Barriers to investments in energy saving technologies

Case study for the industry

Dirk Jan Masselink*

Supervisors: **Dr. B.W Daniëls (ECN), Prof. Dr. H.C. Moll (IVEM) & Dr. L.C.W.P. Hendrickx (IVEM)**

* Dirk Jan Masselink; Student Energy and Environmental Sciences (IVEM) at the faculty of mathematics and natural sciences, University of Groningen, E-mail: Dirkjanmasselink@gmail.com.

ECN-E--08-057 July 2008

“*Technologies are not now, nor will they be, in the foreseeable future, the limiting factors with regard to continuing energy efficiency improvements.*”

~ Report United Nations, 1997 ~

Acknowledgement/Preface

This report is the last barrier to the study Energy and Environmental Sciences (IVEM) at the University of Groningen (faculty of Mathematics & Natural Sciences). In the Dunes of Petten I worked on this thesis from October 2006 till April 2007. The study is performed in cooperation with the Energy Research Centre of the Netherlands (ECN), where I was situated during this period.

During my stay at ECN I was provided with a lot of information about the working field of energy. I am very grateful to all of my colleagues at ECN policy studies, in special to Bert Daniëls, my supervisor at ECN. I also want to thank my supervisors at the IVEM, Henk Moll and Laurie Hendrickx, for their helpful advises. Of course, without the help of the respondents this study was not possible, so thanks to all the persons who gave their comments and view on the topic, and the persons who co-operated to the interviews.

Dirk Jan Masselink,
Groningen, The Netherlands
May 2007

Contents

List of tables

List of figures

Abbreviations

CPBP	Critical Payback Period
EIA	*Energie Investeringsaftrek,* or Tax relief for investments in energy-saving equipment and sustainable energy.
PBP	Payback Period
SME	Small and Medium Enterprises

Summary

To realise future energy saving targets, the government needs to increase energy reduction rates. One option to increase energy savings is found in removing barriers to investments in cost-effective energy saving technologies. Many technologies save energy and are at the same time cost-effective. The low adoption of these technologies by the industry is embedded in the 'energy efficiency gap' discussion. While technologies are (apparently) cost-effective, different barriers obstruct, or limit, their implementation.

This study identifies five clusters of barriers that limit investments in costs-effective energy saving technologies, regarding the viewpoint of an industrial firm. The first group of barriers originated from increased uncertainties for energy saving technologies. Different barriers increase the risk perception of a company, thereby decreasing investments in energy saving technology. A second cluster of barriers embeds hidden costs. Whereas the investments costs often overlook typical (hidden) costs, inclusion of these costs negatively influences an investment decision. Lack of information and problems with applying the information are laid down in the third cluster of barriers. While information about possible energy saving technologies and internal energy use is often lacking, or companies are not able to handle the information, investments can be lower. A fourth group of barriers is the result of the way an organization is structured and the prevailed culture. These aspects may act as an obstacle to investments in energy saving technologies. The last cluster of barriers is related to the availability and allocation of capital. A company can simply lack financial funds or internal budgeting restrictions inhibit investments. Figure 4.1 presents a complete overview of the identified barriers (page 27).

The overview of factors that may occur as barriers to energy saving technologies is used as input for the second part of the study. Eleven respondents ranked the barriers on the base of their importance in explaining the energy efficiency gap. 'Availability and allocation of capital' showed up as most important hurdle for investments. Companies often have other investment priorities, or the current machines are still sufficient. In addition, 'risk and uncertainties' is indicated as important group of barriers as well. Whereas the overall economic trend influence the rate of investments, also uncertainties about the cooperation of the new technology with other machines in the process is an important barrier.

While the results of the interviews increased insight in the energy gap discussion, the study points out the difficulty of identifying the most important barriers. The individual respondents all had a clear view on the relevance of the barriers, however the agreement among the respondent is very poor. It is expected that the background and characteristics of the respondents largely determines his/her viewpoint. Nevertheless, the many different insights in the 'energy efficiency gap' discussion, exposes the complexity of the problem. Creating one-best solutions to overcome the barriers is therefore impossible, a mixture of measures is needed to take away the most obvious and concrete barriers.

1. Introduction

1.1 Problem formulation

Reduction in energy use is an important issue within Dutch energy policy. Whereas the energy saving target was 1.0 percent per year (EZ, 2005), Dutch government recently increased this goal towards an annual energy reduction of 2.0 percent (CDA *et al.*, 2007), which is in accordance to the advise from the *'VROM-raad'* and *'Algemene Energieraad'* (VROM-raad & Algemene Energieraad, 2004) and a motion by Van der Ham and Spies (Tweede Kamer, 2005). The ambitions for speeding up reduction rates are high, but monitoring shows that current reduction speed in the Netherlands is 1.0 percent[1], which is lower than the proposed policy goal for 2008 (Gijsen *et al.*, 2006). To test the feasibility of a 2 percent reduction speed, the Dutch Ministry of Economic Affairs asked ECN to investigate the policies and measures needed. Daniëls *et al.* (2006) conclude that a 2 percent reduction speed is possible with additional measures, but it will bring additional costs of € 3.5 billion. According to Daniëls *et al*. (2006) the suggested measures for achieving energy efficiency improvements of 2 percent will require a "*considerable effort of governments, citizens and companies to overcome societal barriers.*"

With a share of 40 percent, the industrial sector is the largest consumer of primary energy in the Netherlands (Dril & Elzenga, 2005) and substantial energy saving potentials can be expected here. Actual energy savings in the Dutch industrial sector amounts to 1.1 percent per year[2] (Gijsen *et al.*, 2006), which is lower than the proposed policy target, and estimations for the future show that when current policies are maintained, the energy reduction rate between 2010 and 2020 will be in the range of 1.0 percent per year (Dril & Elzenga, 2005). Achieving future energy norms therefore requires additional measures and investments in energy saving options, which is laid down in the national energy report (EZ, 2005). Significant potential for energy saving is possible in the industry (i.e. Blok & Visser, 2005; Menkveld *et al.*, 2005). Even significant energy savings are possible at low costs (Dril, 2005), but different barriers limit the potentials to be realized. The presence of not implemented cost-effective energy saving technology is addressed in the energy efficiency gap discussion as laid down by for example Golove and Eto (1996), and Jaffe and Stavins (1994b).

To speed up energy savings and to stimulate the adoption of more energy saving technologies policy measures are needed. One of the main tasks of ECN policy studies is to provide ministries with advice about policy implications and the effects of policy instruments. Different models are used for the foundations of these advices, one of them, the Save-Production model, is an energy model for the Dutch industry and agriculture. As indicated by Daniels and Van Dril (personal communication) the additional research is needed for the identification, valuation and integration of the barriers-concept into the SAVE-Production model.

1.2 Research goal and questions

The research goal of this study is twofold. First, an explorative study for the identification of barriers that block investments in energy saving technology is designed. These results are used as input for the second part, where the relevance of the identified barriers is tested. The next research questions are the central question during this study:
Which barriers can block investments in energy saving technology?
What is the relevance of these barriers in explaining the efficiency gap?
What is the best way to integrate these barriers into the SAVE production model?

---

1 Data for 2004, 95 percent reliability interval between 0.7% and 1.3%.
2 Data for 2004, 95 percent reliability interval between 0.7% and 1.5%.

The results of the first two questions are laid down in this report and the answer to the third question is provided in an additional note to ECN.

1.3 Method description and structure of the study

For answering the proposed research questions different methods are used. In essence the report consists of three sections. First, a broad survey about the 'energy efficiency gap' discussion is presented. The second section presents a framework for the identification of the barriers, and the third part focuses on the importance, or relevance, of these barriers.

Literature about the energy gap discussion has been analysed in the introduction chapter. A summary of the concept is presented together with an indication of the size of this gap. In addition, an example is provided to illustrate the possibilities for energy efficiency improvements in motor driven systems

The second part focuses on the identification of barriers that may obstruct investments in energy saving technologies. The section starts by showing how a company decides whether to invest in energy saving technology from a neoclassical point of view. Within this theory, it is assumed that companies act rationally and invest in technologies that are profitable. Subsequently the barriers that can negatively influence the investment decision are summarised in a conceptual model. This framework is primarily created with help of a literature study. After the construction of the initial framework (or conceptual model), the results have been discussed with several expert in this field. These experts include university professors, professional consultants, and energy managers. The remarks by those respondents have been used as input for the final framework. Therefore, where this report first introduces the conceptual model, followed by the discussion on the individual barriers, in reality the process was the other way around. First, literature has been reviewed and experts have been interviewed, to end up with the conceptual model.

For the creation of an empirical study that analyzes the relevance of the barriers, the conceptual model is used. Ideally, a broad survey among respondents from all industrial sectors would be preferred[3]. However, problems that originate from the limited time available, high associated costs, and problems with finding representative respondents, another approach was preferred. A small-scale study was performed based on interviews with key persons linked to the industrial sector. Eleven respondents were selected using the following criteria:

- Theoretical background in the issue of 'barriers to investments in energy saving technologies'.
- A good knowledge of decision making procedures in the industry.
- Overview of barriers that block investments in energy saving technology.

Summarising, the respondents have close connection to business, and a good overview of barriers. The combination of the theoretical as well as the practical background made in-depth interviews possible. The eleven respondents are characterized as professional consultants, energy coordinators[4], energy researchers, and a respondent from the ministry of economic affairs. The interviews took between one and two hours each, and started with open questions about general barriers to investments in energy saving technologies. Subsequently, the respondents were asked to indicate the relevance of selected barriers[5]. After each interview, the respondents could give their opinion about the interview. In Chapter 5 presents the quantitative results of the interviews.

[3] See for example the studies by (Velthuijsen, 1995), (Gillisen et al., 1995), and (Groot et al., 2001).
[4] The energy coordinators interviewed for this study, all originated from large companies.
[5] More about this approach can be found in Section 5.1.

Eventually the most important results from the interviews are compared with other studies on the topic, and the validity of the results is tested. The discussion and conclusion of the study, together with answers to the research question can be found in Chapter 6.

1.4 Scope, assumptions and definitions

Barriers to investments in energy saving technologies can be found in all sectors, but this study only focuses on the industry. While most of the barriers found in the industry, also apply for example in the services sector, or build environments, it is expected that the nature and relevance of the barriers will be different. The main focus of the study is on barriers that block investments in the Netherlands. Dutch studies on the topic, together with input from Dutch respondents guide as basic input for the study. Second, studies from other industrialized countries[6] have been used to complement the Dutch studies.

In essence the study looks at barriers on industrial level. No distinction has been made between small companies and large companies, or energy intensive and extensive firms. This high aggregation level is usable for an explorative study, but for a more practical goal a lower level of aggregation may be preferred. To take advantage of both approaches, the study starts explorative, but during the conclusion the most important barriers will be attached to firm and sector characteristics, if possible.

Before continuing with the actual study, some definitions of main concepts are needed. These concepts will be widely used in the study, and are defined below. First a clear definition for energy saving is needed, in accordance to Boonekamp *et al.* (2001) the basic definition for energy saving is:

Energy saving = *"Performing the same activities or fulfillment of functions using less energy."*

As illustrated by Boonekamp *et al.* (2001) and Boonekamp (2005) the terms energy saving and energy reduction are not as simple as they look. If for example, a company decides to install an energy saving technology this can result in a particular energy saving. But often the output (fulfilment of the function) of the new machine is not identically to the previous one[7]. In this case, the outputs of the two machines are not identical and are difficult to compare. It makes measurement of real energy saving difficult, but for usage in this study, the simple definition is sufficient.

The focus within this study is on the investment decision process of a company, regarding investments in energy saving technology, and the aspects that influence the final go or no go decision. This study regards **an investment as an investment in a technology that results in energy saving**, unless implicitly mentioned otherwise. It is widely accepted that additional energy saving can be achieved through more widespread adoption of existing technologies, and many of these un-adopted technologies are cost-effective (Jaffe & Stavins, 1994a), which are often called ‘no-regret’ options (Ostertag, 2003). These options or technologies can be defined as:

No-regret options = *“No- regret options are those options whose benefits exceed the associated costs and increase profits of a company.”*

---

6 For more information on barriers to investments in energy efficiency in developing countries I refer to Worrell *et al. (Worrell et al., 1997)* and a report by the United Nations Development Programme (UNDP) on sustainable energy strategies (Takada et al., 2007).

7 Think of higher failure rates, better quality of the output etc.

Ostertag (2003) presents a more practical definition for usage within the context of a company. She argues that the Payback Period of a no-regret option has to be compatible with cut-off criteria observed by managerial practice, i.e. mostly between 2 and 5 years, but we will come back to this statement in Section 3.3.

The prospect of cost-effective energy savings looks attractive, but still a lot of these technologies are not implemented. This discrepancy between the expected optimal situation and actual energy savings is known as the '*energy-efficiency gap*' or '*energy paradox*'[8]. The term '*efficiency gap*' originates from a report by the Solar Energy Research Institute (SERI, 1981) and is defined as[9]:

Energy-efficiency gap = *"The difference between levels of investment in energy efficiency that appear to be cost effective based on engineering-economic analysis and the actual levels.*"

The fact that some technologies, are technologically and economically attractive, have not been implemented in practice, can be explained in terms of barriers, or blocking mechanisms. Sorrell *et al.* (2000) define a barrier as[10]:

Barrier = "*A postulated mechanism that inhibits investment in technologies that are both energy efficient and (apparently) economically efficient."*

While barriers influence investment decisions negatively, incentives have the opposite effect. Imagine a company that gives environmental issues low priority. The fact that they do not focus on the environment can be a barrier to the implementation of energy saving technology. Looking from another perspective; environmentally focused behavior of companies can be an incentive to the same investments. Barriers and incentives therefore are closely related concepts and sometimes overlap each other, but the primary focus in this study is on barriers to investments.

8 See for example (Jaffe & Stavins, 1994a; Jaffe & Stavins, 1994b; Weber, 1997; Golove & Eto, 1996).
9 Cited from (Golove & Eto, 1996) page 6, but originally from (SERI, 1981).
10 (Sorrell et al., 2000), page 11.

2. The energy efficiency gap

The energy efficiency gap is the difference between the theoretical and real implementation level of energy efficiency[11]. As Jaffe and Stavins (1994b) state: "*the crux of the debate surrounding the efficiency gap lies in differing interpretations of what has been called the paradox of gradual diffusion of apparently cost-effective energy-efficiency technologies.*" Why are, for example, variable speed drives (VSDs) not more widely used, or why do not more companies install a combined heat and power installation. As Golove and Eto (1996) point out: "*The currently low market adoption of [these] energy-efficient technologies, coupled with this unrealized potential, is taken to imply that significant amounts of energy could be saved cost effectively through investments in this equipment because the financing and energy operation costs of such technologies are below the energy costs of currently installed equipment.*" But how large are these potentials and how much energy can be saved by a more widespread adoption of energy saving technologies? An indication of the potentials follows.

2.1 Size of the energy efficiency gap

The first question that arises when analyzing the size of the energy efficiency gap is associated with the definition of the energy saving potential. For example what is economically attractive in this case? And to whom are the techniques useful? For a better understanding of the role of barriers the concept will be put in the context of energy saving potentials. As pointed out by Blok (2007) the amount of energy that can be saved through energy efficiency is commonly expressed in potentials. Blok (2007) distinguishes six different types, which are also graphically presented in Figure 2.1.

- Theoretical potential
- Technical potential
- Economic potential
- Profitable potential
- Market potential
- Enhanced market potential.

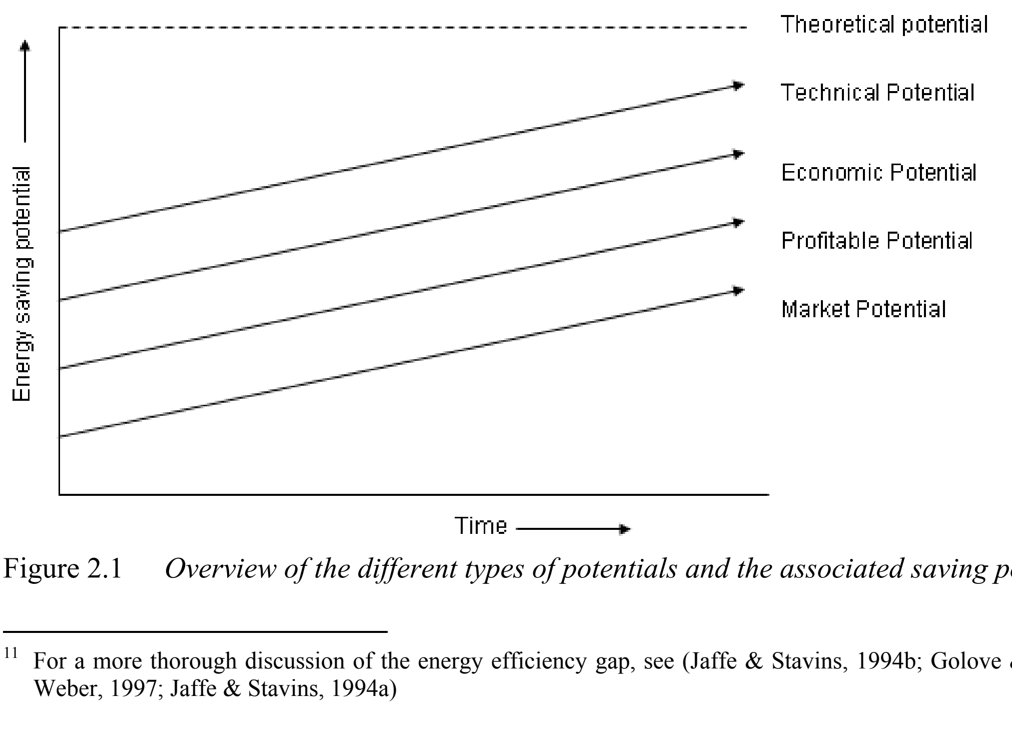


Figure 2.1 *Overview of the different types of potentials and the associated saving potential*

[11] For a more thorough discussion of the energy efficiency gap, see (Jaffe & Stavins, 1994b; Golove & Eto, 1996; Weber, 1997; Jaffe & Stavins, 1994a)

The **theoretical potential** is regarded as the potential that will be achieved when only physical limits are taken into account. The result is a value for the least energy intensive manner in which a certain process can be performed. The technologies that are used for those processes are included in the **technical potential**. For a certain year the expected 'state of technology' is calculated on the base of engineers' calculations, the energy that can be saved by adoption these more energy efficient technologies is called technical potential. Subsequently the **economic potential** takes also economic factors into account. Blok (2007) defines it as "*the part of the technical potential that is economically attractive from a social perspective*", which means that only those technologies are included that show a net present value at a social discount rate, or show Payback periods that are accepted from a social viewpoint.

In reality companies don't use the social discount rate as criterion for their decisions, but they demand higher discount rates resulting in lower potentials. The **profitable potential** represents the energy savings that will be accepted by companies. A large difficulty calculating the profitable potential lies in the fact that the required discount rate (or payback time) differs among sectors and companies, which brings us to the **market potential**. This potential can be regarded as the real potential, while it takes into account all factors that determine implementation in reality. Heterogeneity among firms is included, non-economic barriers are, and even the effect of policies can be included then we speak of the **enhanced market potential**.

As may be clear from the discussion on different potentials, calculation becomes more difficult the more aspects are taken into account. While the theoretical potential is undisputed, technical potential already includes many assumptions about future innovations, and the market potential can be heavily discussed. The fact that the potentials also change in time makes calculation even more difficult. Despite these problems, it will still be useful to obtain insight in the proposed sizes of the different potentials.

Calculation by De Beer (1998) shows for example that for the heavy industry technical saving potential in the long term is 25 percent[12], while the profitable potential amounts to 16 percent. For the light industry energy saving potential is higher, whereas the technical potential is 40%[13], the profitable potential is 14% (De Beer, 1998). In a more recent study De Beer estimates the energy saving potential for the industry in general within the range of 20%-30% (De Beer & Blok, 2003). In her study on the potentials of no-regret technologies, Ostertag (2003) showed a wide variety in estimates. Saving potential for the Netherlands, are identified based on studies by Blok *et al.* (1993), who claimed that the policy objective to reduce CO_2 emissions by 3-5% between 1990 and 2000 can be reached at net negative costs, and Velthuijsen (1993) who identified an energy saving potential of 20% of the Netherlands' energy consumption taking into account a payback time below five year. In a later study Velthuijsen (Velthuijsen, 1995) calculate the efficiency gap at 61.7 percent, which indicates that almost two-third of the economic possible options have not been installed. However calculation of the profitability gap shows that only 7.1 percent of the energy efficiency options considered profitable, have not been installed. This finding is also supported by Swigchem *et al.* (2002) who indicated that out of the 18 options that were found to be cost-effective from an societal point of view[14], 7 of these were indicated as not cost-effective by the different companies[15]. First these figures are based on dated studies, whereas newer data is desirable. But more important the difference between definitions of the potential and the time horizon that was used make comparison of the calculations very difficult.

