Analyzing energy efficiency investments in the process industry - Case Sachtleben Pigments Oy

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Niklas Christian Härus

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Department of Accounting and Finance

HELSINGIN KAUPPAKORKEAKOULU

HELSINKI SCHOOL OF ECONOMICS

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Niklas Härus

ABSTRACT
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ANALYZING ENERGY EFFICIENCY INVESTMENTS IN THE PROCESS INDUSTRY – CASE SACHTLEBEN PIGMENTS OY

Research objectives

The main objective of the study was to determine which investment appraisal methods are most suitable for analyzing energy efficiency investments. The investment analysis methods were examined and improved in order to discover whether the lack of appropriate investment analysis methods constitutes a barrier to energy efficiency investments' acceptance in industrial companies' capital budgeting process. The purpose was to establish a comprehensive view of appropriate practices in energy efficiency investment analysis.

Sources

The theoretical part of the study was compiled out of a wide range of research articles, reports and academic textbooks concerning energy efficiency and investment analysis. The data used in the empiric part consisted of theme interviews with the case company representatives and written material from the company.

Research method

The study was conducted by using theme interviews and informal discussions with the case company representatives. The interviewees consisted of directors responsible for identifying investment opportunities, planning investments and preparing investment proposals. Altogether seven people were interviewed. Additionally, the company's written material, such as investment proposal forms and instructions, was used as a study material.

Results

The study showed that the lack of appropriate investment analysis methods can constitute a significant barrier to energy efficiency investments. Two main areas of improvement were identified in energy efficiency investment analysis: need for more sophisticated analysis of investment risk and consideration of investment's strategic implications. Several methods were proposed for improving energy efficiency investment analysis.

Keywords

Energy efficiency, energy efficiency investment, investment analysis

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Niklas Härus

ENERGIATEHOKKUUSINVESTOINTIEN ARVIOINTI PROSESSITEOLLISUUDESSA – CASE SACHTLEBEN PIGMENTS OY

Tutkimuksen tavoitteet

Tutkimuksen päätavoitteena oli tutkia, mitkä investointien arviointimenetelmät soveltuvat parhaiten energiatehokkuusinvestointien arviointiin. Arviointimenetelmiä tutkimalla tarkoituksena oli selvittää, ovatko puutteelliset arviointimenetelmät yksi syy energiatehokkuusinvestointien syrjintään investointipäätöksenteossa. Samalla tutkimuksen tavoitteena oli luoda kokonaisvaltainen kuva tarkoituksenmukaisesta energiatehokkuusinvestointien arviointiprosessista.

Lähteet

Tutkimuksen teoriaosan lähdemateriaali koostui pääosin laajasta joukosta tieteellisiä artikkeleita, tutkimusraportteja ja akateemisia oppikirjoja koskien energiatehokkuutta ja investointien arviointia. Empiriaosassa lähteinä käytettiin teemahaastatteluita case -yrityksen edustajien kanssa sekä yrityksestä saatua kirjallista lähdemateriaalia.

Tutkimusmenetelmä

Tutkimus toteutettiin case -yrityksessä teemahaastatteluin ja epävirallisin keskusteluin. Haastateltujen joukko koostui yrityksen johtajista, joiden vastuualueena oli investointikohteiden tunnistaminen, suunnittelu ja esittely päätöksentekijöille. Tutkimuksessa haastateltiin yhteensä seitsemää henkilöä. Lisäksi yrityksen sisäistä kirjallista materiaalia, kuten investointiesityksiä ja ohjeistuksia, käytettiin tutkimuksen lähdemateriaalina.

Tutkimustulokset

Tutkimus osoitti, että puutteelliset arviointimenetelmät ovat yksi merkittävä syy energiatehokkuusinvestointien syrjintään investointipäätöksenteossa. Samalla tunnistettiin kaksi investointien arvioinnin parannuskohdetta: kehittyneemmät riskianalyysityökalut sekä strategisten näkökohtien parempi huomiointi investoinnin arvioinnissa. Lisäksi tutkimuksessa esitettiin suositukset sopivista menetelmistä energiatehokkuusinvestointien arviointiin.

Avainsanat

Energiatehokkuus, energiatehokkuusinvestointi, investointien arviointi

FOREWORD

This thesis has been written as a part of a more extensive research project *Energy efficiency from a business management perspective* funded by the Finnish Agency for Technology and Innovation (Tekes). I was hired to the department of Accounting and Finance in the Helsinki School of Economics in November 2008 to begin with the background research. After working full-time with the project at the Laboratory of Energy Economics and Power Plant Engineering in Helsinki University of Technology since January 2009, I finished my thesis in June 2009.

The study was conducted in collaboration with Sachtleben Pigments Oy and I want to express my thanks to all the company's interviewed representatives for the fluent coordination. Another thank you goes to my supervisor Professor Teemu Malmi and instructors Tuija Virtanen, D. Sc. (Econ.) and Mari Tuomaala, D. Sc. (Tech.) for their assistance and valuable viewpoints throughout the research process. I also want to thank my co-workers at the laboratory and my friends and family for their interest and support.

Espoo, June 8, 2009

Niklas Härus

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1. INTRODUCTION

1.1 Background and motivation

During the last decade or so, energy efficiency has gained increasingly importance and has an emphasized role in the public policy agenda of most developed countries. With the accelerating growth of energy consumption and scarcity in energy sources, saving energy has become the most rapid, easiest and effective way to answer the challenge of our energy dependence. World energy demand is forecasted to expand by 45 % between now and 2030, which equals an average growth rate of 1.6 % per year (Figure 1). Energy efficiency is also the key for reducing CO_2 emissions and preventing climate change. By saving 20 % in energy consumption, it is possible to secure 50 % of the necessary reductions of CO_2 emissions. Consequently, the European Union has set an objective to achieve 20 % energy savings by 2020. (EC, 2005) The importance of energy efficiency is also linked to commercial and industrial competitiveness. In Finland, industry is responsible for over 50 % of total energy consumption and 80 % of this energy is used in the process industry. Thus, energy constitutes a great item of expenditure for companies in the process industry and there is a considerable potential for improving energy efficiency in the industry. (EK, 2009)

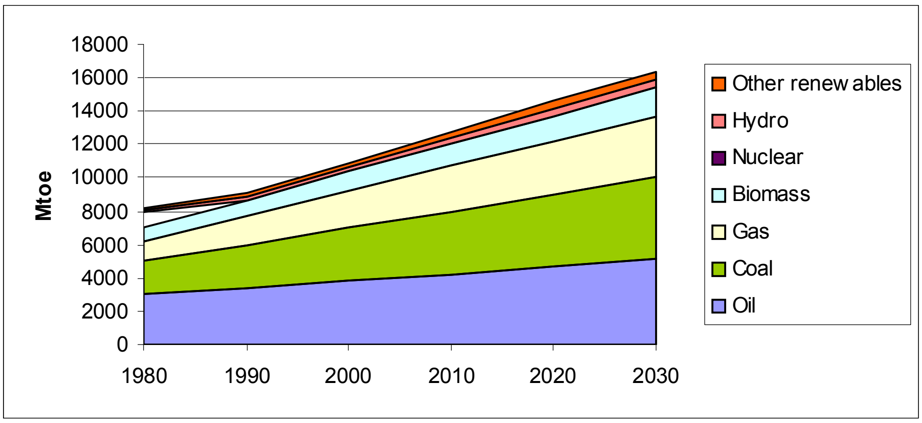

Figure 1. Energy consumption growth in the world (IEA Energy Outlook, 2008).

Energy efficiency can be improved by making investments to replace existing equipment or modify entire manufacturing processes to reduce the use of energy in the process (UNESCAP, 1999). However, several research studies have shown that industrial firms do not always implement cost-efficient energy efficiency investments, implying the existence of a so-called energy efficiency gap. Energy efficiency gap refers to the difference between the most energy efficient processes and technologies available and those actually in use (The Allen Consulting Group, 2004). Companies are often unable to quantify the saving effect of energy conservation measures and have no clear understanding of the financial values, risks and volatilities related to the investment (Ramesohl et al., 1997; Mills et al., 2006). In addition, non-energy benefits have often been disregarded in investment analysis even though they may even exceed the value of energy savings and have often valuable strategic implications (Pye & McKane, 2000). Energy efficiency investments have been perceived as operative investments as they do not necessarily represent the core business area of companies (Sandberg & Söderström, 2003). Consequently, there has been a lack of consideration of the possible strategic opportunities energy efficiency investments provide as well as their strategic position in the company's investment portfolio. The lack of understanding of all the aspects of energy efficiency investments has resulted in the dominant use of simple investment appraisal methods, such as the payback period method. Despite its explicitness, the payback period method limits the analysis to the near term and often excludes many attractive energy efficiency investment opportunities (Jackson, 2008).

In order to narrow the energy efficiency gap and promote the acceptance of energy efficiency investments, more comprehensive analysis tools are needed to justify energy efficiency investments to corporate decision-makers. Firstly, the use of different risk analysis techniques should be considered to gain an understanding of the sources of risk in energy efficiency investments and to forecast the saving effects more reliably and accurately. Secondly, a strategic approach to energy efficiency investments should be established to analyze the possible link between energy efficiency and corporate strategy as well as the strategic position of energy efficiency investments in the company's overall investment portfolio. Strategic viewpoint should also be used to broaden the analysis from direct energy savings to other benefits and opportunities and the possible sources they provide for competitive advantage. By widening the analysis perspective to risk analysis and strategic viewpoints, the benefits and implications of energy efficiency investments can be understood more thoroughly, which will eventually lead to better investment decisions.

1.2 Research problem and objective of the study

This study focuses on the analysis tools used in energy efficiency investment appraisal. The study was conducted in a case company operating in the process industry. The main research problem can be expressed as follows:

How should energy efficiency investments be analyzed in capital budgeting?

The main research problem can be further processed into three distinct research questions:

1) *What is the present state of energy efficiency investment appraisal in the case company?*
2) *What risk analysis tools are best suited for analyzing energy efficiency investments?*
3) *What kind of strategic implications are related to energy efficiency investments?*

The objective of the study is to determine the present state of energy efficiency investment analysis in the case company and evaluate the applicability of different investment evaluation approaches by analyzing a specific energy efficiency investment in the case company. The risk analysis tools and strategic approaches will be applied to analyze the investment in order to evaluate their contributing effect to energy efficiency investment appraisal. The purpose is to use the investment as a concrete study example to provide results that can be generalized to the whole industry.

The empirical part of the study was conducted by using theme interviews and informal discussions with the case company representatives. The interviewees consisted of directors responsible for identifying investment opportunities, planning investments and preparing investment proposals. Also the company's Chief Executive Officer was interviewed due to his considerable influence on investment approval on the company's board of directors. Altogether seven people were interviewed. Additionally, the company's written material, such as investment proposal forms and instructions, was used as a study material.

