* relationship; however, a relationship can become static due to previous experience of the relationship. Similarly, to increase potential energy efficiency, both individual industrial SMEs and the government must accept their responsibility and behave in a mature *adult–adult* fashion. Earlier research has demonstrated that politicians and industry both attempt to shift responsibility to each other or to the citizenry, to act to bring about sustainable development. At the same time, citizens believe that industry and politicians bear the greatest responsibility for promoting such development (Palm and Tengvard 2011; Palm 2011). Companies usually cite the need for customers to demand ecological products and for politicians to formulate stricter rules. Meanwhile, politicians believe that it is market players who bear the greatest responsibility for the sustainable transition.

This mutual shirking of responsibility results in unbalanced relationships. For example, if industry does not shoulder its responsibility, the government may adopt very strict regulations and rules, which, from a TA perspective, would result in an immature *parent* to *child* relationship. This is the same phenomena barrier theory referred to as the principal–agent relationship. From a TA perspective, bridging these calls for sound leadership from the division manager, CEO, or government, which in practice means a combination of regulation and decentralized responsibility.

TA reveals that previous lack of appropriate policy is a major explanation for why levels of energy efficiency in industrial SMEs still have so much room for improvement. This prior lack of policy is referred to by the authors as the energy

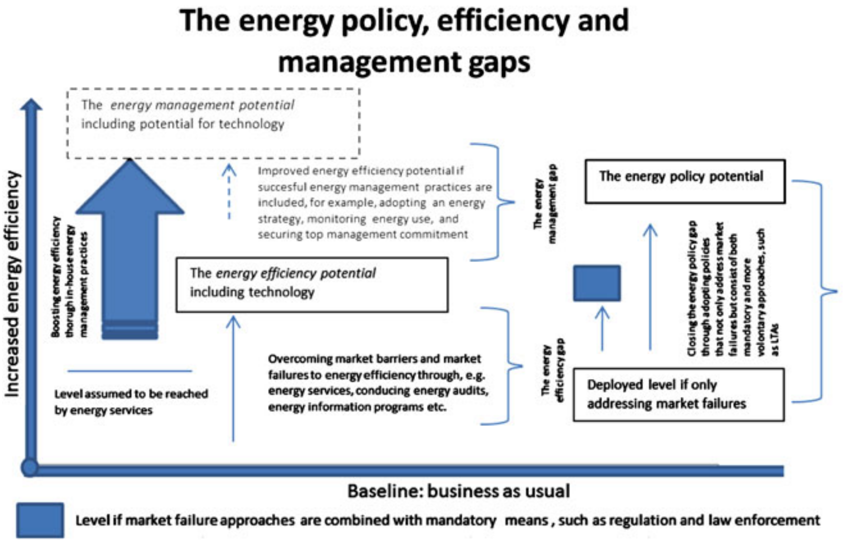

Fig. 8.4 The energy policy, energy efficiency, and energy management gaps

policy gap. Figure 8.4 outlines the energy policy gap and its relationships with the energy efficiency and energy management gaps.

In relation to the above discussion, more extensive use of voluntary approaches, such as LTAs, will be needed to close the energy policy gap; this will in turn narrow the energy management and energy efficiency gaps. As shown in Fig. 8.3, policy approaches that focus solely on market failures can close the gap only part way; the same holds for mandatory approaches such as regulation and law enforcement. To exploit the full potential for energy efficiency offered by a combination of technological and energy management measures, industry and government, acting in concert, must accept and discharge their proper responsibilities. In this lies the great challenge facing individual industrial SMEs, trade associations, and governments, to embrace sustainability principles and turning society in the direction of greater energy efficiency and thus improved sustainability. As argued in Chap. 1, in line with The Natural Step framework (Nattrass and Altomare 2001), it is obvious that this process should proceed gradually, neither too fast nor too slow. The values and knowledge of individuals are decisive for the development of an ecologically sustainable energy system. People's understanding of their responsibilities and willingness to shoulder them are key factors in creating a sustainable society. If no group of actors understands that it is responsible for and capable of taking initiatives that lead to change, we will be caught in an intractable "responsibility trap".