Because of the background of this study, which focuses on the SAVE-production model used by ECN, it is obvious to use the same data as used in SAVE for the calculation of energy saving potentials. For the determination of the technical and profitable potential for the year 2020 calculations with the SAVE production model are used. The technical potential is calculated by as-

[12] Which corresponds to an absolute saving of 300 PJ_{prim}
[13] Which corresponds to an absolute saving of 130 PJ_{prim}
[14] Swigchem *et al.* call it the point of view from the company "Netherlands" and assumed a CPBP of 5 year.
[15] Here a CPBP of three year is used.

suming that all technologies present in the SAVE model are adopted, which results in a potential of 442.6 (PJ). For calculation of the profitable saving potential restrictions are set to the maximum payback period of five years that is often associated with profitable investments from a social point of view. Calculation shows that different technologies exist with very low payback periods (illustrated in Figure 2.2). It is striking to notice that over 80 percent of the technologies, identified in the SAVE model, are profitable and account for around a potential of around 322 (PJ). The potential can be gradually fulfilled by the adoption of these technologies, but it is still clear that many of the showed technologies are already present, and economically attractive, but have not been adopted by many companies.

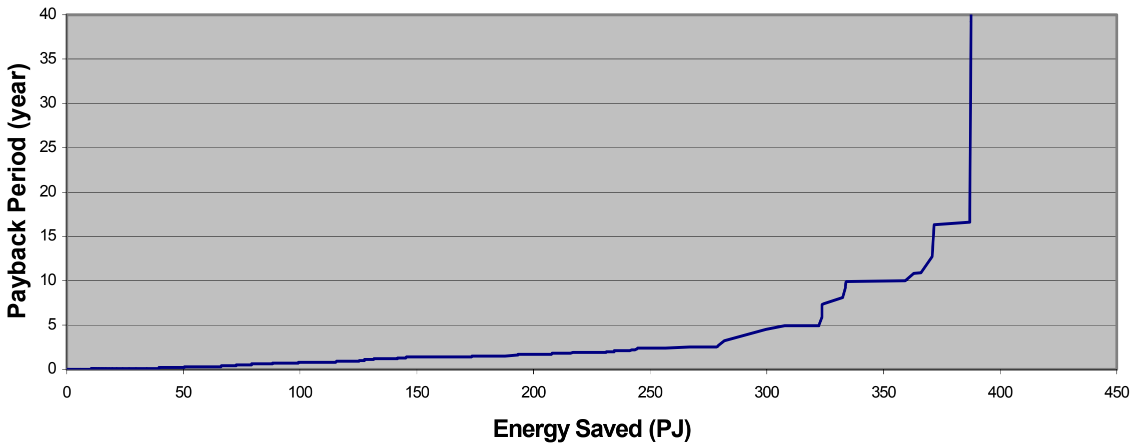


Figure 2.2 *PBP of energy saving technologies in the industry (in 2020)* [16]

Source: ECN, 2006.

2.2 Technology characterization

Like mentioned before, the chance of any technology to be implemented heavily depends on the characteristics of the companies, but a second important factor is the characteristics of the technology. To illustrate the relation between technology characteristics, and the rate of adoption is presented firstly, followed by an example of energy reduction in motor driven systems in Section 2.3.

For a technology to be implemented it passes different stages of development, from applied research to demonstration and eventually large-scale adoption. The phase of development determines in a large extent the possibility of a technology to be commercialised. In addition, the impact that is associated with adoption of a technology influences the chance of implementation. A machine that easily fits in the current process is more likely to be implemented than a technology that has large impacts on rest of the process and for which many adaptations are needed. De Beer (1998) created a matrix that shows the chance of a technology to be implemented as a function of the degree of technical change on the horizontal axis, and the stage of development on the vertical axis (see Figure 2.3). The arrow indicates the likelihood for a technology to be commercialised and adopted. A radical technology that is still in the applied research phase is less likely to be commercialised than an evolutionary technology that already demonstrated itself. Radical change often requires the development of new knowledge and experience, whereas evolutionary change can build on existing knowledge and experience. The combination of the two parameters quickly gives an idea about the likelihood of a new technology becoming available and the probability for implementation. The distinction between radical, major and evolu-

[16] The calculated payback periods are calculated at the base of the SAVE model by ECN, who used the ICARUS 4 database for the identification of technologies.

tionary changes is important for application in this study. It is assumed that the technologies are already available on the market.

Also Zilahy (2004) identified different types of measures when regarding options for energy efficiency improvements. In total seven categories are identified, of which three considered improvements of machinery and equipment. The first group, 'application of new technology', embeds the replacement or amendment of existing technology. The second group is called 'modification of existing technology' and incorporates modification of important features of existing technology, while modernisation of existing technology without major modifications are places in the third group; 'upgrading and modernisation of the equipment.' The relation with the classification by De Beer (1998) summarised in Table 2.1. The other categories by Zilahy (2004) focused on energy management and controlling, which are out of the scope of this study.

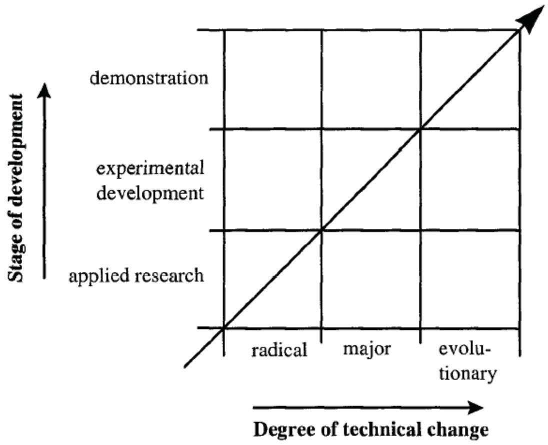


Figure 2.3 *Characteristics of technology and the chance of adoption*
Source: De Beer, 1998.

Table 2.1 *Technology characterisation*

	Typology technology	Characterization
1	Radical	Application of new technology, replacement
2	Major	Major modification of existing technology, retrofit
3	Evolutionary	Minor modification of existing technology, retrofit

2.3 Energy reduction potential for motor driven systems

A great number of energy efficiency improvement measures can be identified, for example the ICARUS database by the Utrecht University (Beer *et al.*, 1994) and a United Nations study by Worrell *et al.* (1997) contain a broad overview of possible measures. Some of these technologies are sector or company dependent, but also many technologies are identified that have a broad range of implementation. One of these, so called crosscutting, technologies is the variable speed drive for motor driven systems, discussed below.

The adoption and implementation of more efficient motor systems can play a significant role in reducing energy use in the Netherlands. In an advise to the Dutch ministry of economic affairs extra investment in efficient motor systems is presented as a possible policy measurement for the increase of the energy reduction rate (Harmelink *et al.*, 2005). The Dutch government already promotes investments in more efficient motor systems by subsidizing investments within the framework of the tax relief for investments in energy-saving equipment and sustainable energy (SenterNovem, 2006a) and the Long-term agreements between the government and industrial companies contain agreements on the implementation of energy saving motor systems. On European level the Motor Challenge Programme is a voluntary programme through which industrial companies are aided in improving the energy efficiency of their Motor Driven Systems (European Commission, 2006).

Motor systems account for a large part of the total electricity use in the industrial sector. In Europe about 65 percent of total industrial electricity is consumed by motor driven systems (De Keulenaer *et al.*, 2004), the Netherlands show similar figures (Blok & Visser, 2005). Different technologies for energy reduction in motor systems exist, of which the following options are most common:

1. Installation of a variable speed drive on motors (VSD/ASD, *toerentalregeling*).
2. Application of high efficiency motors (HEM/EEM).
3. Energy reduction within the motor applications, like pumps, compressors and fans.

Pumps, fans and compressors account for 62% of total motor electricity consumption in the industrial sector (see Figure 2.4b). These applications often require controllable loads that are currently regulated with valves ore other mechanical instruments; application of VSDs can result in significant electricity reductions. Average savings in electricity use associated with the application of VSDs are between 15 and 35 percent (Harmelink *et al.*, 2005; de Wilde & Stienstra, 2006) and application is possible in about 40-60 percent of industrial companies (Harmelink *et al.*, 2005), the total economic saving potential for VSDs in Europe is 162 PJ_e (De Keulenaer *et al.*, 2004). Overviews of possible applications for VSDs is shown in Table 2.4a, strikingly are the low payback periods. The fitting in of VSDs in most of the applications is mainly associated with PBPs of less than 2 years.

a)

Sector	Application	Savings (%)	Payback period (years)
Metals	Reheating furnace	50	1-2
	Fume cleaning	37	2-3
Pulp and paper	Stock transfer pump	65	2
	Paper pulper	13	1
Chemicals and plastics	Cooling water pump	12-30	1-2
	Stirrer batch vessel	52	2-3
	Boiler fan	63	<1
Food and drink	Refrigeration	45	1-2
	Whey solution transport	41	<1
	Vacuum fan (bread depanner - bakery)	41	1-2

b)

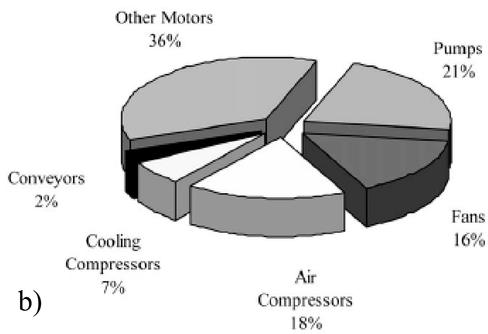


Figure 2.4 *a) Savings and payback periods from VSDs. b) Desegregation of motor electricity use in industry*

Sources: a) European Commission, 1997; b) de Almeida *et al.*, 2003.

Application of high efficiency motors can save 3-5 percent of industrial electricity use (Harmelink *et al.*, 2005), is widely applicable and has an economic savings potential of 86 PJ_e (De Keulenaer *et al.*, 2004). The highest energy reduction can be gained in the field of motor applications. Efficiency improvements in European pumping systems, compressors and fans have saving potential of respectively 151 PJ_e, 83 PJ_e and 64 PJ_e (De Keulenaer *et al.*, 2004). According to de Almeida *et al.* (2001) main potentials for implementation of VSDs in the industry are small and medium pumps and medium fans. Figure 2 gives a graphical overview of the different technologies; installation of a VSD, combined with a HEM and more efficient pumps can reduce electricity use with 59 percent (de Almeida *et al.*, 2000).

Efficient motor systems are applicable in a wide variety of companies and sectors, which makes them 'cross-cutting' techniques. Nevertheless it is useful to look at the share of motor electricity use for the different industrial sectors. Especially the non-metallic mineral sector and the food and tobacco sectors heavily depend on motors for their production processes, but the highest economic savings for EEMs and VSDs can be found in the basic chemistry and paper and cardboard sectors. In 1995 VSDs had a penetration of 50 percent in the paper and cardboard sector in the Netherlands (Alsema, 2001b). Realization of 5 percent extra electricity savings can be realized at an investment of 11 €/GJ of primary energy saved, which corresponds to an average payback time of 2 years[17] (Alsema, 2001b). For the chemical industry Alsema (2001a) calculated saving potentials and costs for the different sub sectors (e.g. organic basic industry and fertilizer industry). On average these costs are in the order of 10-20 €/GJ of primary energy saved (Alsema, 2001a)[18]. The field of application for more efficient pumps, compressors and fans is also very broad, but because the techniques are less general, comparison among sectors is difficult.

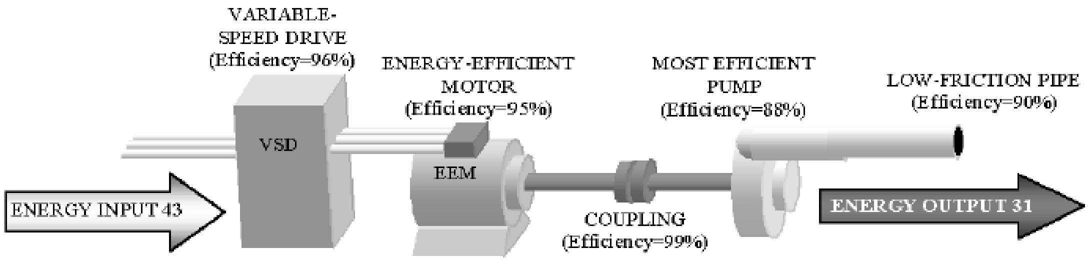


Figure 2.5 *System overview for an pumping system based on different efficient technologies*
Source: de Almeida *et al.*, 2000.

[17] Based on 1995 energy prices.
[18] For information on data uncertainty and reliability read (Alsema, 2001a; Alsema, 2001b).

3. Technology adoption on company level

3.1 Introduction

As was shown in the previous chapter, implementation of more energy efficient equipment can significantly contribute to further energy reductions in the industry. Energy use of existing machines is usually sub optimal and results in large potentials for further energy savings. Jaffe and Stavins (1994a) distinguish three steps which are needed for the widespread saving potential of new technologies, which are (1) invention, (2) innovation, and (3) diffusion. The last step, diffusion, focuses on the gradual process of adoption of technologies, and is analysed in this study.

The central goal of diffusion models is to give a time-path of the number of adopters of a technology, by which the gradual uptake of new technologies can be understood[19]. Rogers (1995) states that adopters of any new innovation can be categorized in five main groups:

- Innovators[20], *the first 2.5% of the adopters, who can be characterized as educated, venturesome, risk taking and they have multiple information sources.*
- Early adopters, *the next 13.5% that are also well educated and can be regarded as social leaders.*
- Early majority (34%), *who form the first half of the majority, are deliberate and have many informal social contacts.*
- Late majority (34%), *the second part of the big mass, with a sceptical attitude towards new technologies, are more traditional and have a lower socio-economic status.*
- Laggards, *the last 16%, who traditionally have small information networks and experience fear of debt.*

The distribution of technology adoption is also shown in Figure 3.1, where the potential for the associated energy saving is presented by the surface under the curve.

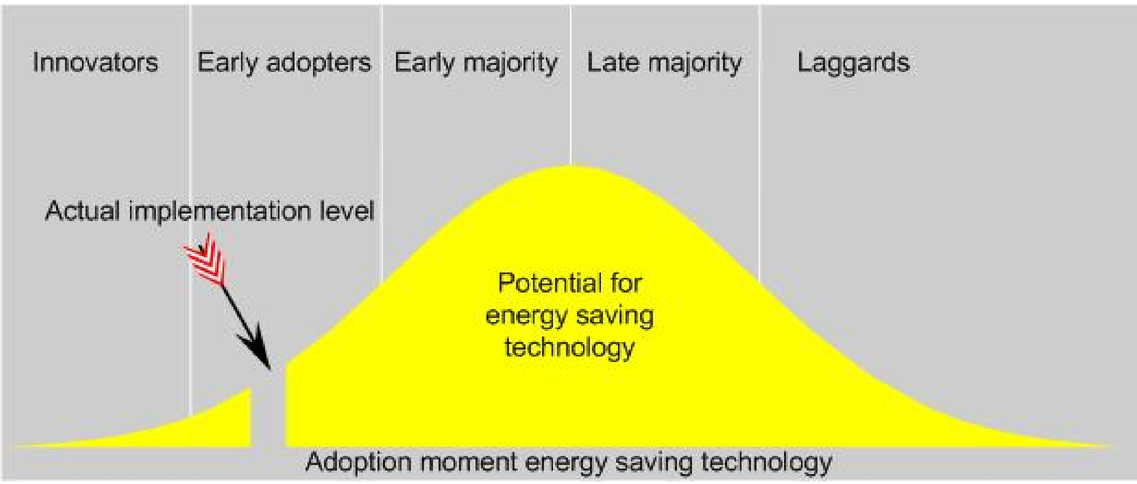


Figure 3.1 *Potential for energy saving as a function of adoption by categories of companies*

---

[19] For more information on the diffusion of new technologies see for example (Rogers, 1995)

[20] A nice example of the importance of innovators is given by (Runhaar et al., 2006), who analysed the effect of environmental leaders on the reduction of environmental impact within companies.

Diffusion can be regarded as the aggregate of individual adoptions (Gillisen *et al.*, 1995). The general equation for the epidemic diffusion model suggests that a new technology will diffuse according to (Jaffe & Stavins, 1994a):

$$\frac{dS_t}{dt} = a.\left(\frac{S_t}{U_t}\right) \cdot \left(1 - \frac{S_t}{U_t}\right) \qquad (1)$$

By which S_t denotes the stock of users that have adopted the technology by time t and U_t represents the sum of all potential users. As cited from Jaffe & Stavins (1994a): "*the first factor in brackets is the probability of encountering an 'infected' agent and contracting the disease (adoption); the second factor is the proportion of the population that is 'healthy' and thereby candidates for 'infection' (adoption). The multiplier, a, is the 'infectiousness' of the disease, and parameterises the speed of the diffusion process.*", Figure 3.2a shows the single adoption decision of a company, which in combination with Figure 3.1 results in the general diffusion curve as presented in Figure 3.2b. These curves often take the form of a so-called s-curve (Dieperink *et al.*, 2004; Jaffe & Stavins, 1994a; Velthuijsen, 1995) and are commonly used in models that predict distribution of new technologies.

The slow initial diffusion of a technology can be explained in different ways (Gherardi *et al.*, 1999). Firstly it can be regarded as a result of the slow dispersion of information and knowledge about the technology, a second theory conceives diffusion as a mainly economic process. Initially new technologies have high associated costs and the risk perceived by potential users is high as well, as the technology gets implemented by more users, costs and perceived risk will drop, which acts as a stimulation for other companies. Empirical studies on adoption rates and diffusion patters show that very high implicit discount rates are needed to explain the slow diffusion of technologies (Howarth & Andersson, 1995). The decision-making process within organizations is "*much more complex than the theory of diffusion assumes, with its obsolete and simplistic model of dichotomous (adopt or not to adopt) and rational organizational decision-making.*" (Gherardi *et al.*, 1999) For a single company to come to an investment decision it is influenced by many aspects. A company, for example, must have access to financial funds, it needs information on the technology and a suitable moment for replacement of current machines is needed. Next to these hard decision aspects, many soft factors play a role. For example personnel abilities, organization culture and priorities are important determinants for investments. The diffusion of a given technology is determined by all of these underlying factors and it is desirable to retrieve more insight in the investment decision on company level, and the barriers that cause the slow adoption of energy saving technologies.

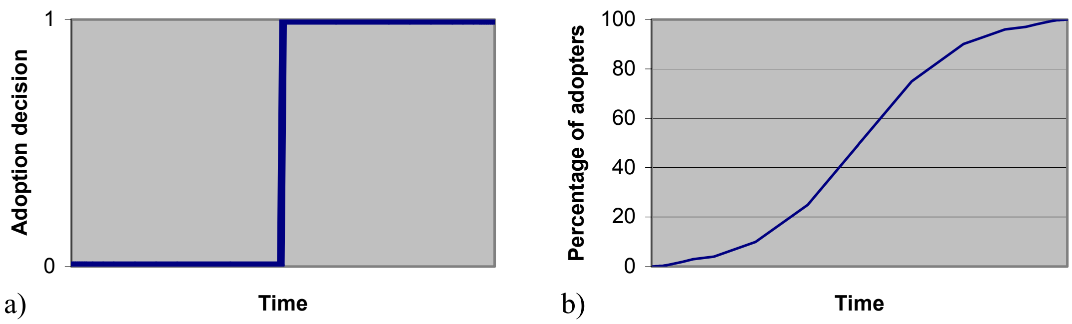


Figure 3.2 *a) adoption decision of a single firm, and b) aggregate diffusion curve*

3.2 Neoclassical decision making theory

The question whether a firm will invest in energy saving technology depends on many factors, but the fundamental incentive is an economic one. This is also stated by Velthuijsen (1995) and Gillisen *et al.* (1995) who mention '*contribution to profits*', '*return on investments*' and '*cost effectiveness*' as the most important decision criteria for investments. A commonly used theory for explaining the investment behaviour of firms is called the neo-classical theory of investment that regards a firm as a "*point that - or who - maximizes a single target function, given certain constraints regarding its production possibility structure and the conditions on the market. It takes rational decisions regarding every aspect of its production process"* (Velthuijsen, 1995). According to this theory, companies will invest in energy efficiency improvements if the associated marginal revenues are higher than marginal costs. Velthuijsen (1995) argues that several simplifying assumptions are made in the neoclassical model, which results in efficiency gaps. These factors include adjustment costs, delivery lags and irreversibility, uncertainty and risk-aversion, imperfect competition, limited finance and governmental policy.

For a company to analyse the profitability of energy saving investments, it can use different economic valuation methods. Examples are the simple cost/benefit analysis, payback period (PBP), calculation of the net present value (NPV), or an analysis of the internal rate of return (IRR). Because the evaluation method says something about the efforts companies put in their analyses, an overview of the methods used follows. In his study Velthuijsen (1995) found that 44% of the companies base their investment decision on a cost/benefit analysis, 35% use the PBP, 6% perform a NPV calculation, and 4% used IRR criteria as the most important calculation method. Another study by Aalbers *et al.* (2004) indicated similar results. Analyzing investments in energy saving technologies at companies that applied for an EIA subsidy, 43% of the companies did not use an explicit method[21], 41% used the PBP, and 4% used the IRR calculation method. Studies by Harris *et al.* (2000) and Gillisen *et al.* (1995) even mention that 80% of all companies use PBP calculations. Aalbers *et al.* (2004) illustrated that the probability of a companies using explicit investment criteria, is similar among sectors, but strongly depends on firm size (see Table 3.1). In general smaller companies are expected to use simpler evaluation methods than larger companies, who make a more thorough analysis.