The study focuses on economic barriers to energy efficiency investments, which can be overcome by improving investment analysis techniques. Organizational and behavioural aspects behind energy efficiency investment decision-making are examined only superficially. However, it can be expected that more sophisticated analysis tools will also have an impact on organizational attitudes towards energy efficiency investments, as individuals gain more comprehensive understanding of the investments' benefits.

1.3 Structure of the study

Figure 2 depicts the structure of the study. Chapter two will explain the key concepts of energy efficiency, energy efficiency investment and energy efficiency gap and discuss the barriers to energy efficiency investments. In the third chapter different investment appraisal methods as well as their use in the area of energy efficiency investments will be presented. The fourth chapter will continue by discussing the risk analysis tools and their applicability to energy efficiency investment analysis. Strategic perspective to energy efficiency investments will be introduced in chapter five. The sixth chapter gives a description of the case company as well as the methodology used in the study. In chapter seven, the results of the study are analyzed and discussed. Finally, chapter eight will conclude by summarizing the findings, acknowledging the possible limitations of the study and making suggestions for further research.

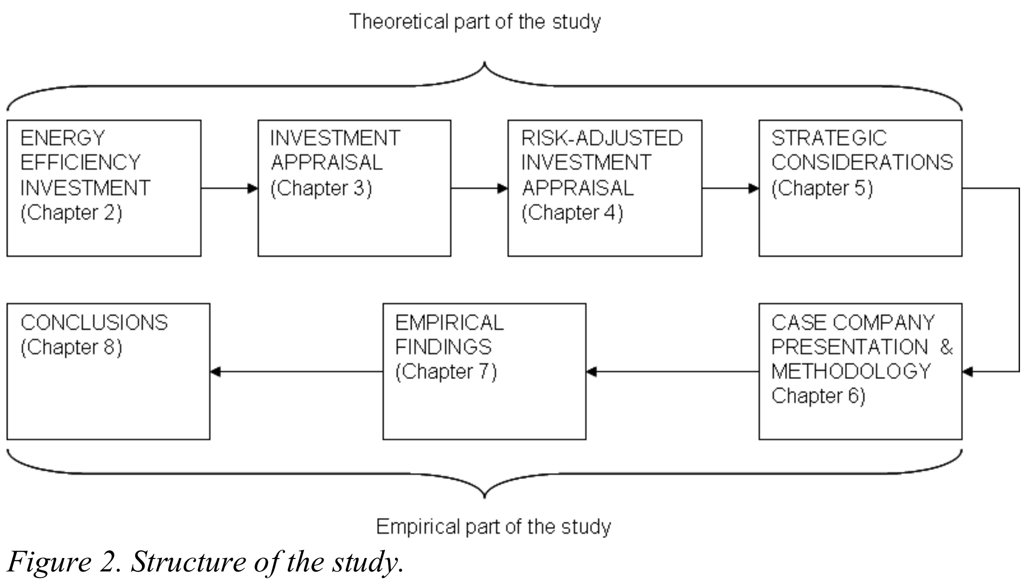

Figure 2. Structure of the study.

2. INVESTING IN ENERGY EFFICIENCY

This chapter establishes a basis for the study by introducing the key concepts of energy efficiency, energy efficiency investment and energy efficiency gap. Furthermore, the barriers to energy efficiency investments will be discussed, which provide a more concrete approach to the research problem of the study.

2.1 Energy efficiency

In general, energy efficiency refers to using less energy to produce the same amount of services or useful output (Patterson, 1994). In industry, it is most often evaluated by using the specific energy consumption (SEC), which is the ratio between the total energy used and a useful output of the process. The ratio is usually measured in physical units such as tons of product (GJ/t). It can be expressed by the following formula (EC, 2008):

$$SEC = \frac{Energy\ used}{\Pr oducts\ produced}$$

SEC provides an indicator of value for energy consumption per unit production. It can be used to monitor the energy use of a process over time. SEC can be further processed into energy efficiency index (EEI), which enables comparison between subsequent years (EC, 2008):

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

The energy efficiency index compares the actual energy consumption and reference consumption. The benchmark is usually obtained from the plant's historical data but sometimes also other references are used, such as BAT (best available technique) values (Tuomaala et al., 2009).

2.2 Energy efficiency investments

2.2.1 Definition

Despite the wide academic literature on energy efficiency, the concept of energy efficiency investment has not yet been specifically defined. On the broadest level, the definition would include all investments that improve energy efficiency. The main problem with this general definition is that energy efficiency investments often produce many other benefits, such as increases in capacity or productivity (Pye & McKane, 2000). While an investment in manufacturing capacity might simultaneously improve energy efficiency, it cannot be justified to categorize all such investments as energy efficiency investments. It is thus rather confusing that companies often make a clear distinction between production investments and energy efficiency investments, even though the concepts are seemingly intertwined. The matrix in Figure 3 illustrates the relationship between investments in production capacity and energy efficiency. Capacity investments are revenue-based; they enable the production of additional volume, which leads to increased revenue streams when the produced output is sold at the market.

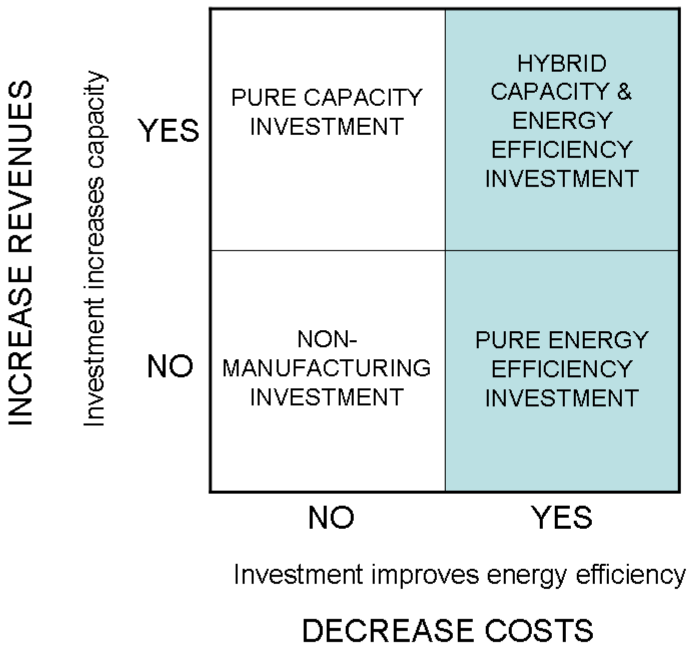

Figure 3. Matrix illustrating the relationship between capacity investment and energy efficiency investment.

It is noteworthy that energy efficiency investments have a different earning logic: their gains are realized through decreased operating costs, which increase the profit margins of the company. For simplicity, it is assumed here that all manufacturing investments aim at either capacity increases or more efficient production processes. Hence, other investments can be categorized as non-manufacturing investments. They include e.g. investments in R&D or marketing and are not discussed further in this study. Pure capacity investments increase capacity but have no effect on energy efficiency and are thus also irrelevant for the purpose of the study. The two remaining categories both improve energy efficiency and the general definition of energy efficiency investment would cover both types of investments. Pure energy efficiency investment focuses solely on improving energy efficiency and is hence conceptually unproblematic. However, in hybrid investments, which have both capacity and energy efficiency effects, the classification is considerably more difficult. It can be argued that in these investments, the main objective of the investment determines if the investment should be regarded as capacity or energy efficiency investment.

It is though questionable if strict categorizations are needed for hybrid investments as they can be simply considered as general manufacturing investments. The main insight provided by the matrix is that corporate managers should be careful when referring the concept of energy efficiency investment because the definition is often confused and misunderstood.

2.2.2 Types of energy efficiency investments

Jackson (2008) makes a concrete categorization by dividing energy efficiency investments into four groups:

1. The purchase of new, more efficient energy-using equipment to replace existing equipment
2. The modification of existing equipment or structural characteristics to operate more efficiently
3. Redesign of existing energy using systems
4. Installation of systems to change operation of energy using equipment

The categorization shows the variety of energy efficiency investment types. Companies can purchase new equipment, modify or redesign their existing processes or even install additional systems for energy efficiency. Basically all groups presented by Jackson could qualify as pure energy efficiency investments or hybrid investments in the previously presented matrix. To elaborate this a bit further, it can be said that investments in groups 1-3 are likely to fall into the hybrid category because purchase of new machinery or structural changes in manufacturing process often increase capacity as well. There again group 4 represents typical pure energy efficiency investment due to the fact that it involves the installation of separate systems for energy efficiency and is unlikely to have any effects on capacity. However, because of their unique characteristics, energy efficiency investments should clearly be analyzed case by case and general conceptualizations should be avoided.

2.2.3 Energy efficiency investment behavior of firms

According to a survey among energy intensive Dutch firms, the share of total investments that industrial companies spend on energy efficiency is on average slightly below 10 %, which equals the share of energy costs in companies' total sales. Most firms perceive energy efficiency as important factor in their investment decisions, even though energy saving is often just one criteria on which a new technology is judged. There are often complementary benefits, such as increased capacity or improved quality, that are considered along with energy saving. Companies expected the relative importance of energy efficiency to increase in the future. (Groot et al., 2001) The incentive to invest in energy efficiency depends greatly on industry characteristics. In energy intensive industries, energy efficiency is an important factor in investment decisions and the share of energy efficiency investments is considerably higher than in non-energy intensive industries. (Sandberg & Söderström, 2003)

Ramesohl et al. (1997) studied the factors contributing to implementation of energy efficiency investments. First of all, the importance of energy efficiency has to be recognized in the company. Motivation behind energy efficiency can be based on environmental concerns, pure economic interest or engineering interest in process optimization. Secondly, an initial impulse is needed to get energy efficiency projects underway. Initial impulses can be roughly divided into production technology related requirements, inspiration of high and middle management and pushes from environmental regulation. Thirdly, the perception of economic feasibility is a mandatory baseline for making the investment decision. The fourth contributing factor is a charismatic change manager, who is able to take the initiative and follow the project through against internal reluctance and resistance. Top management is also playing a key role in fostering an organizational culture that supports the employees' commitment to the investment project. Fifthly, the role of external social networks is of crucial importance. Energy audits, consultancy and corporate networks provide impulses, information and concrete know-how which cannot be built by the companies themselves. (Ramesohl et al., 1997)

2.3 Barriers to energy efficiency investments

Research studies have shown that industrial firms do not always implement cost-efficient energy efficiency investments. It has been frequently suggested that there exists a gap between the current and optimal energy use, namely the energy efficiency gap. It is defined as the difference between the most energy efficient processes and technologies available and those actually in use (The Allen Consulting Group, 2004). The phenomenon has been sometimes called the efficiency paradox, because it represents a situation, in which business firms, which are presumed to be economically efficient, make decisions that do not maximize profits (DeCanio, 1998).