References

Backlund S, Thollander P, Giudici L (2011) Foundry bench: a study of barriers to and drivers for energy efficiency in the foundry industry in Finland, France, Germany, Italy, Poland, Spain and Sweden, Linköping University. Available at: www.ep.liu.se

Berne E (1964) Games people play: the basic hand book of transactional analysis. Ballantine Books, New York

Boulding KE (1956) General system theory: the skeleton of science. Manag Sci 2(3):197–208

Caffal (1995) Learning from experiences with energy management in industry. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). Analysis Series 17, Sittard, The Netherlands

Churchman CW (1968) The systems approach. Dell Publishing Co. Inc., New York

EC (European Commission) (2006) Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing Council Directive 93/76/EEC. EC, Brussel

EC (European Commission) (2007) Observatory of European SMEs

EC (European Commission) (2011) European Commission's homepage. Available at: http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/index_en.htm

IPCC (2007) Contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change, Summary for policymakers. http://www.ipcc.ch/SPM0405.07.pdf. Accessed 8 Oct 2007

Nattrass B, Altomare M (2001) The natural step for business: wealth, ecology and the evolutionary corporation. New Society Publishers, Gabriola Island

Palm J, Thollander P (2010) Interdisciplinary perspective on industrial energy efficiency. Appl Energy 87:3255–3261

Palm J (2011) Energy efficiency in households: policy implementation and appropriation of technology. Nova Science Publisher, New York

Palm J, Tengvard M (2011) Motives for and barriers to household adoption of small-scale production of electricity: examples from Sweden. Sustain: Sci Pract Policy 7:6–15

Ramirez CA, Patel M, Blok K (2005) The non-energy intensive manufacturing sector. An energy analysis relating to the Netherlands. Energy 30:749–767

Sorrell S, Schleich J, Scott S, O'Malley E, Trace F, Boede E, Ostertag K, Radgen P (2000) Reducing barriers to energy efficiency in public and private organizations, SPRU's (Science and Technology Policy Research). http://www.sussexac.uk/Units/spru/publications/reports/barriers/final.html. Accessed 8 Oct 2007

Stern PC, Aronson E (eds) (1984) Energy use: the human dimension, Freeman, New York

Waide P, Brunner C (2011) Energy-efficiency policy opportunities for electric motor-driven systems. IEA (International Energy Agency). Energy efficiency, Paris

Chapter 9

Errata to—Chapter 1: Setting the Agenda; Chapter 2: Improving Energy Efficiency in Industrial SMEs

Errata to:

Chapter 1: Setting the Agenda, doi:10.1007/978-1-4471-4162-4_1
Chapter 2: Improving Energy Efficiency in Industrial SMEs,
doi:10.1007/978-1-4471-4162-4_2

Pages	Item or line	Corrections
8	Chapter 1	Replace "515 %" by "5–15 %"
9	Chapter 1	Replace "Moreover, it is among support processes, such as lighting, ventilation, and producing compressed air that one finds the greatest potential for energy savings (EC 2006)" by "Moreover, it is among support processes, such as lighting, ventilation, and producing compressed air that one finds the greatest potential percentage-vise for energy savings"
10	Chapter 1	Replace "Industrial SMEs represent more than 99 %" by "SMEs represent more than 99 %"
18	Chapter 2, Fig. 2.3	Replace old Fig. 2.3 by new Fig. 2.3

The online version of the original chapters can be found at doi:10.1007/978-1-4471-4162-4_1 and 10.1007/978-1-4471-4162-4_2.

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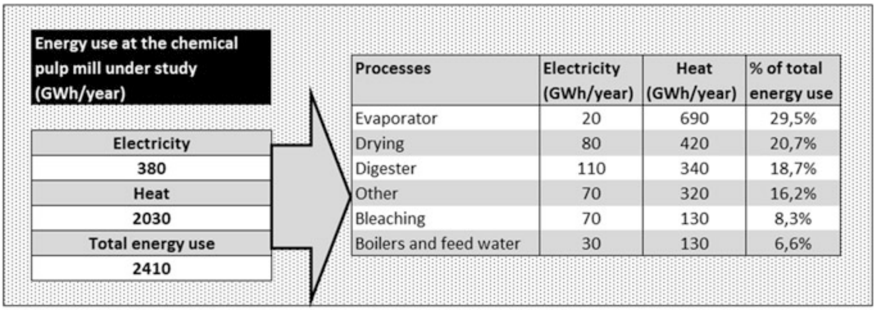

Energy use at the chemical pulp mill under study (GWh/year)

Electricity
380
Heat
2030
Total energy use
2410

Processes	Electricity (GWh/year)	Heat (GWh/year)	% of total energy use
Evaporator	20	690	29,5%
Drying	80	420	20,7%
Digester	110	340	18,7%
Other	70	320	16,2%
Bleaching	70	130	8,3%
Boilers and feed water	30	130	6,6%

Fig. 2.3 Energy use in a Swedish energy-intensive chemical pulp mill (Klugman et al. 2007)

Authors' Biographies

Dr. Patrik Thollander is an assistant professor of energy systems in the Department of Management and Engineering at Linköping University. Patrik is conducting research related to energy efficiency in industrial energy systems. In addition to this, he is involved in courses in energy systems, modeling, auditing, and industrial energy systems. He is also active in the the national interdisciplinary research program, Energy Systems Programme.

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Index

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