The use of these relatively simple evaluation methods is in contrast with most theoretical frameworks, which mainly use NPV calculations as the key determinant of the profitability of investments. While the PBP analysis and NPV calculations are mutually dependent, the key point is that companies in general use valuation methods that are simpler than assumed in most models, as a consequence companies are less aware of the exact size of the savings (in monetary terms) they can obtain. As stated by Stern (1984) payback rules represent a type of routine, "*they economise on managerial effort in examining investment proposals across widely different operations.*" Prove for the relation between the type of evaluation method, and investments in energy saving technology is also proposed by Aalbers *et al.*(2004), who conclude: "*firms using an explicit investment criterion are less likely to adopt energy saving technology compared to firms not using an explicit investment criterion.*"

[21] Which can still mean a simple cost/benefit analysis.

Table 3.1 *Probability of firms using an explicit decision criterion*

Variable	Probability of using explicit criteria [%]
Food industry	29
Agriculture	30
Industry	28
Trade	25
Transport	21
Commercial Services	25
Non-commercial services	28
Turnover between € 0.45 and 4.5 mln	66
Turnover larger than € 4.5 mln	75

Source Aalbers *et al*, 2004.

The fact that the PBP calculation is the most common valuation method and the applicability of the concept in small as well as in large companies pleads for the use of the PBP valuation method in this study as well. The PBP analysis calculates how long it takes before the initial investment has paid itself back, and the simple formula is given below (Gillisen *et al.*, 1995).

$$PBP = \frac{I_0}{B} \qquad (2)$$

Whereas I_o is the initial investment and B incorporates the annual benefits resulting from the investment. The basic formula assumes that the annual benefit stays constant over time and no other costs incur during the lifetime of the technology. An investment is considered profitable if the PBP of the investment is smaller than the Critical Payback Period (CPBP), which is the longest acceptable period for a technology to earn its investment back. The assumption that firms use the PBP calculation as the main decision criteria has many hooks and eyes. In essence the economic model, so also the used PBP calculation, is only correct if the following conditions are met (Groot *et al.*, 2004; Golove & Eto, 1996):

- The decision is a result of rational behaviour (maximising benefits, minimising costs).
- The company has access to full and perfect information, also on market prices, and real costs and benefits associated with the investment.
- No capital restrictions exist.
- There is no uncertainty regarding future costs and benefits.
- Transaction costs are zero.
- A complete set of markets with well defined property rights exist.

The basic economic model needs adjustments or additions if one of more of these criteria is not met. This will cause a change in the calculated PBP.

While the size of the CPBP being of great importance, the strategic characteristics of the investment plays a crucial role as well. As proposed by Hennicke (1998) due to the low priority of energy many profitable proposals are dismissed too early when assessed only from the narrow perspective of energy costs. In many aspects energy saving projects are not really strategic, but can be classified as bottom-line investments, which is also argued by Bremmer *et al.* (2007) and Swigchem *et al.* (2007) in their statement that energy saving is not a goal on itself, but is part of the broader company management.

3.3 Typical payback period for energy saving technologies

As mentioned before it is assumed that companies will invest in a project if the CPBP exceeds the PBP calculated for the project. In essence, the CPBP at company level is the same for all projects that experience the same rate of risk. So investments in energy saving technologies are supposed to be equally valued to other investments (for example projects that expand production capacity, or improve quality). This is also proposed by Watkins and DeCanio (1998) when stating: "*one of the clearest consequences of the neoclassical theory of investment is that the discount rate used to calculate NPVs [ed. so also PBPs] should be the return available on projects in the same risk class…*" However, remarks by energy experts suggest that investments in energy saving technologies are associated with higher CPBPs than comparable other investments. A study by Gruber and Brand (1991) based on a survey by 500 small and medium sized companies on the other hand found no prove for this statement, as can be found in Figure 3.3. Also Gillisen *et al.* (1995) invalidate this statement: ".. *In our studies we did not encounter differences between the evaluation of energy conservation investments and other investments*."

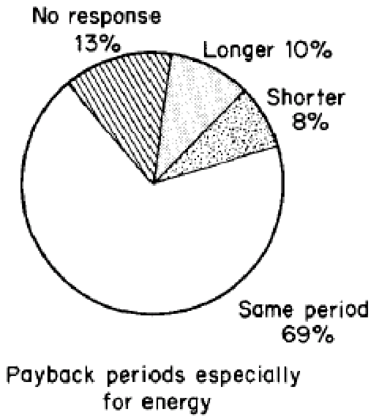


Figure 3.3 *CPBPs associated with energy saving investments, compared to CPBPs for investments in general*

Source: Gruber & Brand, 1991.

At the same time Figure 3.4 shows that there is a wide variance in CPBPs between companies, but by far most companies require a PBP of less than five years. Having in mind that many policy studies regard investments with CPBPs up to five years cost-effective, the results by De Beer *et al.* (1996) indicate that in reality companies demand lower PBPs, which is also stated by many of the respondents that have been interviewed for this study. Ten out of the eleven respondents indicated that investments purely aimed at improvement of the energy efficiency require PBP that are much lower than five years. While no overall PBP can be given, most respondents suggest a period between 2-3 years as maximum accepted.

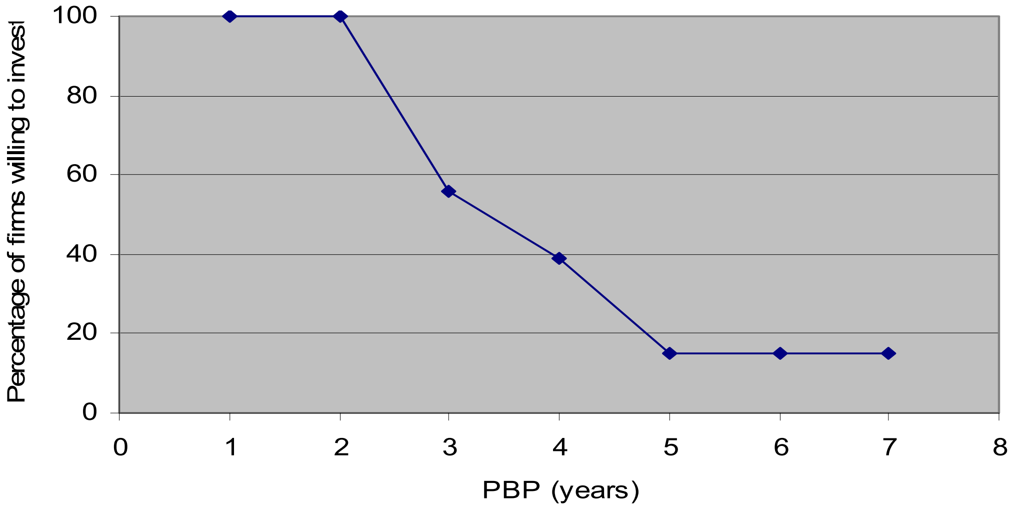


Figure 3.4 *Percentage of firms willing to make an investments with a given maximum PBP*
Note: data from Beer *et al*., 1996.

This finding is in contrast with Velthuijsen (1995) and Gillisen *et al.* (1995), who found average PBPs of 5,8 and 5,5 years respectively. Also Aalbers *et al.* (2004) found a higher PBP, for profit organizations they calculated an average CPBP for energy saving investments of 6,6 years[22]. More stringent investment criteria are proposed by Harris *et al.* (2000), who found an average payback period for energy saving investments of 42 months and DeCanio (1998) who calculated an average PBP of 3,3 years for investments in the US Green lights project. In an earlier study DeCanio even mentions shorter PBPs (DeCanio, 1993).

The previous discussion on the CPBP makes clear that no unambiguous period can be defined for energy saving technologies. As mentioned in one of the interviews individual companies work with different CPBPs, but also other aspects like strategic interest of the invest can make a company accept higher PBPs. More concrete, the PBP used within policy calculation (five years) is heavily cast in doubt by the respondents in this study, but the analyzed literature does not generally underline this statement. The next chapter focuses on the factors, or barriers that can block investments in energy saving technologies.

[22] For the distribution of the CPBPs see the report by Aalbers *et al.* (2004).

4. Barriers to investments in energy saving technology

4.1 Schematic overview of the barriers

Many barriers or obstacles can hinder investment in energy saving technology. In addition, many authors have tried to create an overview of the different barriers as framework for analyzing the relevance of the barriers. While some studies focus on specific parts of the barrier spectrum, others offer a complete overview. Within this broad range of articles and reports, this study heavily draws on the work by Sorrell *et al.* (2000) for the creation of the barrier framework. Together with input from other studies on the topic and important comments and remarks by respondents in the field of energy research, a conceptual model is created that will be used for the analysis Chapter 5. Firstly, this section will explain the structure of the model shown in Figure 4.2.

In essence, the conceptual model represents aspects that in one way or another can influence an investment decision of a company. More specifically all these aspects can possibly be barriers to investments in energy saving technology. Centrally, in the inner oval, the basic investment decision for a given company is presented. A firm will invest in a technology if the associated cost savings or profits exceed a certain critical value[23]. Within this study, the decision procedure regards the so-called no regret technologies implying that from a technical-economic view the investment is profitable.

For the explanation of the fact that many of these no-regret technologies are not being implemented, the model contains various factors that can result in negative assessment of energy saving investments. It is importance to notice that the mentioned factors are not barriers per definition, but they may possibly act as blocking mechanism for energy saving investments. For example, the way a company is structured largely influences the decision making progress. While for some companies it obstructs investments, other companies do not experience negative influence of the structure. Influences on a detailed level are shown at the outside, and generalized towards the inner ovals. The yellow oval acts as link between the surrounding ones where subcategories are identified. In general, the outward level of influence contains aspects that are more concrete. The inner oval presents barriers that are common in literature. The five central factors (Availability capital, organizational aspects, information/knowledge, hidden costs and uncertainty/risk) guide as a collective noun for all aspects mentioned. The barriers within the five clusters are mostly connected to their own cluster, but because no unambiguous categorization is possible[24] interrelations are inevitable. The dashed arrows identify some of the most important relations between barriers of different groups, but in order to make the concept workable the presented categorization is used as base for the rest of the study.

Next to the three levels of influence, distinction has been made based on the nature or actor of the influence. Whereas the blue aspects are mainly determined by the characteristic of the organization, red aspects originate from behaviour on individual level; note that this classification is closely related with the typology by (2000) [25]. The green factors depend on the characteristics of the technology, and the surroundings or external actors determine the white aspects. The latter are typically beyond the control of firms and are the result of the actions by public- and private sector organizations. Some aspects have more actors, indicating that it can influence the

---

[23] Or in this case an investment is considered profitable if the PBP of the investment is smaller than the Critical Payback Period (CPBP) associated with the investment in energy saving technology, see Chapter 3-3.

[24] For a discussion about the difficulties of categorizing the barriers I refer to (Weber, 1997).

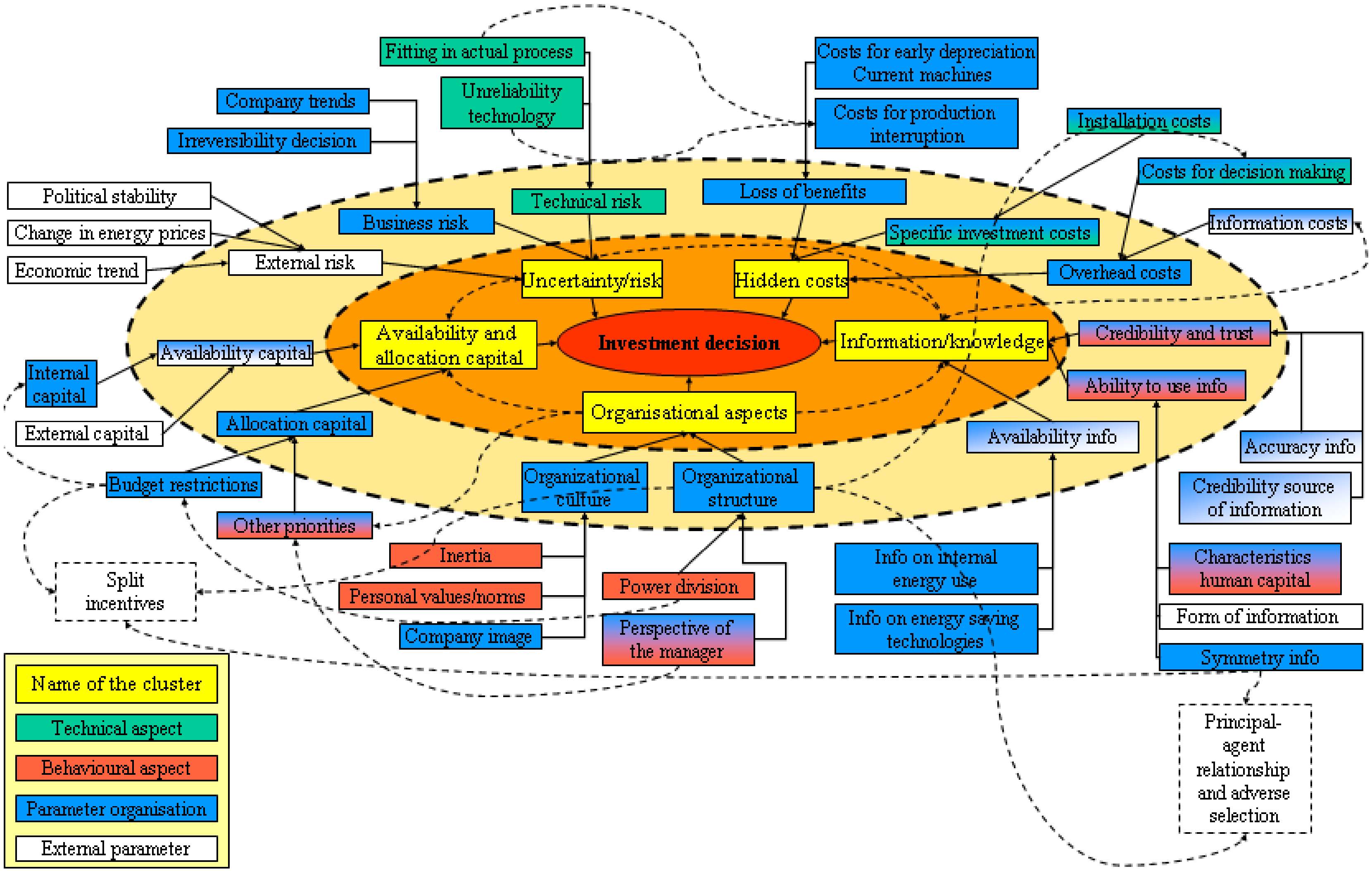
[25] I.e. the red aspects correspond to the behavioural barriers as mentioned by Sorrel *et al.* (2000). Organizational barriers are assigned to the group of organizational aspects. Finally the economic barriers have been subdivided into four other groups (Availability capital, information/knowledge, hidden costs and uncertainty/risk).

investment decision on different levels. The ability to use information, for example, is a matter of the way an organization is structured, but the capabilities of individual employees are crucial as well. In general, all the company is involved as actor within all barriers, because the perception of the company mainly determines the way it deals with the obstacles presented

In literature, ‘split incentives’ and the ‘principal-agent relationship’ are often regarded as separate barriers. While agreeing with the assumption about those factors being barriers, this study regards both barriers as the result or outcome of factors that are already mentioned in the overview. The principal-agent relationship occurs when the principal does not have complete information about the actions of the agent. In the model, this has been identified as a result of information symmetry (who has the information) that is tightly connected to the ability of an organization to use the information. The principal-agent relationship therefore is not mentioned as a separate aspect, but is already embedded in the symmetry and ‘ability to use’ aspects that are both the result of the way a company is structured. The same picture can be drawn for split incentives, which is the result of split budgets and the organizational structure.

The Chapters 4.2 until 4.6 discuss the different barriers. Each section describes one of the five clusters of the model. Whereas the concepts from the yellow oval are indicated by the headings, individual barriers are highlighted in the text.

Figure 4.1 *Conceptual model for the identification of barriers*



4.2 Uncertainty & Risk

The first group of barriers is a result of risk and uncertainties associated with investments. Instead of being an objective and measurable barrier, risk is mainly the result of company perception. In accordance to the theory of rational economic behavior, companies react on risk by applying more stringent investment criteria and a higher hurdle rate for energy saving technologies (Worrell & Price, 2000; Sorrell *et al*., 2000). This negatively influences the adoption of these technologies. It is important to notice that all investments are associated with a certain extent of uncertainties. It is the specific uncertainties associated with investments in energy saving technologies that are regarded as barriers.

Most studies on the barrier topic agree on the statement that uncertainty and risk is an important barrier (Hirst & Brown, 1990; Swigchem *et al*., 2002; Velthuijsen, 1995; Gillisen *et al.*, 1995), but some remarks are needed. As pointed out by one of the respondents interviewed for this study, it is essential to split up risk and uncertainties into different barriers. Sorrell *et al.* (2000) defined three categories of risk:

- **External risk,** *that is associated with the overall economic trend, uncertainty about future fuel and electricity prices and governmental policy.*
- **Business risk,** *regards sector and company trends and irreversibility of decisions.*
- **Technical risk,** which *includes unreliability surrounding new technologies.*

An overview of these barriers follows.

4.2.1 External Risk

It is highly expected that future energy prices will change and influence the implementation of energy saving technologies[26]. Still large uncertainties exist about the actual speed and capriciousness of is change. A commonly mentioned barrier is the **uncertainty about future energy prices.** As a result future cost savings and the profitability of an investment become uncertain, which is also argued by Jaffe and Stavins (1994a): "*Energy saving investments often have much uncertainty about their payback, both because future energy prices are highly uncertain, and because actual energy life-cycle savings in any particular application can only be estimated.*" When energy prices will increase, an investment in energy efficiency is associated with high costs savings, but when the price does not increase that much (or even decreases) the future earnings of the investment fall short.

In markets with strong growth and competition, efficiency, with respect to energy and other inputs, is necessary to survive. In contrast, stagnating markets are poor theatres for innovation and investment, and instead rely on already depreciated equipment to maintain low production costs. A favorable market expectation, **or economic trend**, has been perceived as an important condition for investing in energy efficiency. In markets where increased energy costs can still be recovered in the product price, the influence of changing energy prices on investment levels is uncertain. While general market conditions, like the economic trend, influence not only investments in energy saving technologies, but also other investments, it can be difficult to analyze the exact influence of market situations.

A third external barrier regards the uncertainty about **policy regulations**. Different subsidies and other measures try to stimulate the adoption of energy saving technologies (see text box 1). The effectiveness of policy instruments for the adoption of energy saving technologies has been widely researched. Some of these studies argue that many companies do not include subsidies in their calculations (Swigchem *et al*., 2002), judge subsidies and funding not manageable

[26] Surprisingly Koetse *et al.* (2006b) found that *"...expected increases in energy prices stimulate investments in energy saving-technologies, but surprisingly this effect is absent in large firms.*"

(Hennicke, 1998), or indicate the low impact of subsidies of energy-saving measures (Aalbers *et al.*, 2004; Gruber & Brand, 1991). Despite these figures, an often heard statement is that the government needs to stick to a more consistent and robust policy. No clear evidence has been found to this statement, but as indicated by Worrell and Price (2000): "*Regulation can contribute to more successful innovation, but sometimes, indirectly, can be a barrier to implementation of low greenhouse gas emitting practices.*"

An important characteristic of external barriers is that the companies can not influence it. These barriers are raised by the external surroundings, like the government, sector or national economy. Companies have to deal with it, but in essence they can not remove these barriers themselves, in contrast to the technical and especially the business uncertainties, which are mostly a result of the activities of the company itself.

4.2.2 Business Risk

This kind of risk is associated with activities within the company and the way firms deal with it. Companies in general tend to be risk-averse and prefer to go on with the actual situation, changing to a new strategy is associated with uncertainties and therefore not preferred (Bremmer *et al.*, 2007).

Irreversibility of an investment is one of the key elements involved with business risk. As Soest and Bulte (2001) demonstrated in their study, it may be rational not to invest in a technology that appears profitable from a conventional economic point of view. "*Postponing an (irreversible) investment is costly as short-term energy savings are foregone. However, it enables firms to benefit from an even better technology in the future*." This point of view is shared by De Groot (2000) who illustrates that it can be worthwhile delaying an investment, because of uncertainties about future interest rates and energy prices[27].

A second barrier that is classified as business risk, involves the **company trend**. When a company is doing well, the climate for investments is expected to be positive as well. At the other hand bad results can make a company decide to decrease investments in general, and specifically in bottom-line investments like energy efficiency improvements.

4.2.3 Technical Risk

The last category of risk as mentioned by Sorrell *et al.* (2000) involves the risk associated with the technology and its relation to the process. Most companies will avoid an interruption of production process. Two barriers are identified that underlie these uncertainties. The first barrier is the perceived **uncertainty of the technology** itself, and the second embeds uncertainties associated with the relation between the new technology and the actual production process, or the **fitting in the actual process**.

[27] De Groot (2000) also gives an example of the concept of irreversibility.