Researchers have suggested several barriers to industrial energy efficiency investments that are causing the energy efficiency gap. A distinction can be made between market failure explanations and non-market failure explanations of the paradox. The distinction is relevant because barriers denoted as market failures might justify public policy intervention while non-market failure barriers do not call for policy responses. (Jaffe & Stavins, 1994) Market failure is a condition in any market that results in an inefficient allocation of resources (Sutherland, 1991). There are four types of market failure: incomplete markets, imperfect competition, imperfect information and asymmetric information (SPRU, 2000). These barriers will not be discussed further in this study because the objective is to focus on the barriers that companies are able to influence, namely the analysis tools used in energy efficiency investment decision-making.

Market failures are, however, important considerations for public policy designers in creating an optimal environment for companies to invest in energy efficiency.

Groot et al. (2001) studied the investment behaviour of energy-intensive Dutch firms and identified three main categories of barriers when introducing new energy efficient technology. The distinguished categories were (i) general barriers related to the overall decision-making process; (ii) financing constraints; and (iii) barriers that are related to uncertainty (Figure 4).

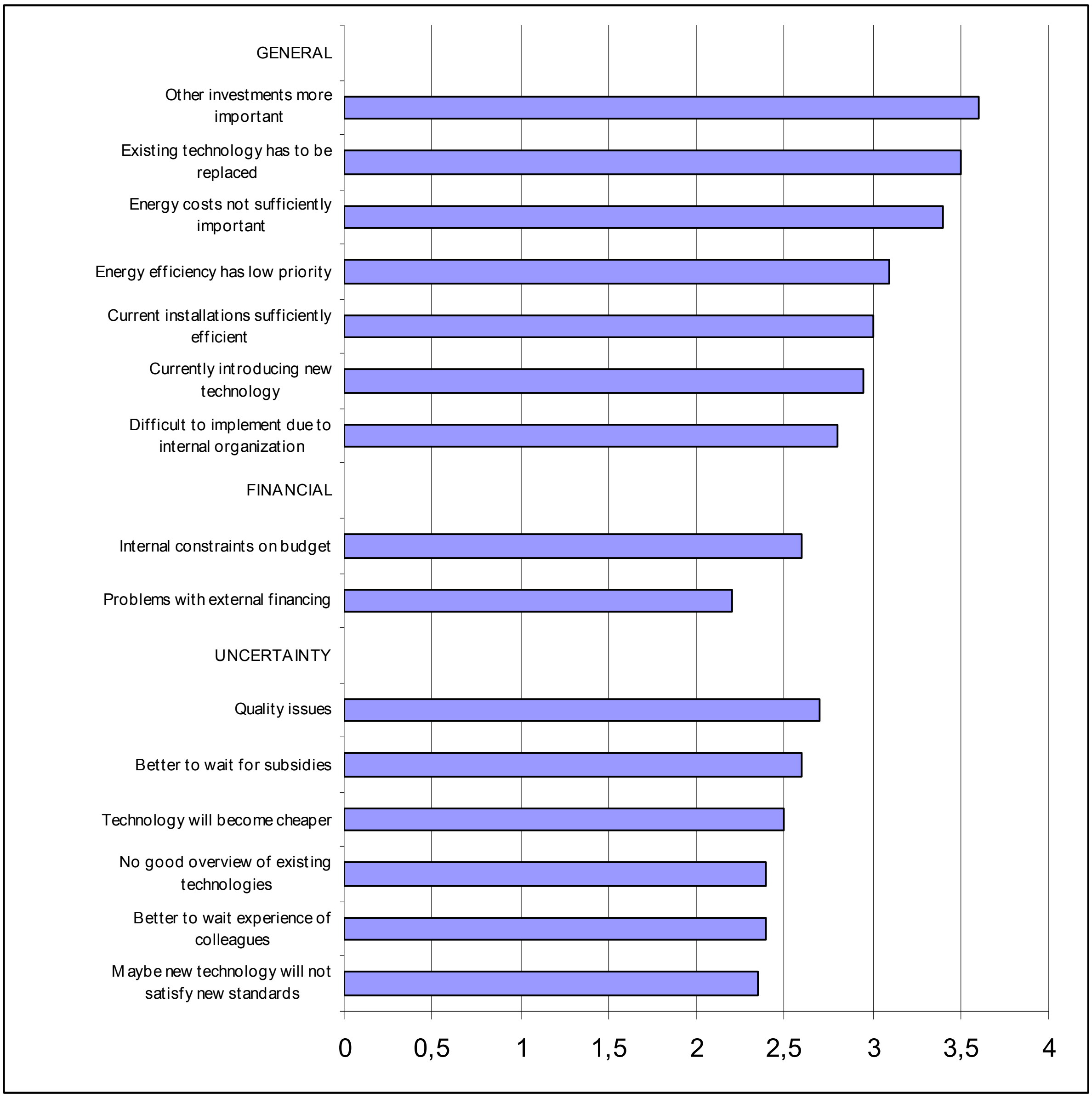

Figure 4. Barriers to energy efficiency investments (Groot et al., 2001).

General barriers include e.g. existence of other investment opportunities, resistance to replacing existing machinery or low priority of energy efficiency. Financial barriers turned out to be a problem of minor importance; once a technology is considered to be sufficiently profitable, companies are able to collect the necessary funds to make the investment. The third category, uncertainty, was of intermediate importance. The key uncertainties were related to future technology, prices and policy developments. (Groot et al., 2001) The study clearly indicated that emphasis should also be put on improving the risk analysis tools used in energy efficiency investments.

The recent study by Sardinaou (2008) recognized two main categories of barriers to industrial energy efficiency investments: (1) financial and market barriers and (2) organizational and human factors barriers. Financial and market barriers include, for example, company's limited access to capital, perceived riskiness of energy efficiency investments, bias in investment calculations and lack of appropriate information. Organizational and human factors barriers include among other things the size of the company, managerial attitudes towards energy efficiency and technical difficulties in adopting new technology. (Sardinaou, 2008) Based on Sardinaou's classification, the focus of this study is on the financial barriers, as the objective is to improve the decision-making tools used in energy efficiency investments. However, it can be expected that more sophisticated analysis tools will also have an impact on organizational and human factors barriers, as individuals gain more understanding of the benefits of these investments.

The study by Rohdin et al. (2007) identified limited access to capital as the largest barrier, which is slightly conflicting with the previous results. It can be concluded that limited access to capital as well as many other barriers, such as lack of budget funding or other investment priorities, derive from the same basic reason: lack of appropriate analysis tools for energy efficiency investments. If the benefits of energy efficiency investments are not understood thoroughly, they are discriminated in the selection process. This is why more sophisticated analysis tools are needed for energy efficiency investment appraisal.

3. INVESTMENT APPRAISAL METHODS

Energy efficiency investments are typically considered as part of the company's capital budgeting decision-making process. There are several methods than can be used to evaluate prospective capital investments. This chapter will provide a brief presentation of the most common methods as well as a review of their use in practise. At the end of the chapter also the use of these methods in energy efficiency investment appraisal will be discussed.

3.1 Payback period

The payback period method is one of the simplest and most frequently used methods. It is defined as the time, which is required for the investment to recover its original cash outlay. There are two main weaknesses in this method. First of all, it does not take into account the cash flows that are earned after the payback date and secondly, it fails to consider the differences in the timing of the cash flows. (Drury, 2004) Despite its obvious weaknesses, the payback period method is the method most widely used in practice. In Finland, 97 % of companies use payback as a primary or secondary method and it is thus the most common investment evaluation method used by Finnish companies (Liljeblom & Vaihekoski, 2004). The results from a survey conducted by Graham & Harvey (2001) also show that especially small firms are more likely to use the payback criterion.

3.2 Net present value

Net present value (NPV) is generally considered as the most correct method for investment appraisal because it focuses on cash and takes into account the time value of money and riskiness of the investment project. The method is hence consistent with the objective of shareholder wealth maximization (Shapiro, 2005). The net present value of an investment project is the present value of the net cash inflows less the project's initial investment outlay. If the resulting NPV is positive, the company should accept the investment project; if it's negative, the project should be rejected. In mutually exclusive projects, the investment with higher net present value should be accepted. (Drury, 2004)

The key strength of the method is that it evaluates investments in the same way as shareholders do and thus maximizes shareholder value. The NPV criterion also obeys the value additivity principle meaning that the NPV of a set of investment projects is equal to the sum of the NPV's of the individual projects. The basic weakness of the method is the fact that many corporate managers have problems in understanding the concept. Companies also often face difficulties in computing the proper discount rate for the investment project. (Shapiro, 2005) Because the theoretical superiority of the method has been emphasized in academic textbooks, NPV is one of the most frequently used methods and has gained significantly importance during the last 20 years (Graham & Harvey, 2001). However, Finnish companies still lag behind the U.S and Swedish companies in their use of NPV: only 52.1 percent of companies indicate that they use the NPV either as their primary or secondary investment evaluation method (Liljeblom & Vaihekoski, 2004).

3.3 Internal rate of return

The internal rate of return (IRR) is the discount rate that will cause the net present value of an investment to be zero. The decision rule in the method is that if the IRR is greater than the opportunity cost of capital, the investment is profitable, will yield a positive NPV and should be accepted. Alternatively, if the IRR is less than the cost of capital, the investment should be rejected. (Drury, 2004) Therefore, the comparison between cost of capital and IRR is effectively a question of determining whether the project has positive NPV or not (Brealey et al., 2008). However, the method has two major shortcomings. Firstly, when an investment has unconventional cash flows, meaning that the cash flows change sign more than once, there may be more than one IRR, which can lead to incorrect decisions. Secondly, in mutually exclusive projects, NPV and IRR may give conflicting results. When investment projects are mutually exclusive, the NPV rule should be preferred over IRR because it represents more realistically the opportunity cost of funds for the firm's shareholders. The advantage of IRR is that managers seem to visualize and understand it better than NPV and it does not require the advance specification of the discount rate. This is why some managers prefer IRR and it is as popular method as NPV both in the U.S. and Finland (Graham & Harvey, 2001; Liljeblom & Vaihekoski, 2004).

3.4 Other methods

Other investment appraisal methods include accounting rate of return (ARR) and profitability index (PI). The accounting rate of return is defined as the ratio of average after-tax profit to average book investment. To apply the method the company should specify its target rate of return and accept investments yielding a greater return than target and reject those falling below it. The weaknesses of the method are that it does not consider the time value of money and it is based on accounting income, not real cash flow. (Shapiro, 2005) The profitability index is a variation of the NPV method and is calculated by dividing the present value of cash proceeds by the initial cost of the investment. If the investment is greater than 1, the investment should be accepted. In case of capital rationing, the profitability index is a valuable tool in allocating the limited available capital in a way that maximizes the NPV's of the firm. (Drury, 2004) According to Graham & Harvey (2001), the PI method is rather rarely used: only 10 % of companies use it in their investment appraisal.

3.5 Use of methods in energy efficiency investment appraisal

Harris et al. (2000) conducted a survey of Australian firms on the factors, which influence companies' investments in energy efficiency. The results show that payback period is by far the most widely used decision-making rule in energy efficiency investments; eighty per cent of firms reported that they use it in evaluating investments. Similar results were obtained already in an earlier study conducted in 1986 of twelve large manufacturers (Ross, 1986). Jackson (2008) argues that payback period is commonly used in energy efficiency investments because of the difficulties in incorporating uncertainty into NPV analysis. Payback as a simple decision-rule reduces risk by limiting the analysis to the near term, where there is least uncertainty. The average payback requirement used by companies in energy efficiency investments was only 42 months (Harris et al. 2000). DeCanio (1993) provides several explanations for the use of short payback thresholds in energy efficiency investments. Managers might be short-sighted because their compensation is often tied to recent performance. Frequent manager rotation may lead managers to prefer projects with short payback periods because they have no incentive to promote a project having a more distant payoff. Quick returns also enhance managers' reputation with the owners, which obviously leads to the choice of rapid payback projects. (DeCanio, 1993)

More alarmingly, just under one third of companies use theoretically correct positive NPV as a decision rule in evaluating energy saving projects (Harris et al., 2000). This indicates that companies tend to use NPV less in evaluating energy efficiency investments compared to other types of investments. The average discount rate used to calculate NPV was 13 percent (Harris et al., 2000). This is slightly higher than the historical return on the stock market (approximately 10 %), which would indicate that energy efficiency investments are perceived somewhat riskier than average investments. Several researchers have expressed the use of overly high discount rates in energy-related investment decisions (e.g. Sutherland, 1991; DeCanio, 1993; Howarth & Sanstad, 1995; Sanstad et al., 1995). DeCanio (1993) argues that high hurdle rates may sometimes reflect the problems of control in a large organization, not the firm's cost of capital. Because the company's owners have difficulties in observing the true profitability of investment projects, they set the hurdle rate substantially above the cost of capital to ensure that only highly profitable investments are undertaken. Therefore some profitable investment projects are rejected for the sake of monitoring and controlling management. (DeCanio, 1993) It has been also pointed out, that different discount rates may be applied to core activities, such as production of output, and peripheral activities, such as energy saving (Soest & Bulte, 2001). If energy efficiency investments truly include risky aspects, a higher discount rate would be justified to compensate for this additional risk. On the other hand, if the discount rate is solely based on subjective perceptions of risk or is otherwise unjustifiable high, the value of energy efficiency investments might be significantly underestimated. The possible risk analysis tools as well as the determination of proper discount rate will be further discussed in chapter four.

To conclude, it seems that theoretically questionable payback period method is especially dominant in the area of energy efficiency investment decision-making and it can be argued that this is one reason for the existence of energy efficiency gap. As presented in this chapter, the net present value criterion is the theoretically superior method in analyzing investments. Therefore the first step in improving energy efficiency investment analysis is to set net present value as the primary analysis method and cut emphasis on the simple, non-discounted cash flow methods.

4. RISK ANALYSIS IN ENERGY EFFICIENCY INVESTMENTS

4.1 Risks in energy efficiency investments

It has been well established that there is a substantial amount of uncertainty related to energy efficiency investments. According to Mills et al. (2006), studies have shown that measured energy savings often deviate significantly from predictions, and typically in unfavourable ways. This has lead to a so-called cream-skimming problem, in which the relatively certain savings opportunities are selected in favour of more promising but complex and uncertain investments. The problem is clearly reflected in the extensive use of payback period method in energy efficiency investment appraisal. Sutherland (1991) also recognises the large spread between observed and predicted energy savings but argues that in the long run the observed and predicted savings are about equal. Uncertainty about future has even been suggested as the potential explanation for the existence of energy efficiency gap because rational investors prefer delaying their investment to avoid bad realization when energy prices fall and the investment becomes unprofitable (Hasset & Metcalf, 1993).

The uncertainties in energy efficiency investments can be classified into economic, contextual, technology, operational, and measurement and verification risk categories (Table 1). Each category has both intrinsic (controllable) and extrinsic (uncontrollable) dimensions. The categorization shows that there are different sources of risk in energy efficiency investments and the source of risk directly affects the ability of risk measurement. Economic, technology and operational risks seem all quantifiable and therefore their implications should be quantitatively analyzed by using risk analysis tools. Contextual risks, such as environmental concerns, are of such nature that their impact can only be considered qualitatively. Measurement and verification risks are naturally present at all times and but their effects should be minimized by conducting model validation and adequate measurement. The categorization can be used to identify all the relevant risks of energy efficiency investment as well as appropriate risk management tools for each risk. (Mills et al., 2006)

Risk category	Examples of risks	Intrinsic factors	Risk management	Extrinsic factors	Risk management
Economic	Energy cost volatility, tariff structures, tariff levels, labour costs			Fuel costs	Hedges
				Demand charges	Hedges
				Cost of capital	Risk-based rates
				Exhange rates	Hedges
				Labour costs	Fixed price contracts
				Equipment costs	Fixed price contracts
Contextual	Quality and completeness of information, enviromental concerns	Information on facility	Due diligence, surveys	Environment	Pre-project data analysis, weather hedges
		Applicability/feasibility	Careful design	Energy service levels	Contractual exclusions
Technology	Equipment performance and lifetime	Equipment performance	Design, specification, measurement	Equipment lifetime	Design, specifications, contractual exclusions
		System performance, equipment sizing	Measurement, design		
Operational	Poor maintenance, shifting operating hours	Degradation of savings	Monitoring and diagnostics	Persistance	End-user training, occupant incentives
		Baseline adjustments, indoor environmental quality	Contractual adjustments, liability insurance		
Measurement and verification	Measurement bias, metering inaccuracy	Data quality	Engineering review		
		Modeling errors, metering precision	Model validation, adequate measurement		

Table 1. Energy efficiency investment risk categories (Mills et al., 2006).

According to a survey by Harris (2000), the majority of firms (58 %) consider themselves conservative or very conservative towards risk in energy efficiency investments. Constantly changing information was regarded as most important source of risk by three quarters of respondents. When evaluating energy efficiency investments, companies tend to avoid or devalue metrics that show evidence of uncertainty. Risks are often included in investment calculations as qualitative descriptions or anecdotal footnotes, which may not have real influence on the investment decision. Another problem is that companies often see the uncertainties simply as liabilities and ignore the potential opportunities they provide. Rather than trying to quantify these uncertainties, companies favour stipulating, instead of measuring and verifying, the potential energy savings. The stipulated savings are discounted to reflect the potential downsides, while ignoring all the potential upsides. The attitude that uncertainty should be avoided rather than quantified limits the perceived opportunities for energy saving projects. Consequently, quantitative risk analysis tools are essential in analyzing energy efficiency investments correctly. (Mills et al., 2006)

4.2 Risk analysis techniques

As pointed out previously, more developed risk analysis is clearly needed in energy efficiency investment appraisal. In this section, several risk analysis techniques will be presented and their applicability to energy efficiency investment appraisal will be discussed.

4.2.1 Adjusting the payback period

A method preferred by many firms is to require shorter payback periods for riskier projects. For example, a project perceived as riskier than average might have a payback requirement of three years instead of the company's general five-year requirement. Besides the theoretical weaknesses of payback period method identified in chapter three, the problem with the method is its subjectivity. The analysis is based on subjective perceptions of the investment's risk and there are no objective methods for determining the adjusted payback period requirement. (Shapiro, 2005) Additionally, the method provides no information on the source and nature of investment's risk and represents an overcautious method designed for worst case scenarios (Jackson, 2008).

According to Jackson (2008), the use of payback period method as a risk analysis tool has resulted in significant underinvestment in energy efficiency technologies. Companies prefer payback period as a risk analysis tool because from a management perspective, there is significant value in using easy-to-apply risk filter tool as long as the costs of simplifying the process are not too great. (Jackson, 2008) The extensive use of payback is also said to reflect the risk aversion of corporate managers towards energy efficiency investments (Jaffe & Stavins, 1994). Jackson (2008) points out, that simple payback techniques can be reliably used to screen energy efficiency investments only if 1) all technologies have the same distribution of expected savings and 2) all technologies have the same lifetime. Given the wide array of energy efficiency technologies as well as variations in energy price, the two conditions are highly unlikely to hold in most circumstances. Thus, the payback period method fails to acknowledge the individual risk characteristics of an investment and constitutes a relatively poor tool to use in addressing investment risk. (Jackson, 2008)

4.2.2 Adjusting the discount rate

Capital asset pricing model

There are basically two techniques available to incorporate risk into NPV investment analysis. A traditional approach is to have the discount rate take into account both the time value of money, measured by the risk-free rate of return, and riskiness of the project's cash flows. Another way is to apply the risk-free rate as a discount rate and adjust the cash flows in accordance with their riskiness. In the traditional approach, the discount rate to be used is often the weighted average cost of capital (WACC) of the company, which equals the required rate of return for average-risk projects. The components of WACC are the company's cost of equity and debt capital, which are then weighted based on the proportions of equity and debt in the company's capital structure. (Shapiro, 2005) Hence, if energy efficiency investments are evaluated as average risk projects, they should be analyzed by using the company's WACC as a discount rate. However, if this is not the case, the components of WACC should be adjusted to reflect the unique risk characteristics of energy efficiency investments.