Box 1: Policy instruments used for the stimulation of energy saving technologies

The Dutch government tries to stimulate investments in energy saving technologies in the industrial sector using levies, subsidies, agreements, trading systems and information. One of the most important measures is the tax relief for investments in energy-saving equipment (EIA, *Energie investeringsaftrek*). By means of the EIA a fiscal advantage is given to companies by making investments in energy saving technologies partly deductible. In 2005, 9.271 EIA requests[28] have been submitted with a total value of € 1.2 billion (SenterNovem, 2006b). Because the number of applications in 2006 exceeded the budget for 2006, the minister of finance decided to close the regulation in October 2006. In January 2007 EIA will be opened again.

Another way of efforts made by the government can be found in the Long-Term Agreements (MJA's, *Meerjarenafspraken*) between the government and industrial sectors for improvements in energy efficiency. The first MJAs ended in 2000 and resulted in an average energy efficiency improvement of 22.3% between 1989 and 2000 (www.senternovem.nl). Presently new MJAs have been arranged with individual companies and branches for a period of 12 years. Next to the MJAs, large companies are involved in the Energy Efficiency Benchmarking Covenant, in which they indicated to belong to the world leaders in energy efficiency in 2012.

An overview of policy measures and their influence on the demand of energy and energy efficiency is given by Van Dril (2005). For the realization of the proposed, stringent energy efficiency goals, effective utilization of these policy instruments will be essential.

4.3 Hidden costs

Hidden costs represent the most common argument against the 'efficiency gap' hypothesis. The claim is that most economic studies fail to include all costs and benefits associated with energy saving investments. Standard PBP calculations differ from reality, since costs will to a large extent be technology- and firm-specific, depending mainly on economic, organizational and human capital factors (Koetse *et al.*, 2006a). In practice many costs are not known or differ among firms (heterogeneity), with wrong profitability calculations as a result (Groot *et al.*, 2004). According to de Groot *et al.* (2004) especially the size of a company, availability of organizational qualities, and the availability of human capital are determinants for the associated profitability of a technology. It is, for example, likely that standard payback periods are systematically at the low side, because especially small and medium sized companies have limited possibilities for exploiting economies of scale (Groot, 2000).

According to Sorrell *et al.* (2000) three main groups of hidden costs can be distinguished. It is important to notice that additional costs specifically associated with energy saving technologies need to be analyzed when the concept is put into practice.

- **Overhead costs,** *which incorporates costs for information systems and for the decision making process.*
- **Specific investment costs,** *embeds additional costs that originate from installation costs, but also additional staff and maintenance costs.*
- **Loss of benefits,** *this group includes benefits that are forgone as a result of the adoption of the new technology.*

[28] For a thorough analysis of the effectiveness of the EIA I refer to (Aalbers *et al.*, 2004).

4.3.1 Overhead costs

Overhead costs are the costs that are (mostly) indirectly related to an investment in energy efficiency. The costs associated with information gathering, or **'information costs'** is a typical example of these overhead costs. The additional expenditures for identifying opportunities, searching for technologies etc. are not directly related to the investment, but they are a necessary precondition of an investment. A second group of barriers involves costs for putting an idea into a final **investment decision**. This decision-making trajectory takes a lot of time, and costs consequently, which can block an energy saving investment of being undertaken.

4.3.2 Specific investment costs

Costs not embedded in the cost price of the new technology, but which are necessary to make the machine fit in the current process form this group. Small companies, for example, often lack the possibility to take care of the maintenance and **installation costs** itself, and need to hire special personnel with higher costs as a result. In addition, costs for wiring and tubing are often ignored, but can bring additional costs that are not included in generic calculations of PBPs.

4.3.3 Loss of benefits

Next to the additional costs of an energy saving technology, loss of benefits also decrease the profitability of a project. As the name indicates, **costs for production interruption** are directly related to failures within the production process. This concept is closely related to technical risks (see 4.2.3). A second part of this barrier is associated with the costs of stopping the production process in order to install the new machinery. This aspect is closely related to the specific investments costs that are mentioned in the previous paragraph. The third barrier that is placed into this category is associated with the costs for early **depreciation of other machines.** Whenever a company decides to invest in a new technology, it needs to take into account the deprecation costs of the actual machine that is not fully depreciated. These costs need to be added to the operation costs of the new technology, influencing the PBP of the new energy saving technology negatively.

Risk and additional costs are closely related. When a company is insecure about the exact costs of a new technology, it will add a premium for this risk. An illustration of the role of uncertainties about specific investment costs, maintenance costs and costs for production interruption is given in Box 2.

Box 2: The bathtub

During one of the interviews, a respondent came up with a nice illustration of the development the operational costs of machinery and equipment. For simplicity reasons it is called the 'bathtub model'. Figure 4.2 shows the different phases after a new machine has been installed. During the first phase the equipment is being installed. Instead of proper functioning from the first moment on, typical shortcomings appear (so called child-diseases), with maintenance costs as a result. During the second phase the operational cost of the new machine will drop due learning effects, and eventually equilibrium shall be reached, characterized by its low operation costs. Then it reaches the fourth phase. The machine gets old and small defects appear, it needs to be repaired. Eventually in the fifth phase large modifications and maintenance is insurmountable. The result is an increase of the operation costs, which is a typical moment for a company to decide for replacement. The new machine has lower reference operation costs, but again high initial costs. The bathtub will be replaced!

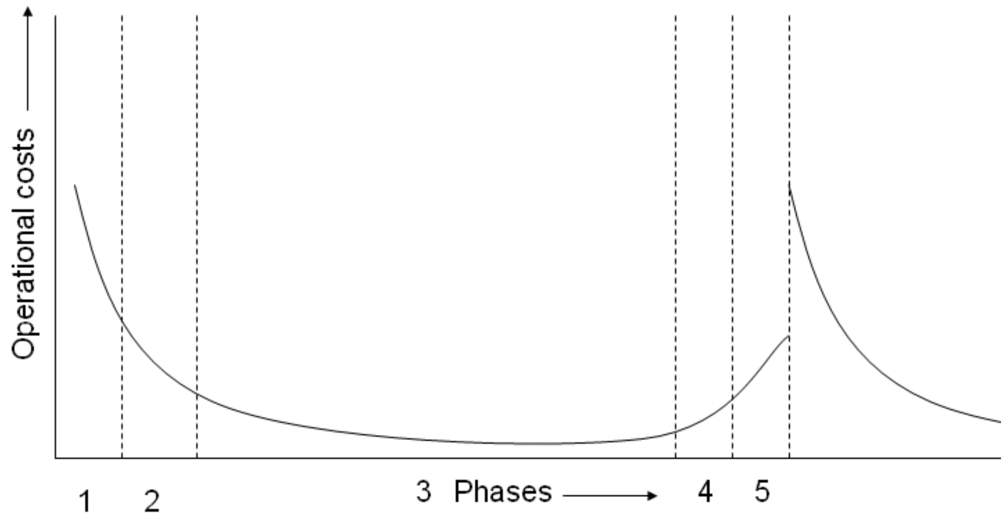


Figure 4.2 *The bathtub model*

4.4 Information & Knowledge

The third group of barriers is associated with limited information and knowledge. Before continuing with the grouping of the individual barriers, the presence of market failures is addressed shortly. While some of information barriers are market failures, others are the result of the way organizations deal with information, and create barriers. The division between market failures and other barriers is important when thinking about solutions to overcome these hurdles. Drawing on the study by Sorrell *et al.* (2000), four types of neo-classical market failures can be defined, of which two (number 3 and 4) are related to problems with information and knowledge:
1. Incomplete markets
2. Imperfect competition
3. Imperfect information
4. Asymmetric information.

Externalities are an example of the first market failure; they occur when property rights are not well defined and when the exclusivity principle[29] of markets is violated. A very common externality is associated with pollution, from a social point of view these costs should be internalized in the costs of a product or service. In the case of energy conservation, the price of energy can be charged with a pollution fee, which represents the externalities from a societal point of view. An increase of the energy prices leads to higher benefits associated with energy saving investments, and can reduce the payback time. In general, externalities imply a situation where the actions of one company affect the welfare of others in a way that is not reflected in market prices. Another example of externalities deals with the time (or moment) of investment and the public good aspect of information. As Golove and Eto (1996) point out *"... the information created by the adoption of a new technology by a given firm also has the characteristics of a public good. To the extent that this information is known by competitors, the risk associated with the subsequent adoption of this technology may be reduced, yet the value inherent in this reduced risk cannot be captured by its creator.*" Although 'incomplete markets' is classified as market barrier to the implementation of energy saving technologies, and justify policy intervention, it is less relevant in explaining the efficiency gap. The second type of market failures is closely related to the irreversibility of an investment as discussed in the section on uncertainty and risk barriers. The third and fourth market failures are more important and will be discussed below.

[29] Exclusivity refers to the situation in which all the costs and benefits of an action accrue to the owner.

Imperfect information
In order to make markets work well, participants in a potential exchange must be fully informed about the objects of exchange and about conditions and objects in other markets. The information and data on the energy situation and efficiency potentials have to be made visible, touchable and understandable, because energy is often perceived as an abstract, technical and complex issue (Hennicke, 1998). There are several dimensions of imperfect information, of which the following aspects have been distinguished for usage in this study:

1. **Availability information**
2. **Credibility and trust information**
3. **The ability to use or act upon information.**

4.4.1 Availability information

Lack of information or the poor availability of information refers to a situation where no clear information is available, or where the investor does not obtain available information. The primary claim of the information aspect within the concept of market failures is that "*the energy service market produces and transmits insufficient information about the energy performance of different technologies. This leads consumers to make sub-optimal decisions based on provisional and uncertain information, and consequently to under invest in energy efficiency*" (Sorrell *et al*., 2000). This statement focuses on the supply side of the information, but this study especially focuses on the demand side of information. Potential investors may **lack a clear overview of the energy saving technologies** available to the company, but also information on current energy use and the energy performance of new technologies is often missing. Koetse *et al.* (2006b) argue that "*investment in energy-saving technologies is substantially higher in those companies that are well-informed on available new technologies*"[30]. In general a low information level, or 'information gap' hinders investments in energy saving technologies. Next to the limited information about energy saving technologies, **limited insight in the companies energy use** is indicated as a barrier. To say it simple, when you do not know where energy can be saved, there is no incentive to invest in energy efficiency.

4.4.2 Credibility and trust in the information

Accurate information may be difficult to obtain, since sellers of technologies may have incentives to exaggerate or manipulate performance data. A seller can have advantages by selling another (less efficient) technology, or does not know about the energy efficiency performance of the machines he/she sells. It is expected that companies prefer to buy from suppliers that are trustworthy according to their perception. Also **'credibility and trust'** in other sources of information are crucial in accepting, and using the information. Information from colleagues or specific journals is often preferred over information from less credible sources.

4.4.3 The ability to use or act upon information

The third aspect of the information barrier, the ability to use or act upon information, does not originate from a market failure, but mainly deals with incompetence on company or individual level. Information that is not understood by a company is useless. The **characteristics of the employees as well as the form of the information** determine the ability to use the information. Imagine a company that has access to all available information on energy saving technologies and internal energy use. When it does not have the employees that can handle it or simply miss the expertise for understanding the information, it becomes useless. As proposed by different respondents to this study, historically, many companies cut back their labor costs to gain profit

[30] Remark: Koetse *et al.* (2006b) only focused on small firms.

maximization[31]. As a result experienced (and expensive) employees have been fired and no knowledge transfer has taken place to the other employees. So to say, companies have thrown away knowledge that is crucial to improve (energy) efficiency.

In addition, the way in which the information stream inside the company is arranged also influences the ability of a company to act upon the information. An example is the **asymmetric division of information**, whereby one party in to a transaction has access to different levels of information than other parties. Sorrell *et al.* (2000) classify asymmetric information as a special category of market failure, but because it can be regarded as a special form of imperfect information, here the concept is integrated within the imperfect information framework. Typical forms of asymmetric information are 1) split, or misplaced, incentives, 2) adverse selection and 3) principal-agent relationships, which are discussed in text box 3.

[31] This statement is underlined by Ramirez et al. (2005), who indicated that between 1993 and 1998 the decrease in labor intensity outpaced the decrease in energy intensity by a factor of 3.

Box 3: Split incentives, adverse selection, and the principal-agent relationship

Split incentives refer to transaction where the economic benefits of conservation do not accrue to the person who is trying to conserve. The concept is mainly focused on the residential sector[32], and in that way it also influences companies that rent their buildings. Split incentives occur on different levels in and outside the organization. In their study Sorrell *et al.* (2000) found that split incentives between the seller and purchaser of equipment is regarded as the most important form of split incentives by organizations. But also difference in interests between departments was indicated as a barrier. An important remark is that incentives within a company are mainly induced by the way an organization is structured. Especially the 'split incentives' barrier is difficult to classify into one cluster of barriers. While it is put forward as informational barrier in this study, other studies regard it as an organizational barrier. Detailed argumentations for both classifications can be found. But most important the reader needs to take into account that no unambiguous classification is possible. The following example illustrates that split incentives are closely related to the way a company is structured. From the viewpoint of the energy department it can be desirable to invest in energy saving technologies, because it reduces energy costs, but the purchase department only looks at investment costs while it can not account for the reduced energy costs. When additional investment costs are compensated by the reduced energy costs, the investment is profitable for the company as a whole, but will not be done. In this case individuals that make up the business firm may all be rational seekers after their own interest, but the outcome of their collective action may be sub optimal which is also mentioned by DeCanio (1993). Another example of split incentives within a company is associated with the shortsightedness of management. Managerial compensation is often tied to recent performance, and in many companies, managers are rotated trough different jobs every few years. A manager who is in post for only a few years has no incentive to initiate investments that have longer payback times (DeCanio, 1993).These managerial aspects are more thoroughly included in the 'organizational structure' section (4.5.1).

Adverse selection is closely related to the accuracy of information. It exists when one party has private information, before entering into a contract to buy or sell. For example the seller of a new technology may have information on the quality of the product that is unavailable to the buyer, and which will result in a higher price because of this asymmetric information. Adverse selection of information thus results in sub optimal information supply to companies.

Principal-agent relationships are a typical form of the moral hazard effect, where the action of one party is unobservable to a second party. The agent is the party who acts and the principal is the party whom the action effects. "*The principal's problem is to ensure that the agent acts to her benefit, but she lacks complete information*" (Sorrell *et al*., 2000). The principal-agent relationship occurs at different levels. Firstly it can occur on a market level, whereas different parties work under a contract, critical and accurate observations of the work progress and performance by the individual parties is difficult. In this case we can speak of a market barrier. On company level a principal-agents relationship is often the case between managers of the company and engineers who proposed an investment. Whereas the latter has more information about an investment project, the first one has to decide. The lower information level of the manager can result in suboptimal decisions. An example of this barrier is presented by DeCanio (1993) who shows that if the estimated returns to most types of prospective investment projects are biased systematically upward, then management may impose a higher hurdle rate[33]. This can inhibit energy efficiency investments whose returns are forecast accurately.

---

[32] A classical example is the landlord-tenant relationship. The landlord may be unwilling to retrofit an apartment to reduce energy use, because the associated profits will be realised by the tenant.

[33] A study by 121 companies found that 80 percent of the respondents believed that revenue forecasts of capital budgeting proposals are typically overstated, this kind of informational bias might lead managers to set overly strict criteria for new investments, thereby blocking some profitable energy saving projects (DeCanio, 1993).

The different information failures mentioned all have the potential to limit energy saving investments. Till now no clear **costs aspects** have been attached to the different failures, but in principle a lot of the market failures (and also barriers) will dissolve when they do not have a (unrealistic high) price label. For example lack of information is a clear market barrier, but when a company puts enough money in research or is prepared to pay a lot of money for information, the market will create information itself. Also monitoring of current energy use is mentioned as a problem, but when monitoring systems become free to use, it will affect the implementation level. So unbiased and complete information may be available, but the additional effort and time associated with obtaining it, will bring extra costs to the company. Inclusion of the different costs results in higher calculated payback times and thus negatively influences investments. The cost part of information in general was presented in more detail within the hidden cost aspect section (Section 4.3).

4.5 Organizational barriers

A company is not a single entity that acts with a single mind, but consist of many individuals who act together under a complex system of contracts (DeCanio, 1993). Organizational barriers refer to the internal aspects of a company that limit adoption of energy saving technologies. As put forward by Simon (1979) "*...the elaborate organizations that human beings have constructed in the modern world to carry out the work of production and government can only be understood as machinery for coping with the limits of man's abilities to comprehend and compute in the face of complexity and uncertainty*".

For a theoretical explanation of the investment behaviour of firms Velthuijsen (1995) distinguishes different types of behavioural mechanisms or 'theories of the firm'. Where the neoclassical theory (Section 3.2) is extreme in is simplification, the organizational theory of the firm is on the other side of the theoretical spectrum. Instead of considering firms as static points, the organizational theory regards firms as "*organizational bodies, consisting of several hierarchically placed but imperfectly co-ordinated sub-particles or sub-units, each with possibly differing goals, and consequently, differing views, attitudes, interests, instruments and constraints*" (Velthuijsen, 1995). The organizational theory used by Velthuijsen is mainly based on the theory by Cyert and March (1963). The central issue of the theory is in the assumptions that companies are bound to restriction, or bounded rationality, which avert companies to **optimize** their management; instead, firms try to **satisfy** their wishes. The organizational theory is especially useful for analysing larger companies, because hierarchical structures and organizational slack is typically linked to larger firms. According to the organizational theory, firms operate along a set of rules of behaviour, which are the result of bargaining, adaptive learning and feedback.

In contrast to the economic barriers, organizational hindrances are not widely applied in models for the quantification of energy savings. This mainly originates from the fact that the organizational barriers are difficult to quantify (DeCanio, 1993) and the perspective is underdeveloped. Exceptions are the studies by DeCanio (1998; 1998; 1993) and Zilahy (2004), who specifically focused on the influence of organizational (and also behavioural) barriers to the implementation of energy saving technologies, and give prove for the relevance of these barriers. Also Sorrell *et al.* (2000) created a framework, completed with input by energy experts.

The following two concepts explain the efficiency gap from an organizational perspective:
1. **Organizational structure**
2. **Organizational culture**

4.5.1 Organisation structure

The structure of a company is determining the investment decision structure in a large extent. While it cannot be defined as a real barrier, it is clear that the structure of company constrains the range of viable options for improved energy efficiency. Daft (2001) presents a division between companies that have a horizontal organization design at one side, and firms with a vertical structure on the other side (see Figure 4.3). Vertical structures result in hierarchical and bureaucratic decision-making processes, where the top management of the company makes the main decisions. Companies with vertical structures are designed for efficiency and are sometimes mentioned as mechanistic companies. Horizontal decision structures can be found in organic companies and are characterized by decentralized decision-making, few rules and loose relationships. These companies mainly act in turbulent environments and are designed for learning and adaptation. The two structures presented here are extremes and most companies contain elements of both. The structure of the company influences the decision-making process and procedures. Sorrell *et al.* (2000) assumed that the present structure influences the following three aspects:

- Flows of information within and outside the company
- Asymmetries of information
- Capacity to acquire and analyze information.

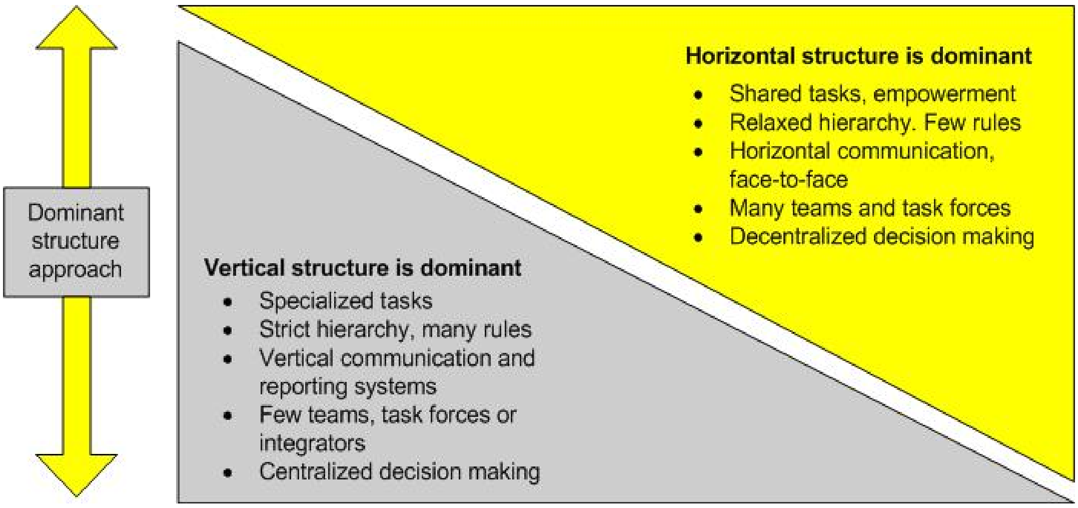


Figure 4.3 *Organizational structures with their characteristics*
Based on Daft, 2001.

The first aspect is closely related with the form of decision making within the company. In companies with decentralized structures central management takes decisions on all aspects of management based on limited information[34]. This is a typical matter of the principle-agent relationship and imperfect information, mentioned in text box 4.4.4. A typical saying is that a team is more than the sum of the individuals, which also accounts for information processing. Teams and taskforces are good instruments for analyzing information on energy saving options and can partly take away information barriers. Closely related with the organizational structure is the

[34] Decisions are based on information presented to the management, who cannot go into detail on every aspect, because they have to divide their time between more projects.

concept of **power**. Power influences who gets what, when and how and can take a variety of forms, including (Sorrell *et al*., 2000):

- Formal authority
- Control of scarce resources
- Structure
- Information & knowledge.

Whereas formal authority regards the position of energy managers within the organization, control of scarce resources is associated with budgeting issues, in which energy saving not always has a high priority. When the issue of power is put in the context of barriers to energy saving investments, the main issues are related with the position of the actor that is responsible for implementing energy efficiency within the organization. To quote Hennicke (1998): "*The internal change manager (CM)[ed. or in this case the energy manager] is often placed within (technical) middle management (production manager, technical staff). In these cases policy-making is confronted with an internal actor constellation characterised by a motivated and competent key actor with limited decision power, who often has to gain support and commitment by a decision-maker (top management) who is much less attracted by the project.*" Closely related to this finding is the conclusion by DeCanio (1993), who argues that human capital investments in energy conservation expertise will be low if the compensation and prestige of the managers responsible for energy use are less than the rewards for other positions

A second barrier that is associated with the structure of a company is the **perspective of the manager**[35]**.** It is the manager who takes the eventual decision and has the power are also subject to a lot of influences. While it is difficult to indicate the exact influence of this aspect, it is clear that is an important precondition for investment in energy efficiency. A typical barrier to the implementation of energy saving technology is the short-sightedness of managers, resulting in short PBPs required. A third aspect of manager's influence is their personal attitude towards energy saving technologies and the priority they give to these projects. As proposed by Ross (1986): "*Corporate management is preoccupied with many other responsibilities and assigns low priority to cost cutting. Also top management feels unable to decentralize or delegate open-ended responsibility for investment in smaller projects, especially since information and decision costs for smaller projects are relatively high*". Managerial aspects are closely related to the barriers of information costs, and availability of information, after all, time is money and these are often interchangeable. Maybe the most important remark is placed by Hennicke (1998): "*If the commitment of top management cannot be achieved during the project, the activity is threatened to fail. In order to achieve top management support, suitable arguments and an adequate presentation of the proposal have to be prepared by the internal key actors.*"

4.5.2 Organizational culture

The second organizational aspect that hinders the implementation of energy saving technologies theory deals with organizational culture. As pointed out by Sorrell *et al.* (2000): "*While it cannot be framed as a barrier, it may nevertheless be a relevant variable in explaining adoption of energy efficient technologies.*" It is strongly related to the behavioural perspective. Culture is the core of basic assumptions and beliefs of a company; the position of environmental values is a typical example of it.

Currently, the topic of climate change results in a raising consciousness for environmental issues. Including the importance of energy saving. The call for a positive **environmental image** therefore can act as trigger for investments in energy saving technologies. A nice overview (see Figure 4.4) of behavioural and cultural influences is presented by Hennicke (1998). It shows that culture is as a very complex characteristic of a company, which underlies many aspect of

[35] This barrier is located on the interface between organizational structure and culture.

management and therefore it is assumed that it also influences the level of energy efficiency improvements. **Personal values, norm and attitudes** are the core of a company and determine the perception of problems and opportunities. Commitment for investments in energy saving technologies on the work floor as well as for the top management[36] is important. As Stern (1984) states: "*People resist change because they are committed to what they are doing, and they justify that inertia by downgrading of contrary information*"

A possible explanation for why people pass up information that is both useful and free is that they do not trust the source. The communication source by which information is provided to companies can be important, past experience with the source is thereby an important factor. **Resistance to renewal, inertia and personal involvement** are therefore key characteristics of a company regarding its attitude towards investments in energy efficiency, although different to measure. The impact of motivating and demotivating factors in the implementation process of energy efficiency improvements has been investigated by Zilahy (2004).

The differences in organizational structure and cultural issues also underlie the concept of heterogeneity, mentioned in the previous section. Constraints that raise difficulties in incorporating the technology in the existing production process on the other hand are also organizational barriers. For example limited physical space is an example of an organizational barrier according de Groot *et al.* (2001), that is not embedded in the framework by Sorrell *et al.* (2000). This study classifies issues relating variety in implementation possibilities originating from technical and economical viewpoints under the concept of heterogeneity. Limited space in this case is regarded as an aspect of heterogeneity as well.

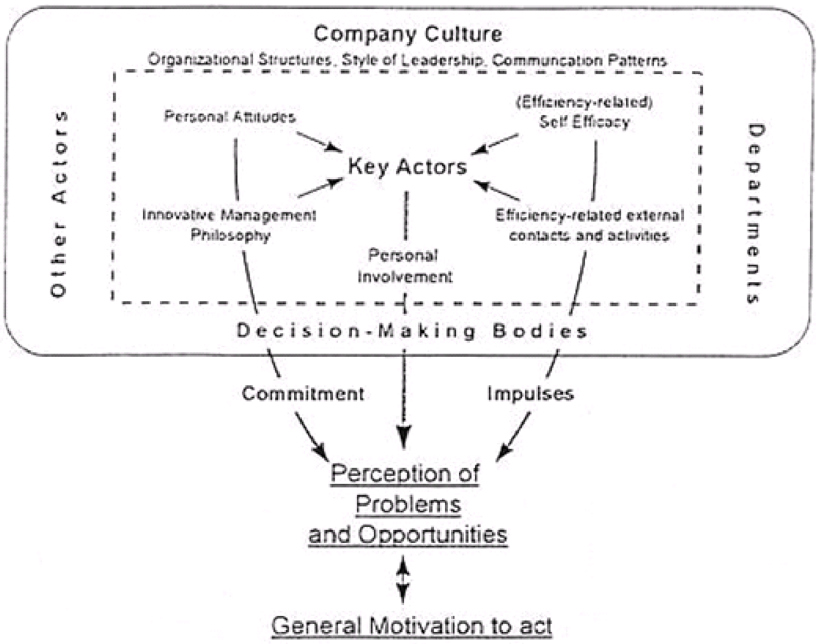


Figure 4.4 *Influence of company culture and other organizational and behavioural aspects on the decision making process*

Source: Hennicke, 1998.

4.6 Availability and allocation of capital

The last cluster of barriers deals with capital restrictions or so-called lack of capital. A necessary precondition for an investment is the availability and access to financial means. A company can do this in different ways as shown in Table 4.1. The table shows that most companies use their

[36] See the section about the perspective of the manager on page 35.

own reserves as means for financing the investment, followed by external capital borrowed at a bank.

Table 4.1 *Overview of how companies finance investments in energy saving technologies*

Financial source	Used by
Own reserves	56
Borrow at bank	46
Use of governmental subsidies	27
Fixed part of investment budget	11
Capital market	9
Emitting stock certificates	1

Source: Velthuijsen,1995.

The cluster can be split up into two dimensions, where the first focuses on the restriction of borrowing money, the second originates from internal budgeting, or allocation, within a company, therefore thus barrier is divided into following aspects:
- **Availability capital**
- **Allocation of capital.**

4.6.1 Availability Capital
Restrictions to the availability of money are identified as barrier to investments in general, and for energy saving technologies specifically. When a firm wants to invest in such a project, it needs financial funds, whether internal or external. Especially for small and medium sized companies capital availability may be a major hurdle in investing in energy efficiency improving technologies due to limited access to banking and financial mechanisms (Worrell & Price, 2000). Following Velthuijsen (1995), Gillisen *et al.* (1995) distinction is made between **availability of internal capital an external capital**. In case banks and other financial institutions are not willing to finance seemingly profitable investments, it can be seen as a market failure. But this assertion should be made carefully, because banks can have good (rational) reasons for not lending, like solvability and liquidity restriction (Sorrell *et al*., 2000).

4.6.2 Allocation of capital
Within their financial borders companies make choices regarding the investments according a priority list, and energy efficiency typically comes bottom of the list (Sorrell *et al*., 2000). If a firm has **other investment priorities** than energy saving it will block the implementation of energy saving technologies, this result is stated by De Groot (2001), Rohdin & Thollander (2006) and Rohdin *et al.* (2007). Capital rationing, or **budget restriction**, is often used within firms as an allocation means for investments, leading to even higher hurdle rates, especially for small projects. The other investments, although sometimes profitable as well, are simply not installed, because the firm has to choose between the many projects. Allocation of capital is closely related to perception of the manager, and is typically different among firms.

4.7 Extended conceptual model
Until now, the conceptual model is regarded as a static model showing the aspects that influence an investment decision for a single company and, at a given point in time, and assuming one technology. This typology is suitable when generating an overview of possible barriers, but it lacks the aspects of time dependency and heterogeneity. Eveland (1987) states that technologies are embedded in organizational contexts. Each change has repercussions for the whole system,

'ripple effects' across both space and time. The degree of this rippling effect can vary among firms and partly determines the possibilities for implementation.

4.7.1 Heterogeneity

Heterogeneity is not embedded in the conceptual model implicitly. Heterogeneity, or differences among companies, is an important concept within the energy-efficiency gap discussion (Groot *et al*., 2001; Jaffe & Stavins, 1994a). Heterogeneity of companies results in adjustment of the energy saving potential, because investments can be cost-effective on average, but for certain individual firms they are not. For example, the age of current machines can influence the adoption decision. Imagine a company that has invested in energy saving technology only a few years ago. It is not expected that they will replace these machines on the short term.

Heterogeneity is an additional layer to the model, representing the distribution among firms (Figure 4.5). When for example company A has a high risk perception for a given technology, company B a moderate etc. a distribution can be created. Heterogeneity within the barrier model is the result of many companies making the same decision. Each of the companies does this within his own environment with differences in perceptions as a result. While for example a given firm has sufficient budget for energy saving investments, another does not, so the first company regards budget restrictions as a major barrier, while the latter does not.

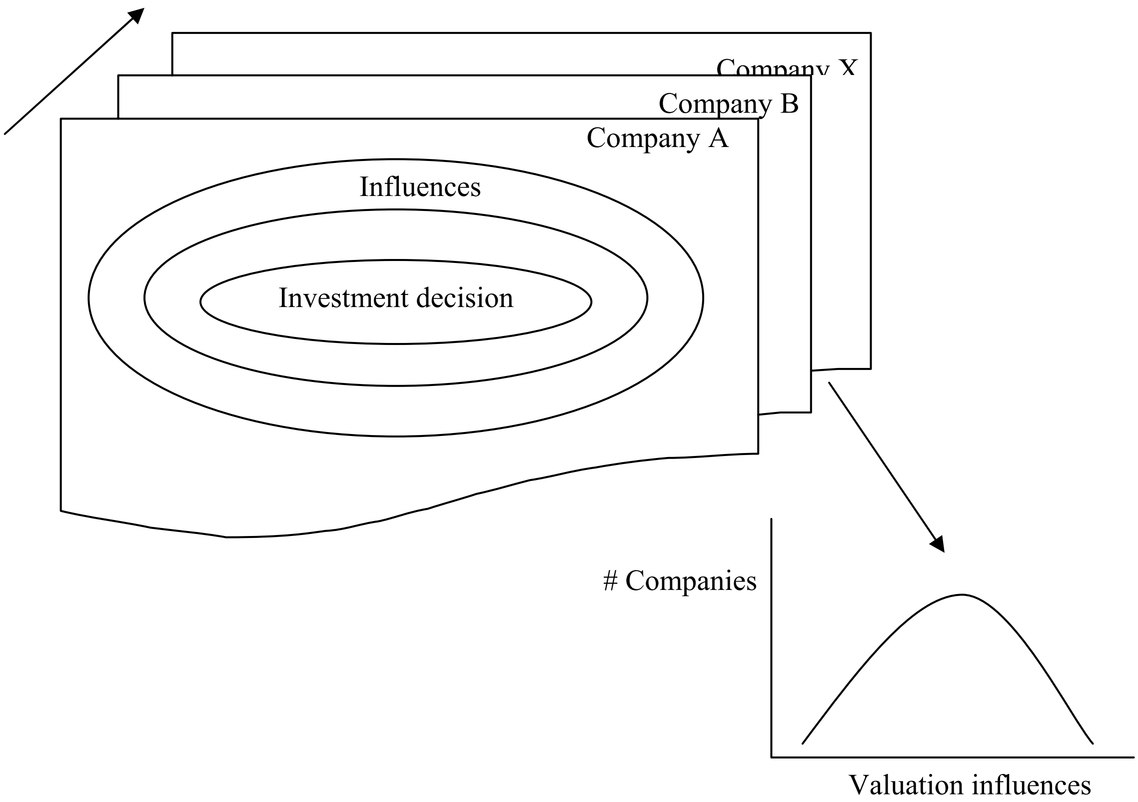


Figure 4.5 *The conceptual model in relation with the concept of heterogeneity*

4.7.2 The element of time

The second concept added to the conceptual model is time dependency, or the inclusion of phases within the decision making process. Until now, an investment decision is presented as a single decision that has is made on a specific moment in time. In reality, this is not the case.

According to the AIDA model from marketing theory, four phases characterize the implementation process of a company:

- **A**ttention
- **I**nterest
- **D**esire
- **A**ction.

Every stage has its own typical obstacles that need to be overcome. When a company, for example, does not have a clue about possible energy saving investments, other barriers can be neglected in the light of the information barrier. Therefore, some barriers will only play a role if others do not (or at least significantly) block the investment in an earlier stage. This sequence is put in the barrier concept to show the time dependency of certain barriers. Studies by Hennicke *et al.* (1998) and Bremmer *et al.* (2007) provide an overview of phases that underlie an implementation process. Together with input from respondents, these views were used to create Figure 4.6. Five stages are identified, which have their own associated barriers. From a rational point of view, an investment is made if all criteria have been met. A short description of the model follows after which the relation to the barrier model is presented.

The first phase regards the presence of opportunities for energy saving within the company. When a company is not aware of its own energy saving potential in general, or when it does not have information about energy saving technologies available, there is no motive for investment in energy saving technology at all. Many actors are involved in this step, for example engineers can identify opportunities, but also involvement off the management or individual workers and advise from external actors can lead to opportunities for energy saving.

When the first hurdle has been taken, the next phase involves the motivation for a company to do an investment. There are different reasons for a company to invest, of which the most important one is an economic one (see Section 3.2).But it can also be the case that the authorities make investments in certain technologies obliged, which triggers a need to invest. In addition, environmental values can lead to investments. Imagine a company that aims for a green attitude, who is more likely to invest in energy saving technology than its competitors who are less aware of their environmental image. In general; if there is no motive for an investment the other steps will not be reached.

The third phase regards the possibility of an investment in general. When a company has an opportunity for energy saving and it has a need to invest, it can still be the case that the new technology does not fit in the current production process, or the company lacks the expertise to implement a new technology. Another problem that is typical for the first step is the availability of capital to finance the investment.

When the investment is possible, the profitability of the investments is calculated. For the calculation of the cost-effectiveness, the fourth phase, all hidden costs and risk surcharges need to be included. If the investment has a lower PBP than the CPBP used by the firm this light will be set to green to come to the last hurdle.

Here, in the fifth phase, the energy saving investment is compared with other investments that can be made. A company will only choose for the energy saving technology if this investment is the most attractive and advantageous option presented.

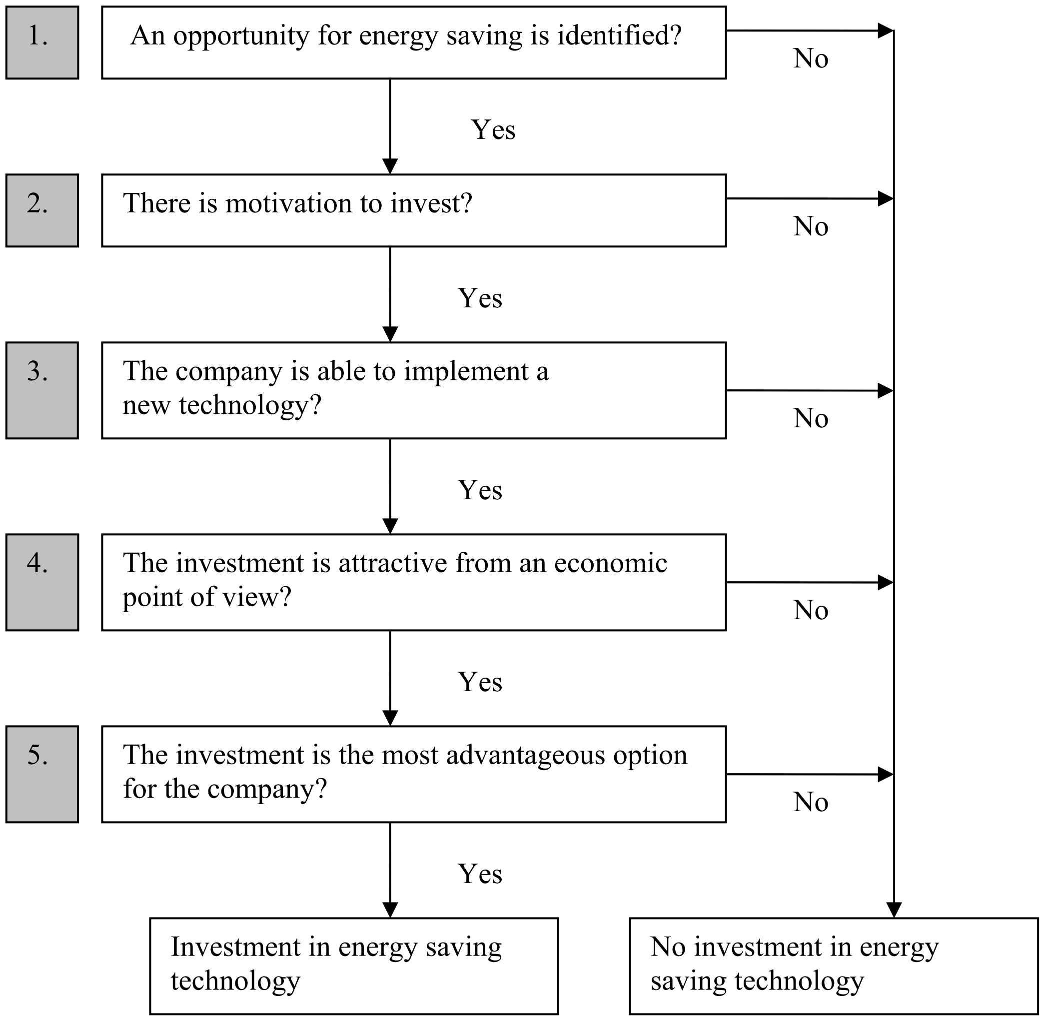


Figure 4.6 *Sequence of aspects needed for investment in energy saving technology*

Box 4: Typology of companies based on the experienced barriers

The fact that not all the barriers occur on the same moment is also illustrated by Reddy (1991). In his study, he analysed the barriers problem from the viewpoint of different actors. One of the actors identified is the group of energy consumers, which are not only individuals or households, but also enterprises. Within this group, Reddy identified six types of consumers, selected on the nature of barriers that are typical for the group and can keep them away form new investments. These groups are discussed below, and are summarized in Table 4.2, whereas the first column identifies the category of consumers, the second column shows the typical barriers for these consumers, and finally the relation with Figure 4.6 is shown. The phases in the table correspond to the phases in the figure.

The ignorant consumer simply does not have information about efficiency measures, they do not know about possibilities within the company to reduce energy use or lack information about benefits that can be accrued by adoption of energy saving technologies. The poor and/or first-cost sensitive consumer is hindered by capital restriction, or shrinks back for the high initial costs that are associated with typical energy saving investments. For the third group energy costs are not important in comparison with other costs. As a result energy saving investment has low priority and there is no motivation for action.

Even if a consumer is fully informed, has no capital restrictions and is motivated to invest in energy savings, practical problems can hinder the investment. Imagine a company that lacks know-how, or expertise for the implementation of the new technology. This group of consumers is helpless and not able to take up the new technology. The fifth group of consumers are characterized as risk averse. Uncertainties about future developments thereby result in postponing of investments, especially for companies that are reluctant to risks. The last typology, the inheritors of inefficiency, faces contradictions in incentives. While these firms can be willing to do investments, but are inherent to indirect purchase decisions. Someone else makes the final decisions, but these consumers face the results.

Table 4.2 *Categorisation of firms and the typical barriers associated*

	Category	Barrier characteristics	Phase
1.	The ignorant	Lack information	1
2.	The poor and/or first-cost sensitive	Capital restrictions Reluctant to high investment costs	3 / 4
3.	The indifferent	No motivation Energy costs not important	2 / 5
4.	The helpless	Lack know-how and expertise	3
5.	The uncertain	Risk aversion	4
6.	The inheritors of inefficiency	Contradiction in incentives	5

5. Relevance of the barriers

While the previous chapter focused on the identification of barriers, and a theoretical framework for analysing their relevance was created, this chapter focuses on the question: what is the relevance of the different barriers? At the base of an empirical study experts have been asked to giver their view about the hindrances that block investments in energy saving technology. This chapter presents the result of these interviews, primarily based on the applied ranking of the barriers, complemented by typical statements from the respondents.