The cost of equity capital for an investment is generally calculated by using the capital asset pricing model (CAPM), which has been the most influential model in the theory of finance since it was introduced in the mid 1960's. CAPM assumes that the project is solely financed with equity capital, and thus provides a proper discount rate for fully equity-financed projects. The model is based on the insight that in a competitive market the expected risk premium of an asset varies in direct proportion to asset beta, which is the sensitivity of the asset to market movements. The total risk of an asset has two components: unsystematic risk and systematic risk. Unsystematic risk is the random variation in the return of an investment and can be eliminated by using diversified portfolios. If investors are able to efficiently diversify this risk, it should not be rewarded a risk premium. On the other hand, systematic risk is reflected in the entire market and is hence non-diversifiable. This risk is due to macroeconomic factors and affects the returns of all companies (Drury, 2004). Managers should only be concerned about the risk that they cannot eliminate by diversification, as measured by the asset's beta coefficient. The risk premium for an asset equals the asset's beta multiplied by the market risk premium. As the project cost of capital equals the risk free rate added by the project risk premium, the CAPM-calculated required return on an investment project can be expressed by the following equation: (Brealey et al., 2008)

$$r_i = r_f + \beta(r_m - r_f)$$

where r_f is the risk-free rate of return, β is the asset's beta coefficient and r_m is required rate on market portfolio. The following example illustrates how the CAPM can be applied in calculating the required return of an investment:

Example of calculating required rate of return with CAPM:

Yield on Finnish government 10-year bonds = 3.5 %
Historical market return = 9 %
Investment beta = 1.5

$r_i = r_f + \beta(r_m - r_f)$
r_i = 3.5 % + 1.5*(9 % - 3.5 %) = **11.75 %**

The risk-free rate of return is typically measured by the yield on long-term government bonds. In February 2009 the yield on 10 year Finnish government treasury bonds was about 3.5 % (Treasury Finland, 2009). The CAPM assumes that the required market risk premium is equal to the expected market risk premium. Therefore the market risk premium cannot be determined with precision because the historical differential return on the market over treasury bonds does not necessary equal the expected market risk premium. (Shapiro, 2005) Fernandez (2004) points out that it is a common mistake to think that historical and expected market risk premiums are equal. The historical market risk premium has been somewhere between 7 and 8 percent. Many academics and practitioners estimate the forward-looking risk premium below its historical average, to 5-6 percent. (Shapiro, 2005) In the example the investment was considered riskier than market portfolio, which was reflected in the beta coefficient's value of 1.5. The main problem of CAPM is that it is immensely difficult to determine betas for individual investment projects. This problem will be discussed in the next section.

Systematic risk

Systematic risk of an investment is measured by the beta coefficient, which is the sensitivity of the investment project to market movements. Because direct information about future project returns relative to predicted market returns does not exist, the only practical way is to find a firm, or preferably a portfolio of firms, that shares the same risk characteristics and use the firm's beta to estimate the project beta. (Shapiro, 2005) For energy efficiency investments, Energy Service Companies (ESCO's) would probably constitute the most appropriate reference group for the estimation of beta. Energy service companies are professional businesses providing the design and implementation of energy saving projects and therefore it can be concluded that their betas should reflect the general riskiness of energy efficiency investments. Unfortunately, it proved out to be difficult to find a listed ESCO company focusing solely on energy efficiency investment activities. A sample of such companies' betas would have provided valuable information about the riskiness of energy efficiency investments.

Due to the difficulties with obtaining appropriate data in beta estimation, it is necessary to take a different approach to the problem and use basic reasoning to understand the systematic risk of an energy efficiency investment. Systematic risk the risk reflected in the entire market and is mainly dependent on firm characteristics. The market risk of an investment basically derives from the changing demand for the company's products or services. When considering the pure capacity investment introduced in chapter two, the relationship between market demand (sales volume) and investment return is linear, as illustrated in Figure 5.

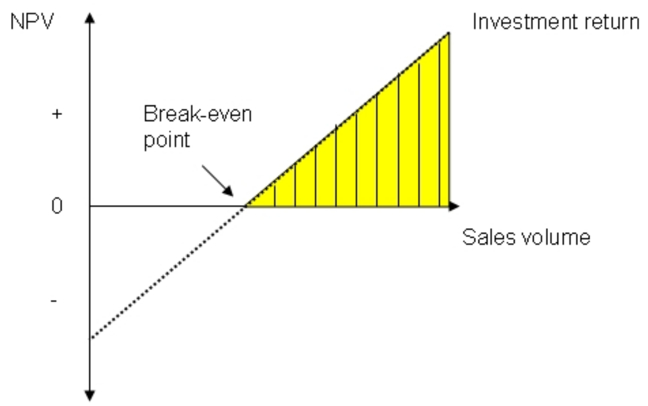

Figure 5. Relationship between sales volume and capacity investment return.

Investments in capacity enable the production of additional volume and produce revenue by selling the additional output at the market. Break-even point is the sales volume at which the investment return equals zero. At volumes less than break-even point the project is unprofitable and the profitability of the investment increases in line with sales volume.

The main question to be asked is if energy efficiency investments are any different in terms of market sensitivity and should therefore be granted higher beta values. To answer this, the earning logic of energy efficiency investment should be examined. Figure 6 shows the relationship between company's energy costs and production volume and possible effects of energy efficiency investment.

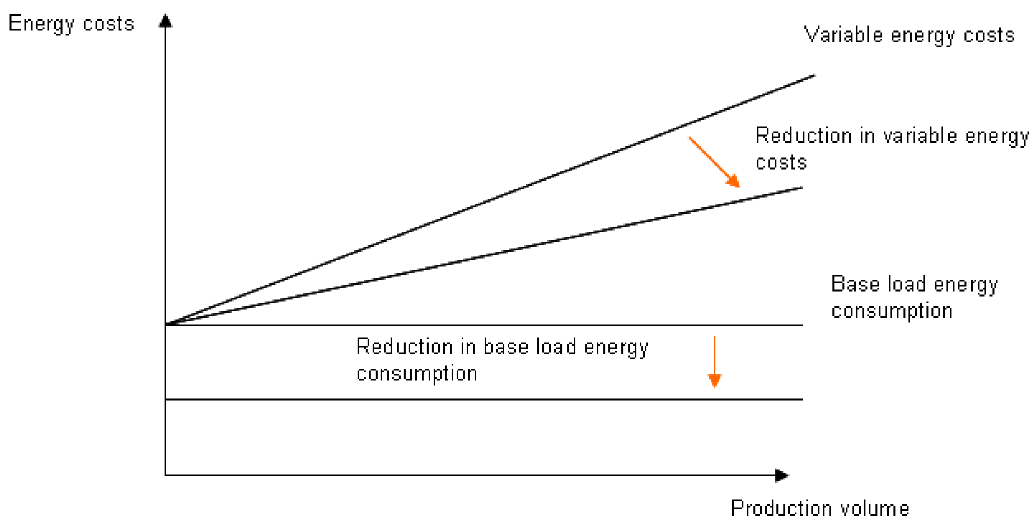

Figure 6. Possible effects of an energy efficiency investment.

The energy costs of an industrial company can be divided into variable and fixed costs. Typically the majority of the energy costs are variable but there is often also a fixed energy consumption level, i.e. base load energy consumption, which remains constant at all production volumes. An energy efficiency investment can either affect the variable costs of energy or the fixed level of energy consumption. When considering the differences between capacity investment and energy efficiency investment, the distinction between these two investment types becomes noteworthy Investments lowering variable costs realize their gains through lower production costs per unit and would appear less risky to market changes compared to capacity investments because the gains are not dependent on sales volume but production. However, in the long run the company cannot keep producing more than can be sold at the market and production is likely to be adjusted to respond to market conditions. Therefore the actual difference is merely a timing difference: energy savings realize at the time of production whereas capacity investment returns materialize at a point of sale. From a risk analysis perspective two are in essence similar and it can hence be argued that for these types of energy efficiency investments the systematic risk should equal that of all other manufacturing investments. On the other hand, energy efficiency investments having an effect on fixed energy consumption level realize their savings irrespective of market conditions. Therefore for these types of investments the systematic risk should actually be lower than for capacity investments.

Unsystematic risk

As indicated above, energy efficiency investments are unlikely to have higher required rates of return because of their systematic risk. Nonetheless, the major risk of many energy efficiency investments is the random unsystematic risk; namely the risk of future energy prices. The finance theory suggests that unsystematic risk should not be considered as long as it can be eliminated by using efficient portfolios. However, most companies are unable to effectively diversify their energy efficiency investments. Additionally, the CAPM assumptions about zero transaction costs and marketable assets are rarely valid in reality. Sutherland (1991) proposes that in large publicly held corporations the CAPM assumptions about efficiency are valid because the investments are reflected in the company's securities traded in the market. He asserts that when energy efficiency investments are taken by large publicly held corporations, the required rate of return should be comparable to that of any other asset in the same (systematic) risk class. In the case of small, privately held businesses, the illiquidity, transaction cost and inability to diversify risk will require a higher return than is required by public corporations.

Johnson (1994) acknowledges the inability of companies to diversify their energy conservation investments but concludes that CAPM leads only to rough approximations in analyzing the proper discount rate. Deriving from Johnson's analysis, it can be concluded that due to its complexity, unsystematic risk of energy efficiency investment should not be included in the discount rate of the project. Additionally, energy price being the major source of unsystematic risk, knowledge about the extent of uncertainty is considerably lost if the range of possible investment outcomes is summarized in a point estimate, i.e. discount rate. Rather, the unsystematic risk in energy efficiency investments should be quantified in the cash flows of the project by using applicable risk modelling tools, such as simulation analysis.

Conclusion

The capital asset pricing model asserts that energy efficiency investments have the same systematic risk compared to company's general production capacity investments. Therefore an appropriate discount rate would be the cost of capital of the company. In energy efficiency investments having effect on fixed energy costs, an even slightly lower discount rate might be justified. Implications of unsystematic risk caused by varying energy prices should be quantified in the investment project's cash flows due to the inability of measuring such complex uncertainty in a point estimate.

4.2.3 Adjusting cash flows

Instead of including the investment's risk in the discount rate, it is possible to adjust the project's cash flows to reflect their riskiness. Adjusting the cash flows makes it possible to consider the magnitude and timing of risks and their implications for the projected cash flows. A common technique is to adjust the cash flows to reflect the expected effects of each identified risk. Adjusting the cash flows reflects the unsystematic risk of the investment project and hence it should not be included in the discount rate of the project. However, if the project bears a risk that is systematic in nature, then the discount rate should be adjusted to reflect its implications. (Shapiro, 2005)

Another possible technique is the certainty equivalent method, which incorporates both systematic and unsystematic risks in the project's cash flows. The certainty equivalent of a risky cash flow is defined as that certain amount of money that the decision-maker would just be willing to accept instead of the risky amount. The method is implemented by converting each expected cash flow into its certainty equivalent by using a conversion factor that can range from 0 to 1.0. The NPV of the investment is then calculated by discounting the certainty equivalent cash flows at the risk-free rate of return. Many financial theorists consider the certainty equivalent method conceptually superior because it accounts for the riskiness of each individual cash flow and enables managers to incorporate their own risk preferences directly in the analysis. However, the method is rarely used in practice due to the difficulty in generating valid certainty equivalent factors. (Shapiro, 2005)

Adjusting the cash flows instead of the discount rate is supported by the fact that the use of high discount rates penalizes later cash flows unfairly more heavily than current ones and therefore does not avert the need for careful risk evaluation (Shapiro, 2005). Using a constant discount rate also assumes that the project risk does not change, even though the situation is often quite the opposite in reality (Brealey & Myers, 2003). The adjustment of cash flows makes it possible to include all available information about the impacts of specific risks on the future returns of an investment (Shapiro, 2005). Consequently, Johnson (1994) has promoted the cash flow adjustment technique in energy efficiency investment analysis due to the inability of the decision-maker to summarize knowledge about the investment's risk in the discount rate. As concluded in the previous section, the unsystematic risk of energy prices seems suitable to be incorporated in the cash flows instead of the discount rate. However, the determination of certainty equivalent factors is likely to pose a serious problem for the application of this approach. Additionally, certainty equivalent method constitutes an insufficient method in capturing the uncertainty of fluctuating energy prices. A suggestion by Johnson (1994) has been that the extent of uncertainty should be included as distributions of potential cash flow values instead of using point estimates for cash flows. Such an approach would describe the risks of uncertain variables more comprehensively and show the range of the outcomes believed possible. This kind of analysis can be conducted by using sensitivity and simulation analysis, which are discussed in the next sections.