5.1 Approach

To obtain insight in the relevance of the barriers, eleven respondents have been selected for a structured interview. During these interviews the respondents were asked to rank different sets of barriers. Each set contained the most important barriers out of the clusters created in the previous section. These barriers have been put into more concrete (Dutch) descriptions in order to make the respondents feel familiar with the concept (see Appendix A). Within each cluster between 5 and 7 barriers were selected for the ranking procedure. Because it is difficult to rank multiple barriers at once, the method of pair-wise comparison has been applied. Within this method respondents were asked to compare the barriers in a one to one relation, which eventually results in a matrix with (X-1)! comparisons[37] (Appendix B). The respondents, for example, will be asked whether they consider 'lack of information about energy saving technologies' a more relevant barrier than 'lack of information about internal energy use'. If true then one point is added to the barrier 'lack of information about energy saving technologies', otherwise the other barrier receives one point. The applied method results in a structured and objective ranking of the barriers within the individual clusters.

Subsequently, the average value of the eleven respondents is used to generate an overview of the relevance of the barriers. This average value is divided by the number of barriers inside the cluster to acquire a weighted average that can be compared among the different clusters. So a barrier that obtained 2.5 points in a cluster of five barriers has the same average value compared to a barrier with 3.5 points in a group of seven barriers.

Eventually the respondent was asked to create a ranking among the clusters (head groups) of barriers at the base of the same method used for the ranking inside the clusters. The results are presented below, but first the consistency of the answers given by the respondents, will be discussed.

5.2 Consistency check

In total, each respondent answered 81 pair-wise comparisons to come to an overall ranking. An important barrier will obtain a high rating (maximum score is [X-1]), whereas the least important barriers receives zero points. Ideally the barriers will be consistent[38] or logically ranked, but when no clear distinction can be made, barriers can have the same rating. This consistency of the answers is tested at the base of simple consistency check. A consistency of 100% means that the respondent came to a logical ranking in all matrices, whereas a consistency of 50% indicates that within each matrix no ranking could be obtained[39]. For each of the respondents the consistency is presented in Figure 5.1.

---

37 Where X represents the number of ranked barriers, and (X-1)! means (X-1)+(X-2)+…..+ 1.

38 A consistent ranking is regarded as a ranking from 1 till X, without barriers being valued equally.

39 A low consistency indicates circular reasoning, i.e. barriers A is regarded more important than barrier B, barrier B more important than C, but barrier C is subsequently higher valued than barrier A.

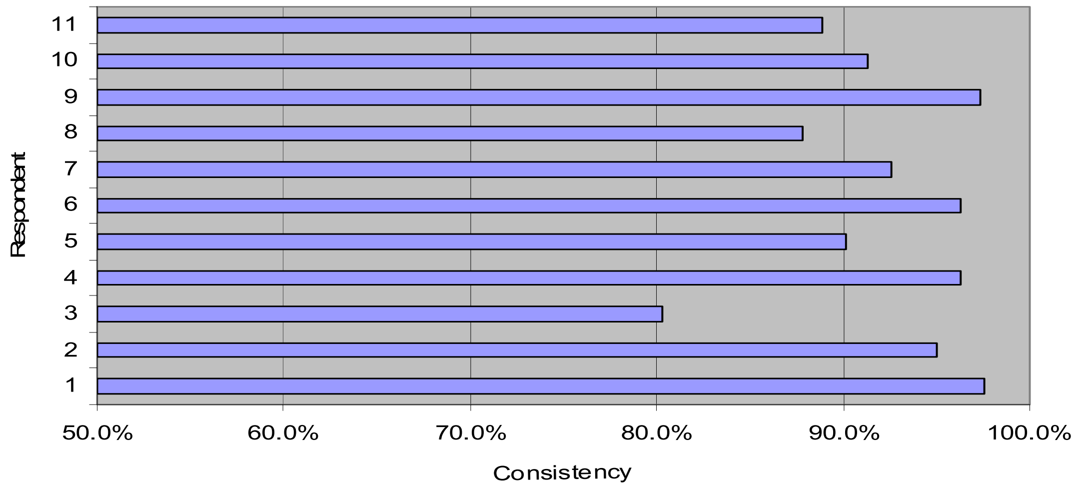


Figure 5.1 *Consistency of the ratings by the respondents*

Where most of the respondents show an acceptable consistency (average 92.1%), respondent 3 falls short with a value of 80.2%. A low consistency can have two reasons. Firstly it can indicate low attention at the side of the respondents, but secondly it can also indicate that the barriers are difficult to rank and closely related. If the second statements would be true, it is reasonable that more respondents experience low consistency, which is not the case. But looking at the outcome of this study regarding the results with and without respondent three, no significant differences can be found. Therefore the results include respondent three.

5.3 Inter-rater reliability

Now we know the consistency of the individual respondents, it is useful to test the agreement among the respondents. Whereas the average ratings for the individual barriers are a good indication of the relevance, the agreement among the different raters says something about the robustness of the rating. To indicate the level of agreement among the respondents, a statistical measure, called Fleiss' kappa, is used. Fleiss' kappa is a generalization of Scott's pi statistic, a statistical measure of inter-rater reliability. It is also related to Cohen's kappa statistic. Whereas Scott's pi and Cohen's kappa work for only two respondents, Fleiss' kappa works for any number of respondents giving categorical ratings to a fixed number of items. In this case, the eleven respondents rated X barriers within each cluster on a scale of 1 to (X-1). If the value of kappa (K) is higher than 0, some kind of agreements can be identified, whereas a value of 1 can be interpreted as perfect agreement (see Table 5.1).

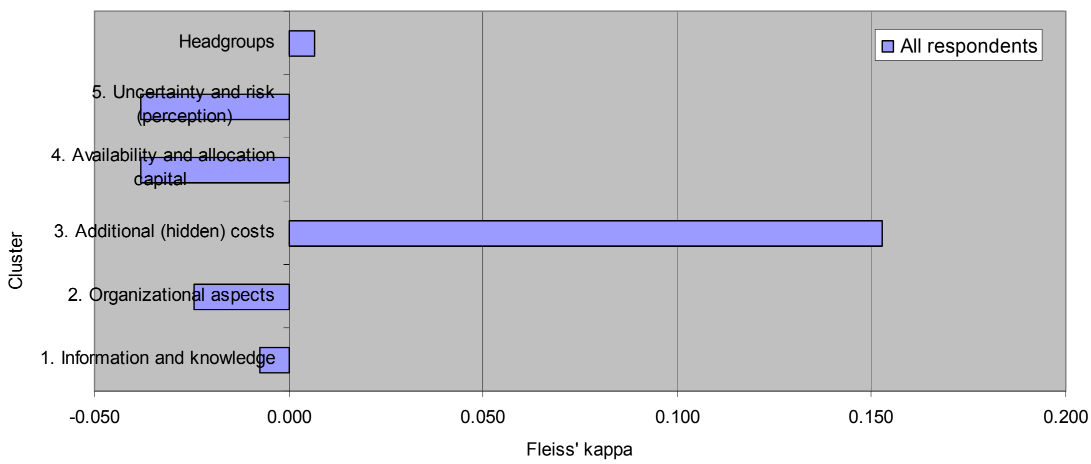


Figure 5.2 *Inter-rater reliability for the six categories used in this study*

Table 5.1 *Interpretation of Fleiss' kappa values*

K	Interpretation
<0	Poor agreement
0.0 - 0.20	Slight agreement
0.21 - 0.40	Fair agreement
0.41 - 0.60	Moderate agreement
0.61 - 0.80	Substantial agreement
0.81 - 1.00	Almost perfect agreement

From the consistency check and the inter-rater reliability values, it can be concluded that most respondents had a clear opinion about the relevance of the different barriers, but the opinions among the respondents differ. As a result, it is difficult to come to a generally accepted conclusion about the relevance of the different aspects. Still the next sections provide an overview of the results and discuss the relevance of the proposed barriers.

5.4 Results

5.4.1 Relevance of the clusters

To get insight in the relevance of the different barriers, the first step is to indicate which of the head groups, or clusters, is indicated as most important by the respondents. The ranking of the clusters is presented in Figure 5.3 and shows that the fourth cluster, availability and allocation of capital, is generally regarded as the most important group of barriers. Three of the respondents indicated the fourth cluster as most important, while four respondents argued that is was the second most important group. Also 'uncertainty and risk' was valued as most relevant cluster by three raters, but only three respondents rated this group of barriers second.

The second group, organizational aspects, is the focus of a lot of discussion. This barrier was also ranked first by three persons, but at the same time six persons put this group on the fourth or fifth position. Limited information and knowledge is of minor importance for the explanation of the energy efficiency gap. It was valued fourth or fifth by seven respondents, but in general is was experienced as a larger barrier than the third cluster, additional costs, which was put on the last place by six raters.

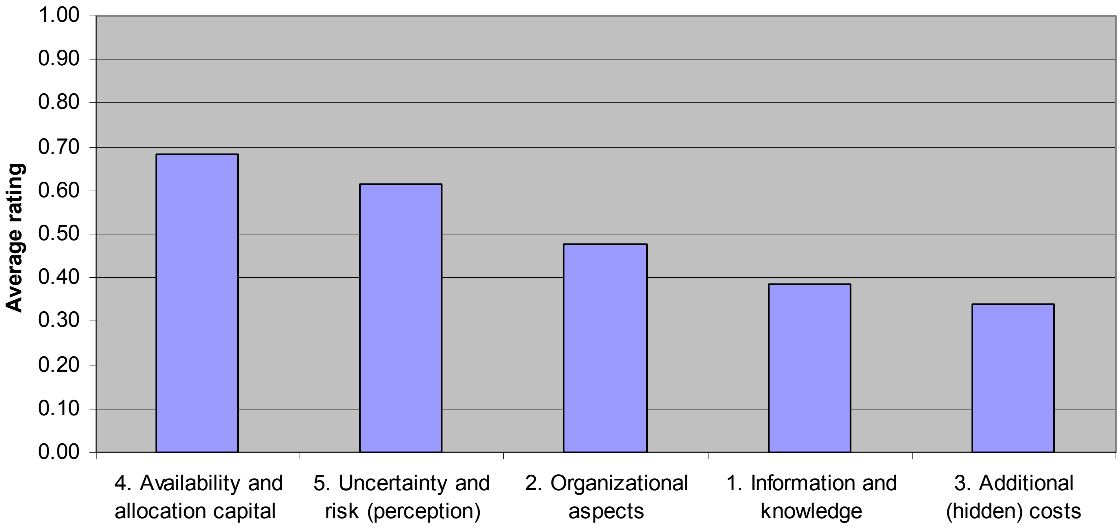


Figure 5.3 *Relevance of the five indicated clusters of barriers*

5.4.2 Availability and allocation of capital

While in general 'availability and allocation of capital' is indicated as most important group of barriers, a look inside the clusters shows that the agreement within the cluster is very poor. The respondents clearly had different views on the relevance of the individual barriers, but agreed on the fact that this group of barriers is very relevant in explaining the energy efficiency gap. Barrier 4.2, current machines not depreciated, as well as other investment priorities (4.1) where mentioned as most important barriers by four out of ten respondents[40,41]. The results are shown in Figure 5.4.

The respondents who mentioned 'availability and allocation of capital' as important group of barriers, argued that the 'current situation of the machinery' is a critical precondition for new investments. When an old installation is still fulfilling its functions, companies do not tend to invest in a new machine, until it covers a strategic decision. This is a very important remark, and mentioned by many of the respondents. For a company to come to an investment decision, the strategic character of the investment was put forward as critical barrier to investments in energy saving technologies. Because investments purely focused on improvement of energy efficiency are seldom strategic decisions, their position on the priority list is typically low. Even when the associated PBP of the technology is acceptable.

The barriers 4.4 till 4.6 have been rated as almost equally important. 'Limited availability of external capital' was mentioned two times as most important barriers, but also two persons found this the least important hindrance. 'Limited availability of internal capital' and 'limited budget for energy saving investment' also show less agreement about their ranking. While the two most important barriers deal with the allocation of financial means, these three barriers originate from the availability of capital. A general view among the respondents was that if an investment was really attractive, the company can arrange financial means. Priority settings are in this case an important determinant of the available budget for investments, and energy saving investments specifically.

The barrier of 'energy costs being only a small part of total costs' (4.3) is generally valued in the lower regions, but even two respondents indicated this barrier as most important. Wherever the 'size of the energy bill' is not a barrier on itself, it determines in a large extent the priority of energy saving technologies. If energy becomes core business, energy saving technologies were indicated as strategic decisions which made them more important.

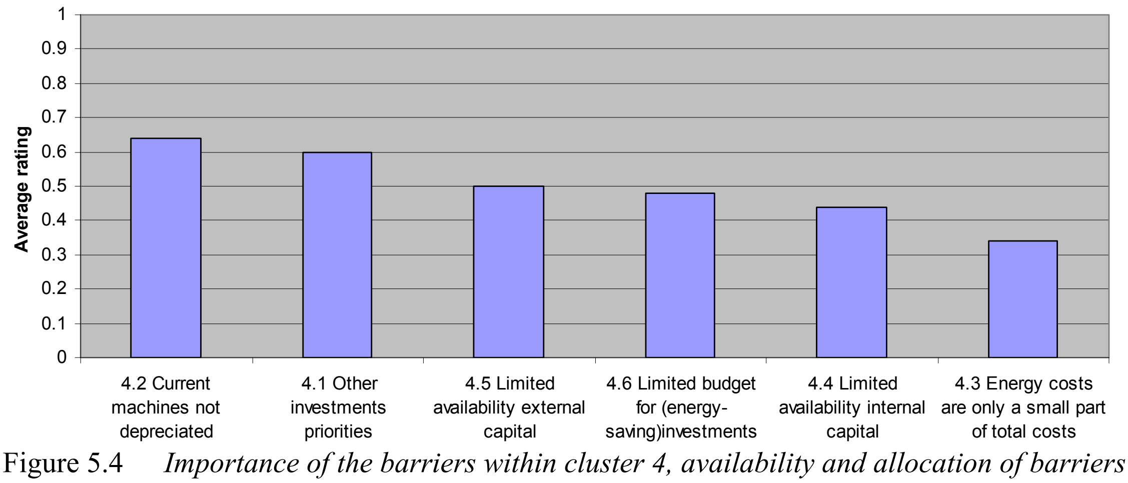


Figure 5.4 *Importance of the barriers within cluster 4, availability and allocation of barriers*

---

[40] One respondent did not complete the ranking within this cluster, so ten ratings are included.

[41] While the consistency of the respondents was not 100%, respondents can rate two or more barriers as most importance.

5.4.3 Uncertainty and risk

The barriers associated with uncertainty and risk perception have been indicated as second most important cluster by the respondents. But just like for the barriers associated with 'availability and allocation of capital', the agreement about the barriers within the cluster is very poor (see Figure 5.2). Wherever each barrier has been indicated as most important barrier at least once, also five of the barriers have been ranked as least important. On average the barriers associated with economic and market trends (5.3) and 'uncertainties about fitting in the current process' (5.1) where valued over the other barriers (Figure 5.5).

The respondents put forward that the level of investments in general, so also in energy efficiency, are closely related to the overall economic trend. In periods of recession investments are generally low and companies tend to focus on other priorities. While this was put forward as most important barriers, it is not specifically a barrier for energy saving technologies. On the other hand uncertainties about 'the machine fitting in the current process' were indicated as barrier specifically for energy saving technologies. As proposed by one of the respondents companies know how the actual machine works and how it combines with the other machines in the process. For a new technology (in this case an energy saving one) there is more uncertainty about the cooperation with other machines in the process. In this case companies tend to be risk averse and take the save way by maintaining the old machine or install a new machine that has fewer uncertainties about its relation to the process.

Although different of nature, the other four barriers averaged between 0.45 and 0.40. A common remark by the respondents was that uncertainty about the technology itself is to a large extent covered by the installer. 'Uncertainties about energy prices' and 'governmental policy' are both classified as external risk. Whereas most respondents remarked that a more consistent policy would result in increase of the adoption of energy saving technologies, they also argued that this barrier is an easy reason for the rectification of their activities (not investing in energy saving technologies). The 'uncertainties about the energy prices' were not indicated as a barrier, but the high level of expected energy prices was indicated as an important incentive for investments in energy efficiency.

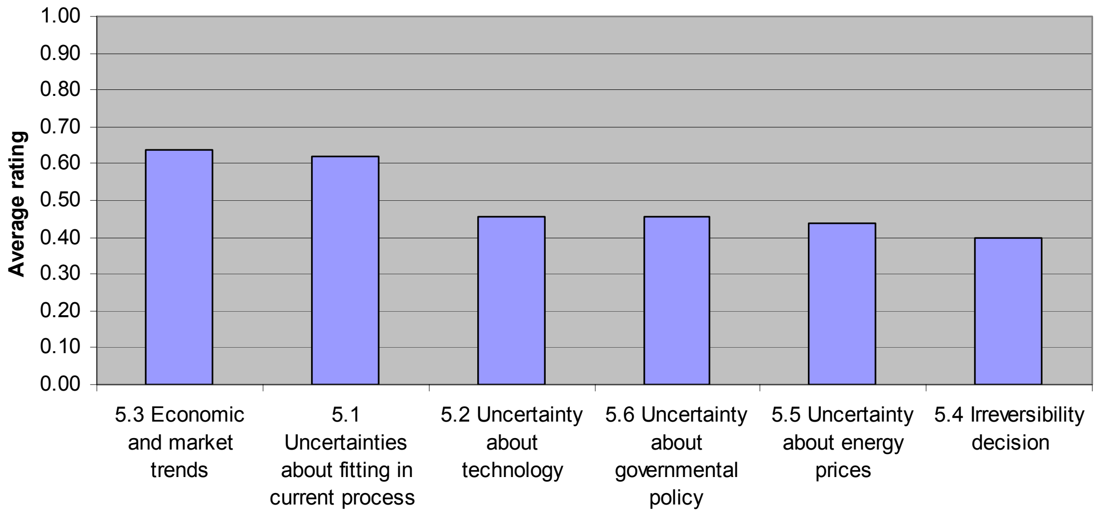


Figure 5.5 *Importance of the barriers within cluster 5, uncertainty and risk*

5.4.4 Organizational aspects

The third group of barriers deals with organizational aspects. As mentioned before the relevance of the cluster a priori was subject to a lot of discussion, but as Figure 5.6 shows, either within the group no clear ranking was identified. Barrier 2.1, 2.3, 2.4, 2.5 and 2.7 have all been identified as most important barrier by at least one of the respondents, but looking at the average rating of these barriers, ‘focus on the short term’ (2.1), and the ‘company structure’ (2.3) can be identified as the most significant blocking mechanisms.

As one of the respondents mentioned, focus on the short term leads to high hurdle rates and focus on short PBPs. Especially for larger firms, the shareholder can strengthen this short term focus, while they often prefer high profits on the short term. While the company structure can be broadly interpreted, many of the respondents agreed that the way a company is build up can significantly influence investments in energy saving technologies. Especially the position of the energy manager was put forward as important determinant for the investments in energy saving technologies. Like one of the respondents mentioned, the presence, and position of an energy manager is a first indicator of the importance of energy issues within the company.

It is clear that the ‘image of the company’ (2.6) and ‘the limited room for individual initiatives’ (2.2) are the least important barriers within the group, together they have been valued as least important barriers by eight of the respondents. Although the first was proposed as important incentive for investments in energy saving technology.

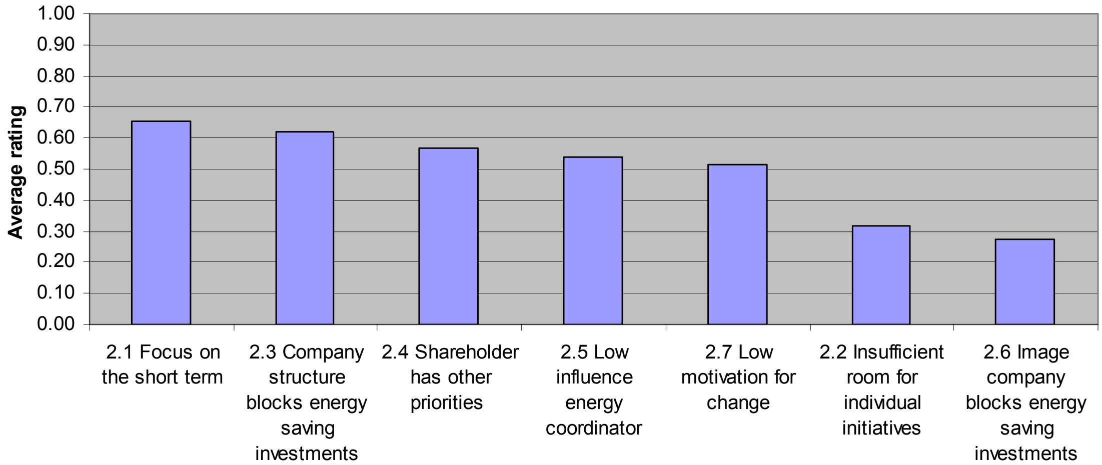


Figure 5.6 *Importance of the barriers within cluster 2, organizational aspects*

5.4.5 Information and knowledge

Figure 5.7 shows the average ratings for the individual information and knowledge barriers. Also here the agreement within the cluster was poor, but six out of the eleven respondents indicated ‘problems with applying the information’ (1.4) the most important barrier. As proposed by various respondents, companies often lack skilled personnel who understand the available information, and are able to apply the information. This lack of human capital was indicated as a barrier for large companies as well as for smaller firms, but especially for larger companies it is indicated as the key information barrier. On the other hand the respondents proposed that barriers 1.2 and 1.3 are especially important for smaller companies. Not only companies lack information about internal energy use and energy saving technologies, also general knowledge at the side of the suppliers of equipment was indicated poor.

‘Incomplete information by the decision maker’ (1.5) was also indicated as significant barriers, but ‘low credibility and trust in the information source’ was not a significant barrier.

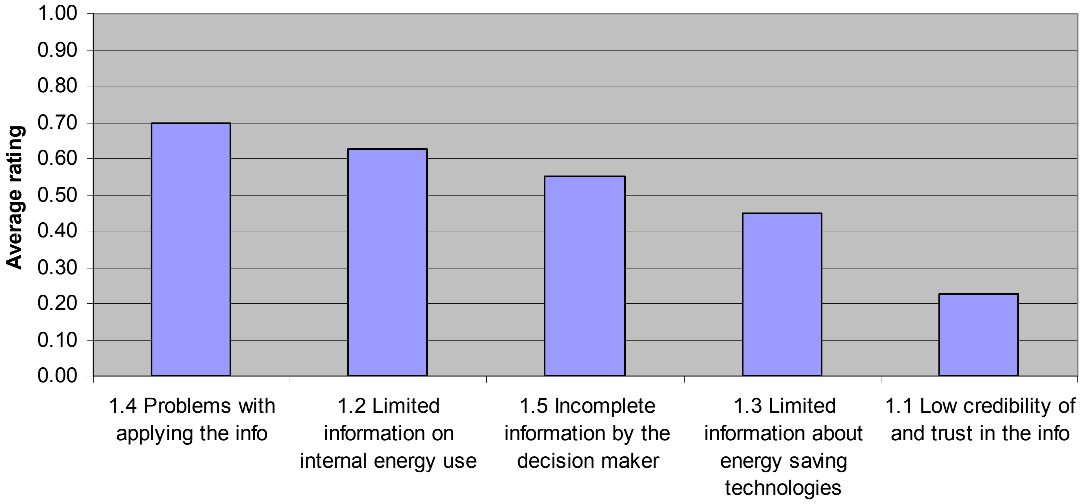


Figure 5.7 *Importance of the barriers within cluster 1, information and knowledge*

5.4.6 Hidden costs

While being the least importance group of barriers, the agreement within the cluster was by far the most significant. Eight out of the eleven respondents rated 'costs for production disruption' (3.5) as most relevant, and six of the respondents indicated 'specific installation costs' (3.4) as second barrier (see Figure 5.8). A general view on these barriers was that they are closely related to the risk and uncertainty barriers. While companies are unsecured about the costs for production disruption they will imply higher hurdle rates.

The 'costs for decision making' (3.2), 'gathering information' (3.3), and 'monitoring energy use' (3.1) are put in the shadow of the other two. While the respondents argued that there are costs associated with these aspects, none of these barriers has been mentioned as most important one, but all three have been rated least important at least three times. Also within this group the respondents argued that the size and characteristics of a company highly influence the size of the additional as a result of economies of scale.

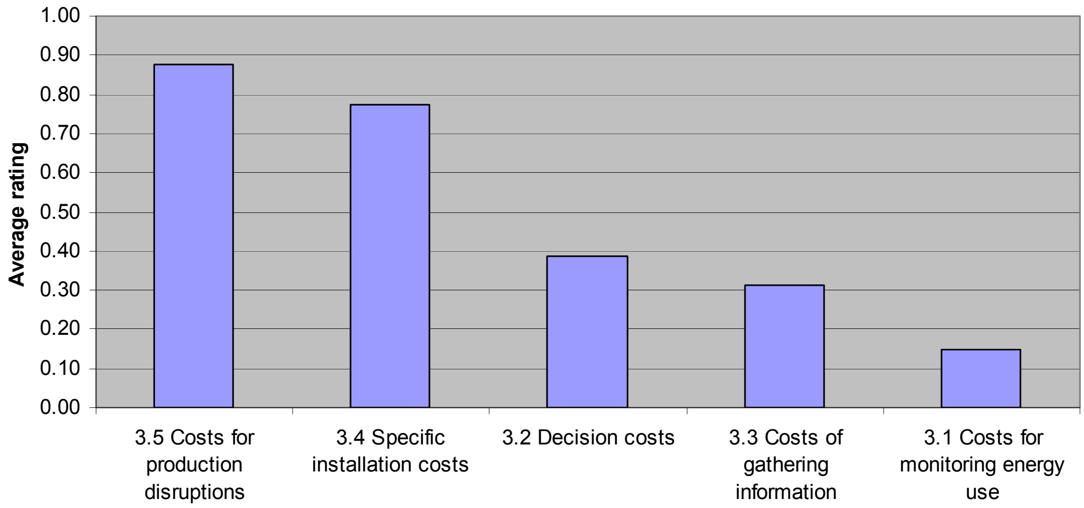


Figure 5.8 *Importance of the barriers within cluster 3, additional (hidden) costs*

5.4.7 Overall ranking

The ranking of the individual barriers as well as the comparison among the different clusters have been presented for each cluster. As proposed, the most important barrier within the 'hidden costs' group may still be less relevant in explaining the energy efficiency gap than the least important barrier within the group 'availability and allocation of capital'. For practical reasons an overall comparison of all the different barriers would be useful. Therefore, Table 5.2 shows the top ten of barriers based on the importance of the barrier within the group corrected for the overall importance of the head cluster. For example, the barrier 'current machines not depreciated' had a score of 0.64 within the cluster 'availability and allocation of capital' and the overall score of this cluster was 0.68 which results in a score of 0.64*0.68 = 0.44. The maximum score is 1 while the lowest score possible is 0. Overall, the barrier 'Costs for monitoring energy use' was valued as least important barrier with a score of 0.05.

Table 5.2 *Ranking of the individual barriers, corrected for the cluster scores*

Rank	Barrier	Score
1.	Current machines not depreciated	0.44
2.	Other investments priorities	0.41
3.	Economic and market trends	0.39
4.	Uncertainties about fitting in current process	0.38
5.	Limited availability external capital	0.34
6.	Limited budget for (energy-saving)investments	0.33
7.	Focus on the short term	0.31
8.	Company structure blocks energy saving investments	0.30
9.	Costs for production disruptions	0.30
10.	Limited availability internal capital	0.30

6. Conclusion and discussion

6.1 Identification of barriers

A widely recognised problem is the limited adoption of energy saving technologies in the industry. While many of these technologies are already available, still high potentials can be identified for energy efficiency improvements within the industrial sector. This study started with a discussion about the gap between possible and realized energy savings; the so-called 'energy efficiency gap'. Subsequently, an indication of the size of energy efficiency gap followed. Chapter 2 ended with an illustration of the energy efficiency gap based on the example of energy reduction in motor driven systems.

The reason for the low adoption level lies in a wide variety of so-called barriers. The first part of the report focused on the identification of these barriers, starting from the viewpoint of a company. Companies act from a rational point of view, with focus on maximizing their profits. Within the framework it is found that most companies use the payback period (PBP) as the primary evaluation method for investment projects. However, where often a social PBP of 5 years is used as maximum accepted period, the respondents almost unanimously rejected this statement, and indicated a maximum PBP of 2-3 years.

For the identification of the barriers, which can block investments in energy saving technologies, literature on the topic has been reviewed and experts in the field haven been interviewed. Figure 4.2 presents the key findings, and the rest of Chapter 4 discusses the individual factors. Again, these factors are not barriers per definition, but they may negatively influence an investment decision for energy saving technologies. In essence, five main clusters have been identified that guide as common nouns for all the other barriers mentioned in the framework. The first cluster, 'uncertainty and risk', included different kind of barriers that result from increased risk perception for energy saving technologies. The 'hidden costs' cluster embeds all additional costs that are associated with an investment in energy saving technology. Moreover, whereas the 'information and knowledge' cluster focused on the problems with finding and applying information, 'organizational aspects' originate from blockades that are put forward by the way a company is structured, and the culture. Finally the fifth cluster, 'availability and allocation of capital', embeds barriers that originate from limited availability of capital and the internal allocation of the financial funds.

While the framework includes many barriers mentioned in literature, it is not exclusive. Like showed by Weber (1997), no unambiguous framework for the identification is possible. Nevertheless, most of the respondents indicated that the conceptual model covers a wide range of the possible barriers. However, the lack of interrelation among the barriers is one of the main disadvantages of the model. A barrier is never an isolated hurdle. In practice, investments are hindered by a set of interrelated barriers, which together block investments. Another disadvantage of the model is the static approach used. This problem was identified in Section 4.7.1, where the dimension of time was put in the context of the model. The same picture can be drawn for the concept of heterogeneity, or differences among firms. While many feasibility and rentability calculations are based on statistics of an average company in reality company characteristics are an important dimension of the barrier discussion. While for one company, a typical technology is cost-effective and the best possible investment, the same investment can be less attractive for another company. Taking these two additional dimensions in mind, the relevance of these barriers is identified using the static model.

6.2 Relevance of the barriers

Eleven respondents applied a ranking to the most important barriers in the model. Together with input from open questions, the answers lead to more insight in the relevance of the different barriers. Chapter 5 presents the results. Whereas a validation of the major findings can be found in the discussion below, first a discussion on the applicability of the results is presented.

The study is based on a sample of only eleven respondents, so no far-reaching conclusions can be drawn. The results are explorative and indicate the main points of focus within the energy gap discussion. In general, the consistency of the respondents was good, but the agreement among the respondents was poor. Only the ranking of the head clusters and the 'hidden costs' group showed some kind of agreement. These findings indicate that the respondents had a clear view on the relevance of the barriers, but these views were very different among the respondents.

Different interpretations of the used terms may be one of the reasons for the low agreement among the respondents. Whenever a respondent was unclear about the meaning of one of the barriers, he/she could ask for an explanation. However, control of the correct understanding by the respondents is difficult and therefore biases are likely to occur. It is not easy to determine whether this is the case. Other explanations may be that the respondents had different parts of industry in mind, or argued from different perspectives. Where some respondents argued from the viewpoint of large companies, others are closer to the perspective of smaller companies. Subsets of respondents were created to test whether characteristics of the respondents could be identified that resulted in typical ratings of the barriers. However, no clear relation between respondents' characteristics and ranking of the barriers was identified. Respondents with similar backgrounds also had different views on the topic. In addition, literature on the topic also shows a wide variety of viewpoints, which makes it difficult to come up with general conclusions.

Below, the major findings from literature are compared with results from literature. Because the analysed studies all have different research approaches, and applied different barriers in their empirical studies, direct comparison is difficult. Nevertheless, they increase insight in the relevance of the barriers.

6.2.1 Availability and allocation of capital

Within the empirical study the cluster 'Availability an allocation of capital' was identified as most important barrier. Especially the fact that current machines are not depreciated yet and the presence of investment with higher priority are identified as major barriers. In general, the most important barriers within this cluster originate from the allocation of barriers and not from the availability of capital in general. Within literature, different opinions can be found on this cluster of barriers. While one group of authors regard availability of capital as an important barrier (i.e. Rohdin *et al*., 2007; Harris *et al*., 2000; Sorrell *et al*., 2000; Worrell & Price, 2000; Velthuijsen, 1995; Kleinknecht, 1989), another group argues that is not, or of only limited importance (i.e. Rohdin & Thollander, 2006; Groot *et al*., 2001; Gruber & Brand, 1991). Especially for small and medium sized companies capital availability may be a major hurdle in investing in energy efficiency improving technologies due to limited access to banking and financial mechanisms. But at the other hand a general opinion is that companies are able to collect funds once a technology is considered sufficiently important. Or to quote Hennicke (1998): "*Once the decision to implement a certain measure of reasonable and manageable size was taken, most companies found ways to finance it. If energy efficiency receives priority, normal business conditions seem to offer a suitable leeway to finance efficiency investments.*"

6.2.2 Uncertainty and risk

The barriers associated with 'uncertainty and risk' have been identified as second most important. In general the 'economic trend, and market situation' are indicated as important barrier to investments, Whereas this barrier is an important determinant of the investment level in general, respondents argued that in periods of regression less priorities are given to bottom-line investments (like energy efficiency improvements), and strategic decisions are preferred. Also 'uncertainties about fitting in the current process' was identified as an important barrier, while the overall performance of a stand alone technology can be guaranteed to a certain extend, its relation to the other machines in the process is less predictable. Below the discussion about the relevance of 'uncertainty and risk' barriers is presented.

A research by Harris *et al.* (2000) showed that 58 percent of the firms stated that they had a conservative or very conservative attitude towards investments in energy efficiency. Combined with the fact that risk-averse companies are found to implement apparently less energy saving options (Swigchem *et al*., 2002), risk and uncertainty seem to be an important barrier. In the same study Harris *et al.* found that 20% of the companies agreed or strongly agreed with the statement that investments in energy efficiency were too risky and that this was an important reason not to implement a specific recommendation. In another study by Hirst and Brown (1990) the perceived risks of energy-efficiency improvements were found to be very important to decision makers in the commercial sector. Also Dutch studies point out the relevance of uncertainties and risk as blocking mechanisms. Gillisen *et al.* (1995) state that "*a considerable compensation is demanded for different (lower) expected returns and for uncertainty.*" At the same time Velthuijsen (1995) shows that "*the effect of the degree of risk involved in the project is estimated to be more than two times as large as the effect of a short payback time*." De Groot *et al. (2001)* argue that uncertainty barriers are of intermediate influence on the overall investment decision, and in a recent study for the greenhouse horticulture sector Bremmer *et al.* (2007) found that companies build in significant safety margins for energy saving technologies. At the other hand Swigchem *et al.* (2002) argue that risk in general, but specifically associated with the production process is not an important barrier.

In general most studies agreed that increased risk perception is of significant importance for explaining the efficiency gap. It was found to be of great importance to split up uncertainties into external and internal risks. Whereas the first can not be influenced by a company itself, the latter is more firm specific. In general companies deal with uncertainty and risk by using higher hurdle rates for investments.

6.2.3 Organizational aspects

'Organizational aspects' were identified as third group of barriers, but within the cluster no clear order could be identified. In general most respondents agreed in one way or another with the statement that the company structure can work as a hindrance for energy saving investments. 'Short term focus' and 'shareholder has other priorities' were found to be linked together. Especially this group of barriers is very difficult to quantify, because it is closely connected to the concept of heterogeneity. While it is accepted that the characteristics of a company influence investments, the concept only receives little attention in comparison to barriers closer to the neoclassical theory. An important notion about organizational barriers is put forward by Velthuijsen (1995), when pleading for the organizational theory. The central issue of the theory is in the assumptions that companies are bound to restriction, or bounded rationality, which avert companies to **optimize** their management. Instead, firms try to **satisfy** their wishes. The organizational theory is especially useful for analysing larger companies, because hierarchical structures and organizational slack is typically linked to larger firms. For SMEs, as well as for larger companies, the commitment of top management with energy saving projects was proposed as important trigger for investments.

6.2.4 Information and knowledge

The barrier group regarding 'information and knowledge' was indicated as less important for explaining the energy efficiency gap. The information barriers are thoroughly analysed in literature. In their empirical study Gillisen *et al.* (1995) found that 20-30% of the technical potential for energy conservation was unknown by the industry. These findings are supported by De Groot *et al.* (2001), who indicate that 30% of the researched companies are not, or only to a minor extent, aware of existing new technologies that are not yet being used in practice by any firm, and 20% have only limited knowledge on technologies that are currently used by other firms. An important finding is that "*knowledge is especially high in large firms that invest heavily and are faced with strong competition*", while the knowledge cap is particularly large in "*small firms facing limited competition and spending relative little on investment.*" [42] Also Gruber and Brand (1991) found that small firms are less informed than larger firms. The respondents to this study had different opinions about the knowledge level of firms, but taking in account their background, the statement that large firms are better informed than smaller companies is underlined. Velthuijsen (1995) did not mention information as a barrier, but implied that proliferation of knowledge is an effective way to stimulate energy efficiency improvements.

As Worrell and Price (2000) make clear "*Information collection and processing consumes time and resources, which is especially difficult for small firms.*" Lack of skilled personnel, especially for SMEs leads to difficulties selecting and installing new energy-efficient equipment compared to the simplicity of buying energy (Worrell & Price, 2000; Reddy, 1991; Kleinknecht, 1989). Harris *et al.* (2000) found that 17% of the companies in their study agreed or strongly agreed that lack of staff with expertise was a reason not implementing an energy saving option, also 28% implied that the statement that they were unclear how to implement is an important hurdle. Another study by Gillisen *et al.* (1995) found a smaller figure: 2% of the companies indicated that they did not invest in energy efficiency technology because they did not have the right personnel. Also in a recent study for the greenhouse horticulture sector Bremmer *et al.* (2007) indicated that farmers often lack the knowledge and expertise to deal with technical information about energy saving options. Hiring consultants to process the information is an option to overcome this barrier, but as analysed by Roos en Van Dril (2004) it is not rational for small energy extensive firms to hire external information by professional consultants.

So where informational barriers were not highly valued within the empirical study, reviewing the literature makes clear that especially within SMEs lack of information is an important barrier to investments in energy saving technologies. Problems with applying the information were proposed as important barrier in SMEs as well as large companies.

6.2.5 Hidden costs

The presence of 'additional hidden costs' is the most general argument against the energy efficiency gap, but the results of this study plead against this finding. Only the 'costs for production' and 'specific installation costs' were identified as important within this study. Whereas these costs are different to quantify, they are closely related to uncertainty and risk. The fact that the other cost barriers are only of minor importance is in accordance with the results by Hein and Blok (1995). But as put forward by Ostertag (2003) and De Groot (2000) hidden costs are especially firm, and technology dependent.

[42] The study also shows that the chemical sector has particularly high knowledge, while the metal and food industry are less informed.

6.3 General discussion and recommendation

The results show that companies act to a high extent rationally. As indicated investments in energy saving technologies are often low on the priority list of companies. Even when the investment is (apparently) profitable, other investment options often block investments in energy saving technology. Because companies are bound to their financial borders, the allocation of financial funds to strategic, and the most profitable projects, is very rational. On the other hand, the argument that 'current machines are not depreciated' is not completely rational. From an economic point of view, an investment is profitable if the operational costs of the new machine are lower than for the old one. However, as was put forward by many of the respondents, time limitations, and the low importance of energy efficiency, make companies decide to continue with the current machines. Therefore the concept of bounded rationality is preferred, by which companies satisfy their goals instead of optimize.

'Uncertainty and risk' and 'additional hidden costs' both originate from economics as well and result in an increased hurdle rate for energy saving investments. Especially external uncertainties where indicated as major trigger for investments in energy saving technology, instead of being a barriers. The internal risks are closely related to the availability of knowledge. When companies have more insight in the possibilities for energy saving, know about available technologies, and have more insight in the costs, uncertainties will drop as a result.

The low agreement about the relevance of the barriers is one of the key findings in the study. Especially in studies like this one, where a high level of aggregation was used, opinions varied widely. This finding pleads for studies on a lower level, for example using sectors, or individual companies. A high level of heterogeneity within these subsets is essential to overcome the overall problem of heterogeneity as mentioned in this study. Next to the heterogeneity among firms, also distinction among technologies is needed. The characteristics of an energy saving technology determine in a large extend the nature of the experienced barriers. As was experienced during this study, practical problems make detailed studies difficult. Respondents on company level often do not have a clue about the barriers that they experience. Imagine a company arguing that its internal structure blocks investments. A more detailed study is recommended, but this will take much longer than half a year as used for this study. Subsequently, the interpretations of the barriers need to be unambiguous and very concrete to avoid biases in the answers. Recently Schleich and Gruber (2006) provided detailed data about barriers in the commerce and service sector, which can guide as a starting point for further analysis.

Where removal of barriers to energy saving investments is important for governmental policies, some recommendations are needed. In essence investments in energy efficiency are bottom-line investments, and historically do not receive high priority. Current today the public debate on environmental issues in general, and energy efficiency specifically can trigger investments. Combined with the increase in energy prices, external factors stimulate the adoption of energy saving technologies. Governmental policy needs to amplify these external triggers by providing more robust policies and raise awareness of the strategic dimension associated with energy efficiency, especially at the level of top management.

Looking at the individual barriers that were found to be most relevant in explaining the efficiency gap, it is clear that many of these barriers are not easy to solve by the government. Table 6.1 summarises the most important barriers, gives an indication of the level of effort needed to tackle the barrier. An important notion involves the origin of these barriers. Except the fourth and ninth barrier, all barriers involve the characteristics of the company or the environment, and are not directly related to the technology. This implies that the energy gap is not primary caused by the difference between the calculated PBPs of companies and those found in literature. However, the interpretation of the CPBPs and other company and market characteristics are the real determinant of the low adoption levels.