4.2.4 Sensitivity analysis

The method

When considering risk in energy efficiency investments, it is vital to know which investment variables bear the highest risk; i.e. how volatile the investment returns are to changes in each variable. Sensitivity analysis is a tool that studies systematically the effects of changes in the values of investment parameters. In energy efficiency investments, these parameters could include e.g. acquisition and installation costs, maintenance costs, equipment lifetime, employee costs, energy prices and production volume. Additionally, the sensitivity of applied discount rate should be considered. The objective of the method is to investigate how sensitive the project returns are to different assumptions. Sensitivity analysis identifies critical investment variables and provides information on the total risk of the investment project. (Shapiro, 2005)

Sensitivity analysis process

In the first step of the sensitivity analysis, different departments of the company such as marketing, production and engineering should determine the pessimistic, most likely and optimistic values for each of the key investment variables. In the case of energy efficiency investments, company's production and engineering managers are likely to have the relevant information needed for the analysis. For the estimation of future energy prices, the use of specialized consultants might also be necessary. The second step is to calculate a series of project NPV's on the basis of setting each variable at its most pessimistic or optimistic value while holding all the other project variables equal to their expected values. (Shapiro, 2005) Alternatively, it is possible to consider relative changes, such as 10 % change in each variable. However, such approach cannot be recommended as it does not take into account the individual characteristics of each variable. (Hull, 1980) One possible modification of sensitivity analysis is scenario analysis, which creates potential situations, i.e. scenarios, where several key variables are changed at the same time. Forecasters generally prefer giving an estimate of revenues or costs under particular scenario than to give absolute optimistic or pessimistic values. (Brealey et al., 2008)

Strengths of sensitivity analysis

Sensitivity analysis enables managers to perceive the range of possible net present values of the investment and its results can be used to filter out the riskiest investment projects. A basic method for measuring the investments risk is to calculate the difference between the combination of all the pessimistic estimates and combination of all the optimistic estimates. Despite the rather low probability of all optimistic or pessimistic estimations occurring at once, the analysis can be valuable for screening initial investment projects. If the investment is unacceptable when optimistic estimates are combined together, it is almost certainly not worth considering further. On the other hand, if it is acceptable when pessimistic estimates are combined together, it can usually be accepted without further analysis. (Hull, 1980)

Drury (2004) views the role of sensitivity analysis in indicating reasons why the investment project might fail. Management should review any critical variables to assess whether or not there is a strong possibility of events occurring which will lead to negative NPV. The critical variables should also be controlled once the decision has been taken to accept the investment. (Drury, 2004) When considering energy efficiency investments, the strength of sensitivity analysis lies in finding out to what extent e.g. variations in future energy prices or equipment maintenance costs can have an effect on investment's profitability. In addition, by identifying critical risk variables of the investment, sensitivity analysis provides a good starting point for further risk analysis procedures.

Weaknesses of sensitivity analysis

The limitations of sensitivity analysis are that it gives no indication of the probability of the variables' occurrence and considers only changes in one variable at a time (Shapiro, 2005). For example, critical information about the effects of varying energy prices is lost if the analysis is limited to forecasting optimistic and pessimistic price levels. Another methodological problem with sensitivity analysis arises when there is dependence between variables. Two variables are said to be dependent if knowledge of the value of one variable would influence the estimates made for another. (Hull, 1980) If the underlying variables are in this way interrelated, sensitivity analysis becomes less useful because the effects of changes in one variable cannot be analyzed in isolation from others. However, such dependencies are not as prevalent in energy efficiency investments because the investment's key parameters include cost variables and energy price variables, which are unlikely to depend on each other.

Additionally, sensitivity analysis often gives somewhat ambiguous results because terms "optimistic" and "pessimistic" might be interpreted differently in different departments of the company. It is important that managers ensure consistency in the use of these terms. Hull (1980) suggests that there should always be a 5 % chance of the value of the variable being greater than the optimistic estimate and correspondingly 5 % chance of it being less than the pessimistic estimate. It can be rather difficult to think in terms of such probabilities but the insight is that extreme events should not be included in estimations. (Hull, 1980)

Conclusion

Jackson (2008) presents that sensitivity and scenario analyses are rarely applied to energy efficiency investment evaluation. He argues that the extensive presentation of decision variables and outcome distributions is incompatible with the general preference by decision-makers for simple decision rules. The critique is somewhat questionable as sensitivity analysis can be viewed as the simplest and most understandable methods of quantifying risk. Additionally, sensitivity analysis is often applied in analyzing investments in energy production, such as power plants (e.g. Athanasios & Pilavachi, 2009), which basically share the same complexities as energy efficiency investments. Sensitivity analysis might lack straightforward results and provides no clear-cut rule for decision-making but in many cases it can offer a good starting point for analyzing risk of an energy efficiency investment.

4.2.5 Monte Carlo simulation

<u>Background</u>

Sensitivity analysis allows only a consideration of limited number of plausible combinations of variables. In order to consider all possible combinations and their probabilities, Monte Carlo simulation is required. Monte Carlo methods have been used for centuries, but only in the past decades the technique has gained status as a sophisticated method capable of addressing even the most complex applications. Monte Carlo simulation method can be described as a statistical simulation method that utilizes sequences of random numbers to perform the simulation. The name Monte Carlo derives from the Monte Carlo casino in Monaco, referring to the similarity of statistical simulation to games of chance. The method requires that the physical system is described in probability density functions (pdf's). Once the pdf's are known, Monte Carlo simulation proceeds by random sampling from the pdf's to create a distribution of possible outcomes. After performing several simulations, the desired result is often expressed as an average over the number of observations. (Introduction to Monte Carlo methods, 1995)

<u>Simulation process</u>

The Monte Carlo simulation process can be broken down into seven stages (Figure 7).

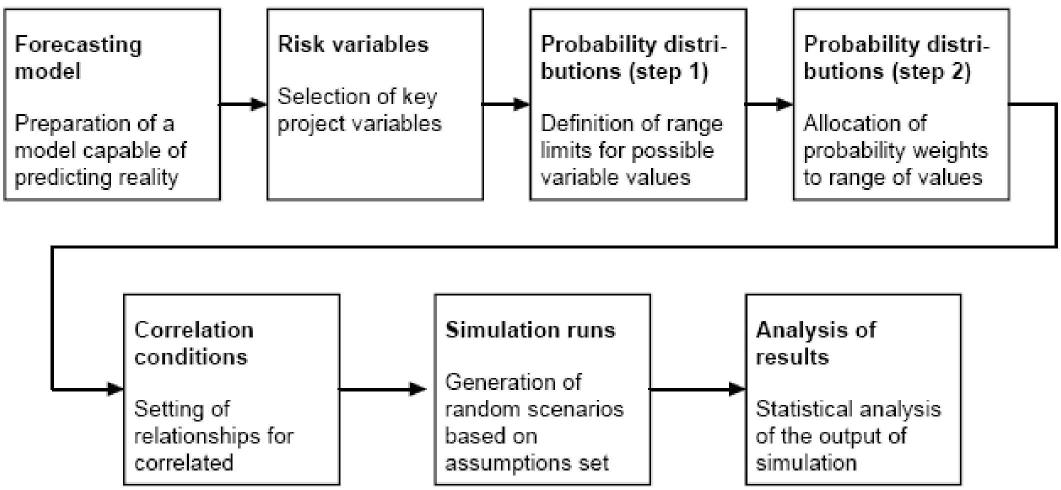

Figure 7. Monte Carlo simulation process (Savvides, 1994).

The process begins by preparing a forecasting model capable of predicting reality with suitable data. The model is a set of formulas that process several input variables to arrive at output variable. Basically the input variables include the benefits (B) and costs (C) of the investment and the output variable is the result (R), such as NPV of the investment project. (Savvides, 1994)

Figure 8 shows an example of a possible forecasting model for energy efficiency investments. Annual energy savings depend on the level of energy price and the investment's contribution to reduction in energy use. The key cost components include acquisition and installation costs as well as possible annual maintenance and labour costs. Additionally, assumptions about economic lifetime and discount rate of the investment project can be included as input variables. The model should depict the dependency between investment's benefits and costs and underlying variables. The relationships between variables are described in formulas which eventually produce output variable, net present value of the investment project. A good model includes all the relevant variables and describes the correct relationships between them (Savvides, 1994).

Forecasting model	€	Variables	Formula
Aqcuisition and installation cost	-30 000	V1	
Energy price	40	V2	
Reduction in energy use per unit	0,5	V3	
Production per year	800	V4	
Cash inflow per year	16 000		F1 = V2 * V3 * V4
Maintenance expenses	2 400		F2 = V4 * V5
Wages	4 800		F3 = V4* V6
Cash outflow per year	7 200		F4 = F2 + F3
Net cash flow per year	8 800		F5 = F1 - F4
Relevant assumptions			
Maintenance cost per unit	3	V5	
Wages per unit	6	V6	
Economic lifetime	10	V7	
Discount rate	10 %	V8	
NPV	21 884		F6 = NPV(V1;F5;V7;V8)

Figure 8. Example of a forecasting model for energy efficiency investments (adapted from Savvides, 1994).