Table 6.1 *Political effort needed to solve the most important barriers*

Rank	Barrier	Level of effort needed		
		Low	Unclear	High
1.	Current machines not depreciated			■
2.	Other investments priorities			■
3.	Economic and market trends			■
4.	Uncertainties about fitting in current process			■
5.	Limited availability external capital	■		
6.	Limited budget for (energy-saving)investments			■
7.	Focus on the short term		■	
8.	Company structure blocks energy saving investments			■
9.	Costs for production disruptions			■
10.	Limited availability internal capital			■

As Table 6.1 shows, many of the barriers that are important hurdles are difficult to solve. A lot of effort is needed to tackle the problems, and the solutions will be complex. For example when other investment priorities are available to a company, it is completely rational not to invest in the less attractive energy saving technology. Policies may be designed that increase the profitability of the energy saving option, or propose the strategic importance of energy efficiency, but still the effects are expected to be limited.

The same picture can be drawn for the first barrier. Convincing a company that an investment in energy efficiency is attractive will take a lot of effort. Most likely, the 8th barrier is totally out of the scope of policy regulations. Proposing a company to change it internal structure for the sake of energy efficiency is not a case of the government, but underlies effective management. The third barrier, resulting form economic and market trends, is partly determined by the government, but has no direct connection to energy saving investments. Imagine the government putting forward measures to stimulate the economic trend, primary to increase investment in energy saving technology. Of course, this is not the case and the economic trend is not directly detached to instruments that stimulate implementation of energy saving technologies.

The only barrier that can be solved with a low level of effort is the ‘limited availability of external capital’. Investments can be stimulated by offering companies attractive funds by which they can invest in energy saving technologies. For example, by lowering interest rates for those investments or obliging banks to provide money for green investments. These measures will remove some of the barriers associated with the availability and allocation of barriers, and secondly it helps to reduce uncertainties. In general, information provision can help to reduce many of the proposed barriers. However, the focus needs to be on removing uncertainties and providing information about the societal importance of energy reduction. This last argument is especially important for removing the 7th barrier, after all energy saving technologies underlie a long term vision and who else than firm’s top management need to be addresses about his/her societal and environmental responsibilities.

During the study, many barriers to investments in (apparently) cost effective energy saving investments were identified. However, the concrete effects of these barriers on the size of the energy efficiency gap are difficult to monitor. For speeding up the rate of energy saving, the government needs to create, and apply a wide range of energy saving measures. Reducing the energy efficiency gap by removing barriers is one of the possibilities. However, selecting the best possible measures puts forward a lot of discussion. This study puts forward that no one-best solution is possible. The governments must apply a combination of measures that focus on the removal of the most concrete barriers that are most easy to solve. Picking those ‘low-hanging fruits’ is expected to result in significant energy savings that contribute to the overall goal of a two percent energy reduction speed.

7. Literature

Aalbers, R.F.T., H.L.F. Groot & H.R.J. Vollebergh (2004): *Effectiveness of subsidizing energy saving technologies, evidence from Dutch panel data* Rotterdam: Erasmus University Rotterdam.

Alsema, E.A. (2001a): *ICARUS-4, Sector study for the chemical industry* (Rep. No. NWS-E-2001-19).

Alsema, E.A. (2001b): *ICARUS-4, Sector study for the paper and board industry and the graphical industry* (Rep. No. NWS-E-2001-02).

Beer, J.G. de (1998): *Potential for industrial energy-efficiency improvements in the long term.* Universiteit Utrecht, Utrecht.

Beer, J.G. de & K. Blok (2003): *Energietransitie en opties voor energie-efficiency-verbetering* (Rep. No. EMAN03049). Utrecht: ECOFYS.

Beer, J.G. de, E. Wees, E. Worrell & K. Blok (1994): *ICARUS, the potential for energy conservation in the Netherlands up till the year 2000 and 2015* (Rep. No. 94124). Utrecht: University Utrecht.

Beer, J.G. de, E. Worrell & K. Blok (1996): Sectoral potentials for energy efficiency improvements in the Netherlands. *International Journal of Global Energy Issues, 8,* 476-491.

Blok, K. (2007): *Introduction to energy analysis*. (1 ed.) Amsterdam: Techne Press.

Blok, K. & E. de Visser (2005): *Energiebesparing: de onbegrensde mogelijkheden* (Rep. No. ECS06066). Utrecht: Ecofys.

Blok, K., E. Worrell, R. Cuelenaere, et al. (1993): The cost effectiveness of CO2 emission reduction achieved by energy conservation. *Energy Policy, 5,* 355-371.

Boonekamp, P.G.M. (2005): *Improved methods to evaluate realised energy savings.* Utrecht University, Utrecht.

Boonekamp, P.G.M., W. Tinbergen, H.H.J. Vreuls & B. Wesselink (2001): *Protocol Monitoring Energiebesparing. CPB, ECN, SenterNovem en RIVM* (Rep. No. ECN-C--01-129). Petten: ECN Beleidsstudies.

Bremmer, J., P. Ravensbergen, T. Dueck, F. Kempkes & J. Verstegen (2007): *Herkennen en Spiegelen, Barrieres en kennishiaten bij energiebesparing in de glastuinbouw* (Rep. No. 3.07.01). Den Haag: LEI.

CDA, PvdA, & ChristenUnie (2007): *Coalitieakkoord tussen de Tweede Kamerfracties van CDA, PvdA en ChristenUnie*.

Cyert, R.M. & J.G. March (1963): *A behavioral theory of the firm*. Englewood: Prentice Hall.

Daft, R.L. (2001): *Organization theory and design*. (7 ed.) South-Western Thomson learning.

Daniëls, B.W., A.W.N. van Dril, Y.H.A. Boerakker, P. Godfroij, F. v.d. Hilst, P. Kroon, et al. (2006): *Instrumenten voor energiebesparing, instrumenteerbaarheid van 2% besparing per jaar* (Rep. No. ECN-E--06-057). Petten: ECN Beleidsstudies.

de Almeida, A.T., F.J.T.E. Ferreira, P. Fonseca, B. Chretien, H. Falkner, J.C.C. Reichert, et al. (2001): *VSDs for electric motor systems* European Commission.

de Almeida, A.T., P. Fonseca & P. Bertoldi (2003): *Energy-efficient motor systems in the industrial and in the services sectors in the European Union: characterisation,..* Energy, 28, 673-690.

de Almeida, A.T., P. Fonseca, F. Guisse, J. Blaise, E. Clair, A. Diop, et al. (2000): *Improving the penetration of energy-efficient motors and drives* European commission.

De Keulenaer, H., R. Belmans, E. Blaustein, D. Chapman, A.T. de Almeida, B. de Wachter, et al. (2004): *Energy efficient motor driven systems* Brussels: European Copper Institute.

DeCanio, S.J. (1993): *Barriers within firms to energy efficient investments.* Energy Policy, 9, 906-914.

DeCanio, S.J. (1998): *The efficiency paradox: bureaucratic and organizational barriers to profitable energy-saving investments.* Energy Policy, 26*,* 441-454.

Dieperink, C., I. Brand & W. Vermeulen (2004): *Diffusion of energy-saving innovations in industry and the built environment: Dutch studies as inputs for a more*.. Energy Policy, 32, 773-784.

Dril, A.W.N. van (2005): *Verdergaand besparingsbeleid. Een verkenning naar kansen en barrières*. In Petten: ECN Beleidsstudies.

Dril, A.W.N. van & H.E. Elzenga (2005): *Reference projections energy and emissions 2005-2020* (Rep. No. ECN-C--05-089). Petten: ECN Beleidsstudies.

ECN (2006): SAVE Production.

European Commission (1997): *Energy Technology, the next steps; summary findings from the ATLAS project*.

European Commission (2006): Motor challenge programme. http://energyefficiency.jrc.cec.eu.int/Motorchallenge/index.htm [On-line].

Eveland, J.D. (1987): *Diffusion, Technoly Transfer and Implementation, thinking and talking about change.* Knowledge: Creation, Diffusion, Utilization, 8, 303-322.

EZ (2005): *Energierapport 2005, Nu voor later* Den Haag: Ministerie van Economische Zaken.

Gherardi, S., R. Holti & D. Nicolini (1999): *When technological innovation is not enough, understanding the take up of advanced energy technology.* Trento, Italy, University di Trento.

Gijsen, A., P.G.M. Boonekamp & H.H.J. Vreuls (2006): *Gerealiseerd energiebesparingstempo in Nederland 1995-2004, berekend op basis van het protocol monitoring energiebesparing* (Rep. No. MNP Rapport 500115002/2006). Bilthoven: MNP.

Gillisen, M., H. Opschoor, J. Farla & K. Blok (1995): *Energy conservation and investment behaviour of firms* (Rep. No. 410 100 102). Amsterdam: Free university of Amsterdam.

Golove, W.H. & J.H. Eto (1996): *Market barriers to energy efficiency: a critical reappraisal of the rationale for public policies to promote energy efficiency* (Rep. No. LBL-38059). Berkeley: University of California.

Groot, H.L.F. (2000): *A framework for analysing the adoption of energy-efficient technologies*. In K. Blok, H.L.F. Groot, E.E.M. Luiten, & M.G. Rietbergen (Eds.): *The effectiveness of policy instruments for energy efficiency improvement in firms* (pp. 11-33). Utrecht: Universiteit Utrecht.

Groot, H.L.F., M.W. Hofkes, P. Mulder & S.A. Smulders (2004): *Dynamiek van technologische-ontwikkeling: innovatie, adoptie en diffusie*. In H. Vollebergh, W. van. Groenendaal, M. Hofkes, & R. Kemp (Eds.): *Milieubeleid en technologische ontwikkeling in de Nederlandse economie* (pp. 45-63). Den Haag: Sdu.

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

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

Harmelink, M., K. Blok, M. Chang, W. Graus & S. Joosen (2005): *Mogelijkheden voor versnelling van energiebesparing in Nederland* (Rep. No. ECS05021).

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

Hein, L.G. & K. Blok (1995): *Transaction costs of energy efficiency improvement* Utrecht: University of Utrecht.

Hennicke, P. (1998): *Interdisciplinary analysis of successful implementation of energy efficiency in the industrial, commercial and service sector* Wuppertal, Vienna, Karlsruhe, Kiel and Copenhagen.

Hirst, E. & M. Brown (1990): *Closing the efficiency gap: barriers to the efficient use of energy*. Resources, Conservation and Recycling, 3, 267-281.

Howarth, R.B. & B. Andersson (1995): *Discount Rates and Energy Efficiency*. Contemporary Economic Policy, 13, 101-109.

Jaffe, A.B. & R.N. Stavins (1994a): *The energy paradox and the diffusion of conservation technology*. Resource and Energy Economics, *16,* 91-122.

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

Kleinknecht, A. (1989): *Firm size and innovation; Observations in Dutch manufacturing industries.* Small Business Economics, 1, 215-222.

Koetse, M.J., H.L.F. Groot & P. Nijkamp (2006a): *Barriers to Investments in Energy-Saving Technologies in Small Firms: The Energy-Efficiency Paradox Revisited* Amsterdam: Vrije Universiteit Amsterdam.

Koetse, M.J., A.J. v.d. Vlist & H.L.F. Groot (2006b): *The Impact of Perceived Expectations and Uncertainty on Firm Investment*. Small Business Economics, 26, 365-376.

Menkveld, M., B.W. Daniels, Y.H.A. Boerakker, H. Jeeninga, P. Kroon, A.J. Seebregts, et al. (2005): *Het onbenut rendabel potentieel voor energiebesparing* (Rep. No. ECN-C--05-062). Petten: ECN Beleidsstudies.

Ostertag, K. (2003): *No-regret potentials in energy conservation.* Fraunhofer institute for systems and innovation research ISI.

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

Reddy, A.K.N. (1991): *Barriers to improvements in energy efficiency*. Energy Policy, 19, 953-961.

Rogers, E.M. (1995): *The diffusion of innovation*. (4th ed.) New York: Free Press.

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

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

Roos, C.J. & A.W.N. van Dril (2004): *Energy saving in retail and restaurants. A closer look at information costs* (Rep. No. ECN-C--04-057). Petten: ECN beleidsstudies.

Ross, M. (1986): *Perspectives on capital budgeting*. Financial Management, 15, 20.

Runhaar, H., C. Tigchelaar & W.J.V. Vermeulen (2006): *Environmental leaders: Making a difference. A typology of environmental leaders and recommendations for a differentiated policy approach*. Business Strategy and the Environment, In Press.

Schleich, J. & E. Gruber (2006): *Beyond case studies: Barriers to energy efficiency in commerce and the services sector*. Energy Economics, doi:10.1016/j.eneco.2006.08.004.

SenterNovem (2006a): *Energie Investeringsaftrek (EIA), energielijst 2006*.

SenterNovem (2006b): *Energie Investeringsaftrek (EIA), jaarverslag 2005*.

SERI (1981): *A new prosperity: building a sustainable energy future* Andover, MA: Brick House Publishing.

Simon, H. (1979): *Rational decision making in business organizations.* The American Economic Review, 69, 493-513.

Soest, P. v. & E.H. Bulte (2001): *Does the energy-efficiency paradox exist? technological progress and uncertainty.* Environmental and Resource Economics, 18, 101-112.

Sorrell, S., J. Schleich, S. Scott, E. O'Malley, F. Trace, U. Boede, et al. (2000): *Reducing barriers to energy efficiency in public and private organizations* (Rep. No. JOS3CT970022). SPRU (Science and Technology Policy Research).

Stern, P.C. (1984): *Energy use: the human dimension*. New York: W.H. Freeman.

Swigchem, J. van, I. de Keizer, J. Roos, F. Rooijers, M. Klaver, S. Strating, et al. (2002): *Energie-efficiency in de industrie, ratio achter investeringsbeslissingen* (Rep. No. 02.6653.07). Delft: CE.

Takada, M., E. Morris & S.C. Rajan (2007): *Sustainable Energy Strategies.* http://www.undp.org/energy/publications/2000/2000a.htm [On-line].

Tweede Kamer (2005): *Motie van de leden van der Ham en Spies over de evaluatienota klimaatbeleid*. Den Haag, SDu. Ref Type: Generic.

Velthuijsen, J.W. (1993): *Incentives for investment in energy efficiency: An econometric evaluation and policy implications*. Environmental and Resource Economics, 3, 23-39.

Velthuijsen, J.W. (1995): *Determinants of investment in energy conservation* Amsterdam: SEO.

VROM-raad & Algemene Energieraad (2004): *Energietransitie: klimaat voor nieuwe kansen* (Rep. No. VROM-raad 045). 's-Gravenzande: Van Deventer.

Watkins, W.E. & S.J. DeCanio (1998): *Investment In Energy Efficiency: Do The Characteristics Of Firms Matter?* Review of economics and statistics, 80, 95-107.

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

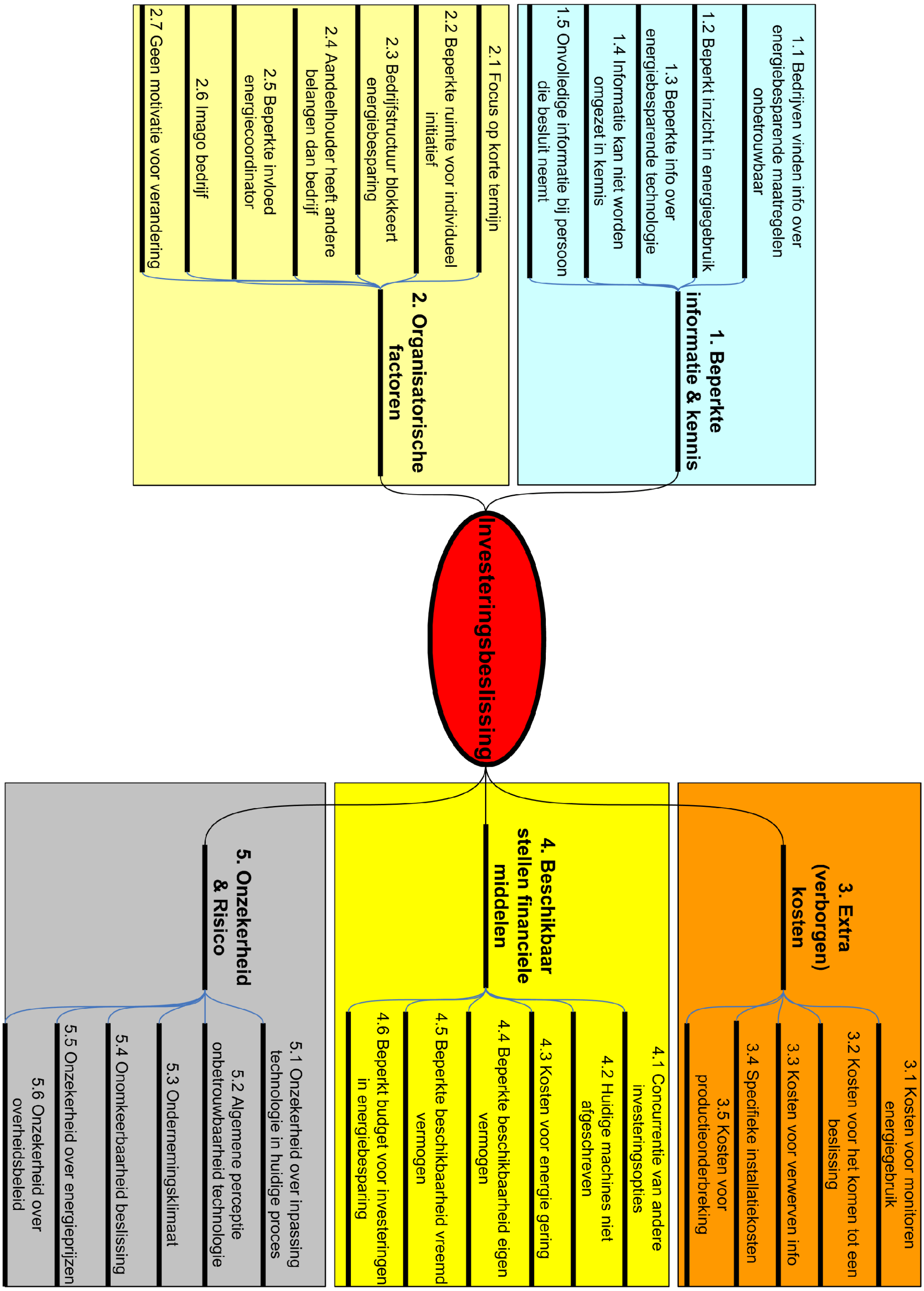
Wilde, H.P.J. de & G.J. Stienstra (2006): *Meer energiebesparing voor de chemie in Rijnmond; Kansen - barrières - oplossingen* (Rep. No. ECN-C--05-092). Petten: ECN Beleidsstudies.

Worrell, E., M. Levine, L. Price, N. Martin, R. v.d. Broek & K. Blok (1997): *Potentials and Policy Implications of Energy and Material Efficiency Improvements* (Rep. No. LBNL-51941). New York: United Nations.

Worrell, E. & Price, L. (2000): *Barriers and Opportunities: A review of selected successful energy-efficiency programs* Berkeley: Lawrence Berkeley National Laboratory.

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

Appendix A Barriers ranked for the interviews



Appendix B Waardering barrieres (only in Dutch)

Respondent	
Datum	

Beperkte informatie & kennis

Barrière	1.1	1.2	1.3	1.4	1.5	**Rank**
1.1	0					**1**
1.2		0				**1**
1.3			0			**1**
1.4				0		**1**
1.5					0	**1**
Score	**0**	**0**	**0**	**0**	**0**	**5**

Organisatorische factoren

Barrière	2.1	2.2	2.3	2.4	2.5	2.6	2.7	**Rank**
2.1	0							**1**
2.2		0						**1**
2.3			0					**1**
2.4				0				**1**
2.5					0			**1**
2.6						0		**1**
2.7							0	**1**
Totaal	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**7**

Extra (verborgen) kosten

Barrière	3.1	3.2	3.3	3.4	3.5	**Rank**
3.1	0					**1**
3.2		0				**1**
3.3			0			**1**
3.4				0		**1**
3.5					0	**1**
Totaal	**0**	**0**	**0**	**0**	**0**	**5**

Beschikbaarheid stellen financiele middelen

Barrière	4.1	4.2	4.3	4.4	4.5	4.6	**Rank**
4.1	0						**1**
4.2		0					**1**
4.3			0				**1**
4.4				0			**1**
4.5					0		**1**
4.6						0	**1**
Totaal	**0**	**0**	**0**	**0**	**0**	**0**	**6**

Onzekerheid & Risico

Barrière	5.1	5.2	5.3	5.4	5.5	5.6	**Rank**
5.1	0						**1**
5.2		0					**1**
5.3			0				**1**
5.4				0			**1**

5.5					0		**1**
5.6						0	**1**
Totaal	**0**	**0**	**0**	**0**	**0**	**0**	**6**

Relevantie hoofdgroepen

Barrière	1	2	3	4	5	**Rank**
1	0					**1**
2		0				**1**
3			0			**1**
4				0		**1**
5					0	**1**
Totaal	**0**	**0**	**0**	**0**	**0**	**5**