The second stage entails the selection of the model's risk variables. A risk variable is defined as one which is critical to the viability of the project in the sense that a small deviation from its projected value is both probable and potentially damaging to the project worth. Sensitivity analysis is often used to identify the critical variables of a forecasting model. There are two reasons why only the riskiest variables should be included in the model. Firstly, the greater the number of probability distributions employed in a random simulation, the higher the likelihood of creating inconsistent scenarios due to the difficulty in monitoring relationships between correlated variables. Secondly, the cost of determining accurate probability distributions of many variables with small impact on the result is likely to outweigh the benefit derived. Therefore the focus should be on the most sensitive and uncertain variables of the project. (Savvides, 1994)

The next two stages are related to defining the probability distributions of the uncertain input variables. A probability distribution describes how probability is distributed over the range of possible values of a variable (Hull, 1980). The most often used probability distributions are normal, exponential, triangular and uniform distributions (Savvides, 1994). Probabilities can be either objective or subjective. Objective probabilities are established mathematically or constructed from historical data. For energy efficiency investments, the estimation of energy prices should be possible by using data on historical price movements. Subjective probabilities are based on managerial judgement, expert knowledge, past experiences and observations of current variables which are likely to influence future events. Subjective probabilities are likely to be used in business investments since past observations or repeated experiments for particular decisions are often not available. (Drury, 2004)

When the proper probability distributions have been found, the potential correlations between input variables have to be considered. Two variables are said to be correlated if they tend to vary together in a systematic manner. If the existence of correlated variables is not taken into account, the results of risk analysis can be distorted. The reason for this is that the selection of input values from the assigned probability distributions for each variable is purely random. Thus, it is possible that the input combinations generated for certain scenarios violate the systematic relationships between variables. The problem can be solved by removing all violated scenarios from simulation results. (Savvides, 1994) As already indicated above, such relationships are unlikely to exist in energy efficiency investments. However, their existence should be considered case by case and possible effects eliminated to ensure the correctness of the simulation results.

The process continues by running the simulations, which is a part in which the computer plays an important role. Simulations can be run by using a spreadsheet program, such as Microsoft Excel. During the simulation the values of the risk variables are selected randomly within the specified ranges and in accordance with the probability distributions and correlation conditions. The results, NPV's of the investment project, are computed and stored following each simulation run. In calculating the NPV's cash flows should be discounted at the risk-free rate because risk is already considered in the project's cash flows (Shapiro, 2005). Typically a sample size between 200 and 500 simulation runs should be sufficient to achieve to make up a representative sample of the number of combinations possible. (Savvides, 1994) The stored NPV's are then illustrated by the computer in the form of a frequency distribution, which can be further processed into a probability distribution of possible NPV's for the investment (Shapiro, 2005). Finally, the simulation results are analyzed with statistical methods. A common way is to calculate the expected value of the investment project, which is the weighted average of all possible outcomes. In addition, standard deviation, minimum and maximum values and confidence intervals might also provide valuable information on project riskiness.

Strengths of simulation analysis

Simulation analysis has been considered as a highly sophisticated and technologically advanced tool for addressing investment risk (Shapiro, 2005). If the probability distributions and relationships between variables are assigned correctly, the simulation model should be able to provide accurate information about the investment's behaviour in reality. Another advantage of simulation analysis is that it drives decision-makers to examine carefully the relationships between the factors affecting the investment's cash flows (Drury, 2004). According to Brealey & Myers (2003), the results from simulation analysis should not only be used to generate a distribution of NPV's but also help to understand the project, forecast its expected cash flows and assess its risk. Once simulation analysis has been conducted, it is far easier to determine an appropriate discount rate for the traditional NPV analysis. In addition, the method enhances decision-making on marginal projects as the probabilities of possible returns are known. For example, marginally positive project could be rejected on the basis of being excessively risky, or one with a lower NPV may be preferred to another with a higher NPV because of a better risk/return profile. Simulation can also be used to screen new project ideas and identify investment opportunities. The results of simulation analysis can be utilized to redesign investment projects to suit the investor's attitudes and preferences towards risk. (Savvides, 1994)

Weaknesses of simulation analysis

Simulation analysis attempting to be realistic often becomes quite complex. Estimating the underlying probability distributions and interrelationships between variables is difficult and time-consuming. (Brealey et al., 2008) Because of the high amount of resources and time needed for the analysis, simulation is often recommended only for the most important investment projects that involve large sums of money (Drury, 2004). In addition, simulation provides no clear cut decision-rule because the resulting probability distribution of possible returns does not ultimately determine whether to accept the project or not. Rather than using rule-specific measures such as NPV, the decision-maker must assess the probability distribution and make the investment decision based on individual risk preferences. (Shapiro, 2005)

Conclusion

Simulation analysis constitutes a comprehensive approach to address the uncertainty related to future energy prices and key cost components of an energy efficiency investment. Rather than providing single point-estimates, the method considers the entire range of possible investment outcomes and their probabilities of occurrence. Such inclusive representation allows individual organizations to better understand the risks and rewards of alternative energy efficiency investments and enables them to accommodate their investments to their ability and desire to bear risks (Jackson, 2008). When the benefits of energy efficiency investments are quantified in such an accurate manner, energy-related risks can be compared with other business risks as well (Mills et al., 2006). The success of the method depends heavily on the ability to construct reliable probability distributions for investment's risk variables. Lack of appropriate data or inability to make fairly reliable subjective assessments might significantly deteriorate the validity and reliability of the results. Simulation should not be applied to energy efficiency projects of minor importance as the method often requires a great deal of time and computing power.

4.2.6 Real options

Investment projects are seldom simple one-time decisions. In most cases, a company's investments are multi-staged and at each step the company must decide whether to push ahead or pull out from the project after gaining new information. (Copeland & Tufano, 2004) The problem with NPV analysis is that it assumes a static environment and does not recognize the opportunity to modify investment projects (Brealey & Myers, 2003). This problem can be addressed by using real options, which incorporates management's flexibility into the project valuation process. Real options enable the investor to put concrete value on the project uncertainties by acknowledging the flexibility managers have in making capital investment decisions (Olofsson, 2003).

Many different types of real options have been distinguished in the academic literature. First of all, companies often hold an option to postpone the investment to gain more market-related information or acquire appropriate skills and resources to undertake the project (Olafsson, 2003). The ability to defer a project gives the firm more time to examine the course of future events and to avoid costly mistakes if unfavourable developments occur (Shapiro, 2005). Secondly, investments can include an option for further expansion. For example, a successful realization of a research and development project may reveal information or lead to results which warrant an introduction of a new product or production method (Olafsson, 2003). Thirdly, an option to abandon the project can hold significant value. If an investment project turns out to be unprofitable, the company can cut future losses by exercising the abandonment option (Brealey & Myers, 2003). Basically a project should be abandoned if the abandonment value exceeds the present value of subsequent cash flows. The fourth group of options are called operating options, which are associated with varying market conditions. By investing in new and diversified technology, the firm may have more flexibility, for example in terms of raw material use in the future. A technology investment might provide an option to the change from one raw material to another and thus protect from price increases in the market. (Shapiro, 2005)

The most suitable investments for the usage of real options are irreversible, sequential investments that are made under uncertainty (Dixit & Pindyck, 1994). Energy efficiency investments seem to fulfill the requirement of irreversibility as they are typically very costly or impossible to reverse and entail a substantial amount of sunk costs. Also the uncertainty surrounding future benefits, i.e. the varying energy savings due to fluctuations in energy prices, is characteristic for energy efficiency investments. (Hasset & Metcalf, 1993) The use of postponement options seems prevalent in energy efficiency investments. It has been argued that companies extensively postpone their energy saving projects and wait for the arrival of improved conditions, referring typically to the rise of energy prices (Soest & Bulte, 2001). Jackson (2008) has also stated that option values have an impact on energy efficiency investment primarily with respect to postponing decisions. He presents that possible new technologies, future tax benefits or need to preserve capital for unforeseen uses might add value for postponing the investment.

It can be argued that also other types of options exist in energy efficiency investments. Despite their common irreversibility, some energy efficiency investments involve sequential decisions, which provide abandonment options. For example, an investment in new energy-saving technology might consist of several implementation stages and each stage would hence provide an option to either continue with the project or abandon it. Additionally, various operating options might be attached to energy efficiency investments. For instance, the efficiency equipment can be installed slowly to match load increases (Awerbuch, 2000). An investment may provide flexibility between raw materials and energy sources, which is an exceptionally valuable option in an environment characterized by highly variable commodity prices (Shapiro, 2005). Finally, energy efficiency investments can also entail strategic options in providing qualitative benefits, such as new levels of quality and reliability (Awerbuch, 2000).

Academic researchers have presented several quantitative methods for valuing real options, such as the Black-Scholes model and binomial model. The main problems with these models are their limited applicability to practice and the fact that corporate managers do not possess the mathematical skills needed to understand them (Lander & Pinches, 1998). It is often impossible to capture the complexity of real options in a simple quantitative model. Nevertheless, real options should at least be considered qualitatively because the failure to account for the options will lead to downward bias in estimating investment's profitability (Shapiro, 2005). The real options framework can also be seen as a strategic tool in linking current actions to uncertain futures (Adner & Levinthal, 2004). The representation of such strategic implications usually cannot be done quantitatively, which enhances the need for qualitative evaluation tools. It can therefore be concluded that in addition to quantitative risk analysis, a comprehensive qualitative strategic perspective is needed in analyzing energy efficiency investments.

5. STRATEGIC PERSPECTIVE TO ENERGY EFFICIENCY INVESTMENTS

5.1 Strategic investments

Investments can be roughly classified into operative and strategic investments. Strategic investments are characterized by having a significant effect on company as a whole and its long-term performance (Marsh et al., 1988; Ghemawat, 1992; Butler et al., 1993). The purpose of operative investments is to maintain the business in its existing form whereas strategic investments typically change the nature of the business (Puolamäki & Ruusunen, 2009). Alkaraan et al. (2006) describe strategic investments as substantial investments that involve high levels of risk, produce hard-to-quantify results and have a considerable impact on long-term corporate performance. Hence, strategic investments might not be desirable in the short-term and are often difficult to justify economically (Aho, 1982). Nevertheless, in the long run strategic investments are necessary in order to build competitive advantages which enhance the company's position in the marketplace (Shapiro, 2005).

It has been argued that pure financial techniques are inadequate in analyzing strategic investments. Overreliance on financial appraisal tools is thought to bias decision-makers against undertaking strategic projects that are crucial to the development of business capability and innovation (Alkaraan & Northcott, 2006). The NPV method places high emphasis on short-term financial results and little emphasis on difficult-to-quantify issues, such as quality enhancement or manufacturing flexibility. This is why strategic investments having long-term benefits often fail to pass the positive NPV test. (Hayes & Abernathy, 1980) Strategic implications are especially of high importance when analyzing investments in manufacturing technology (Shank, 1996). In a study of large U.K. companies, increased quality and reliability of outputs, reduced lead times, greater manufacturing flexibility and reduced inventory levels were identified as particularly important in justifying advanced manufacturing technology investments (Abdel-Kadel & Dugdale, 1998). Thus, if these investments would have been analyzed solely with financial techniques, their attractiveness would have been significantly underestimated.

5.2 Framework for analyzing strategic compatibility

The question of whether energy efficiency investments are strategic in nature is quite far from straightforward. Instead of using previously mentioned rough characterizations, a framework is proposed here which considers the strategic nature of an investment by analyzing it from the perspective of company's internal and external strategic compatibility factors. The consideration of both internal and external factors provides understanding of how the investment supports the company's corporate strategy and allows the recognition of the investment's possible intangible benefits.

5.2.1 Internal compatibility factors

Internal compatibility factors include the company's competitive strategy, manufacturing strategy and technology strategy. The three strategies are hierarchical in nature and tightly linked to each other. The strategic compatibility analysis requires an assessment of how well the investment supports the objectives of each strategy.

Competitive strategy

The pioneering work of Michael Porter in the 1980's established a basis for much of the contemporary academic literature on corporate strategy. Porter identified three potentially successful generic strategic approaches to outperforming other firms in an industry: cost leadership, differentiation and focus (Figure 9). In cost leadership, the firm sets out to become the low-cost producer in its industry. By lowering its unit costs the company can create larger margins which are eventually translated into higher profits. Alternatively, the low-cost position can enable the company to increase its market share by charging lower prices than its competitors. The sources of cost advantage may include e.g. the pursuit of economies of scale, proprietary technology or preferential access to low cost inputs. In the differentiation strategy the company seeks to be unique in its industry along some dimensions that are widely valued by customers. By meeting the unique customer needs, the company may be able to charge a premium price for its product. The firm becomes an above-average performer if the price premium exceeds the extra costs incurred of being unique. Differentiation can be based on the product itself, the delivery system, the marketing approach and many other factors. The third strategy, focus, concentrates on a narrow segment and within that segment attempts to achieve either cost advantage or differentiation. The focuser can gain competitive advantage by dedicating itself to the segment entirely and tailoring its strategy to serve the segment's customers exclusively. A firm using a focus strategy often enjoys a high degree of customer loyalty, and this entrenched loyalty discourages other firms from competing directly. (Porter, 1985)

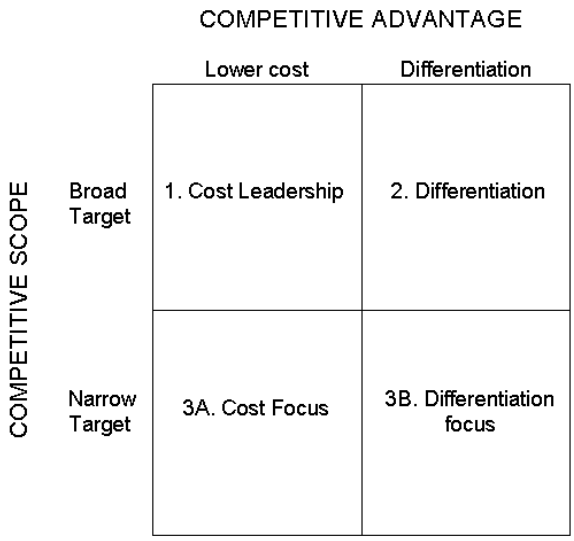

Figure 9. Porter's generic competitive strategies.

When considering the compatibility of energy efficiency investment with a company's competitive strategy, it can be concluded that efficiency investments clearly support the cost leadership strategy. Thus, by implementing in energy saving investments the company can lower its production costs relative to competitors and gain enhanced position in the marketplace. However, when the company is engaged in differentiation or focus strategy, the strategic compatibility is likely to be considerably weaker. Energy efficiency investments rarely provide unique, highly valued attributes to the product or enable the company to serve the needs of a particular narrow customer segment. In such cases the company should consider whether to primarily commit in investment projects that do not contribute to the company's long-term competitive position in the market.

Manufacturing strategy

Manufacturing strategy is concerned with key decisions about the specific role to be played by the manufacturing function of an organization in achieving competitive advantage. Manufacturing strategy should be consistent with the competitive strategy of the business as well as with other functional strategies. (Kerr & Greenhalgh, 1991) Key elements of manufacturing strategy include competitive priorities, which can be defined as a set of objectives for manufacturing. Academic literature has identified four main competitive priorities for the manufacturing function: cost, delivery, quality and flexibility. (Fine & Hax, 1985) Competitive priorities should be used to guide the decisions and establish the plans and policies within the manufacturing structure in order to align the manufacturing capabilities with business strategy. As it is often difficult or even impossible to compete by offering superior performance on all dimensions, the company must choose the priorities it seeks to emphasize. The specification, clarification and pursuit of competitive priorities determine the competitive role of the manufacturing function. (Wheelwright, 1984)

Manufacturing strategy decisions can be classified into structural and tactical categories. Structural decisions have long-term impact and are difficult to reverse; they include decisions related to capacity, facilities, technology and vertical integration. Decisions that are tactical in nature are linked with specific operating aspects of the business; they include decisions on workforce, quality, production planning/materials control and organization. (Hayes & Wheelwright, 1985) The collective pattern of decisions in these eight categories determines the structure and capabilities of a manufacturing organization (Wheelwright, 1984). Strategic capital investments have a meaningful role in implementing the company's manufacturing strategy. Investments have a direct impact on structural decision areas and may also have indirect effects on tactical decision areas. Finally, changes in the decision areas may have complex and unpredictable effects on the competitive priorities of the company. When evaluating an investment, the company must assess its impact on the chosen competitive priorities of the manufacturing function. (Pirttilä & Sandström, 1994) This should be done in analyzing energy efficiency investments, which may have considerable implications to e.g. company's cost and flexibility priorities.

Technology strategy

Technological change is one of the principal forces of shaping competition and industry structure (Porter, 1985). Consequently, the strategic role of technology has been getting more attention and technology has been recognized as a fundamental part of manufacturing strategy (Hayes & Wheelwright, 1984). Technology strategy can be defined as a firm's approach to the development and use of technology. It should be formed in such a manner that contributes to the success of the firm's generic competitive strategy. Technology can affect competitive advantage by either enhancing company's cost or differentiation position. Basically technology strategy includes choices about what technologies to invest in, whether to seek technological leadership in them, and when and how to license technology. (Porter, 1985)

Noori (1990) has identified four main components in formulating a technology strategy (Table 2). In technology assessment, the company should determine its technological resource capabilities and requirements needed to create a strategic advantage for the firm. An understanding of future technological trends is needed so that decisions can be made in the light of potentially available technologies. The second phase involves decisions on the appropriate form of technology the company should pursue. The link between technological change and competitive advantage should govern the choice of new technology. A firm should choose the technologies that have the greatest sustainable impact on cost or differentiation (Porter, 1985). The third component involves consideration of whether the firm attempts to be the first to introduce technologies or adopts only already proved technologies.

Technology assessment	Assess internal resources in terms of flexibility Assess environmental trends through technology forecasting
Technology choice	What technologies should the firm pursue in the future?
Technological leadership or followership	Should the firm be first in its industry to adopt new technology or wait until new technology is proved by others?
Technology acquisition	How should the firm acquire the technologies that it wishes to pursue (develop or purchase)?

Table 2. Main components of formulating a technology strategy (Noori, 1990).

According to Porter (1985), three factors must be considered when deciding whether or not to pursue a technological leadership strategy: 1) sustainability of technological lead to be gained 2) first-mover advantages 3) first-mover disadvantages. Once a firm decides to pursue a particular technology strategy, it must keep these variables in mind and manage its operations and investments accordingly. Finally, technology strategy should determine whether the company seeks to develop the chosen technologies internally or purchase them from an external source. Internal development might be cheaper, could enhance organizational learning and keep the technological information confidential. On the other hand, external acquisition may be justified if the company does not possess the required skills or resources, wants to save the time and effort or seeks to reduce the risks of internal development. (Capon & Glaser, 1987)

Technology is likely to play a major role in many energy efficiency investments. Difficulties in incorporating new technology to the production process and lack of skilled technical personnel are often significant barriers to energy efficiency investments (Sardinaou, 2008). Companies are also unsure of which technologies should be chosen and lack a coherent overview of existing technologies (Groot et al., 2001). Quantitative financial investment analysis is incapable of recognizing investment's suitability to company's technological capabilities and objectives. By applying strategic compatibility analysis, the company's technology strategy is identified and the investment is evaluated based on its compatibility with the priorities chosen in the strategy. In this way the company can choose the technologies that best support its generic strategy and build sustainable competitive advantages.

5.2.2 External compatibility factors

Besides analyzing the investment's compatibility from the perspective of the company's internal strategic priorities, a comprehensive strategic analysis requires consideration of key external stakeholders. External compatibility factors include the company's customers, suppliers, competitors and regulators. Effects on each external group should be analyzed in order to reflect the investment's implications in the company's overall business environment.

Customers

Competitive advantage grows fundamentally out of the value a firm is able to create for its customers. A firm can create value for its customer through two mechanisms: by either lowering customer's cost or by raising customer performance. There are several ways to lower customer's cost. Besides offering directly lower price, the company can lower the indirect costs of using the product or the cost of product failure. For example, by providing more reliable deliveries, customer's inventory levels can be reduced. The alternative mechanism is to enhance customer's performance, which is highly dependent on the customer's perception of desirable performance. Customers will not pay for value they do not perceive and thus the company must create signals of value to make sure the customer perceives the actual value of the product. Typical signals of value include advertising, product packaging, past experiences and company's reputation. In industrial setting, raising customer's performance can also be based on helping them to meet non-economic goals such as status, image or prestige. (Porter, 1985)

Customer's purchase criteria can be divided into two types: use criteria and signalling criteria. Use criteria stems from the way in which the supplier affects actual customer value by either lowering customer cost or raising customer performance. Use criteria might include e.g. product quality, product features, delivery time and engineering support. The signalling criteria refer to the means by the buyer to infer or judge what the supplier's actual value is. Examples of signalling criteria include advertising, attractiveness of facilities and company's reputation. Both criteria have to be met for the company to be able to price a premium for its product. Addressing the use criteria without also meeting signalling criteria will undermine a customer's perception of value. On the other hand, addressing signalling criteria without meeting use criteria will not usually succeed because customers will eventually realize that their needs have gone unmet. (Porter, 1985) Energy efficiency investments that have effects on product quality may have implications for customer's use criteria. Additionally, efficiency investments providing reductions in emissions or other environmentally healthy effects can enhance corporate image and influence customer's signalling value. However, overall the effects of energy efficiency investments on company's customers are likely to remain rather low.

Suppliers

Porter (1985) identified five competitive forces that determine the ability of a firm in an industry to earn rates of return on investment in excess of the cost of capital: bargaining power of suppliers, bargaining power of buyers, threat of new entrants, threat of substitutes and rivalry among existing firms. Porter's framework provides a solid basis for understanding an investment's implications to suppliers. Figure 10 describes the determinants of supplier power identified by Porter.

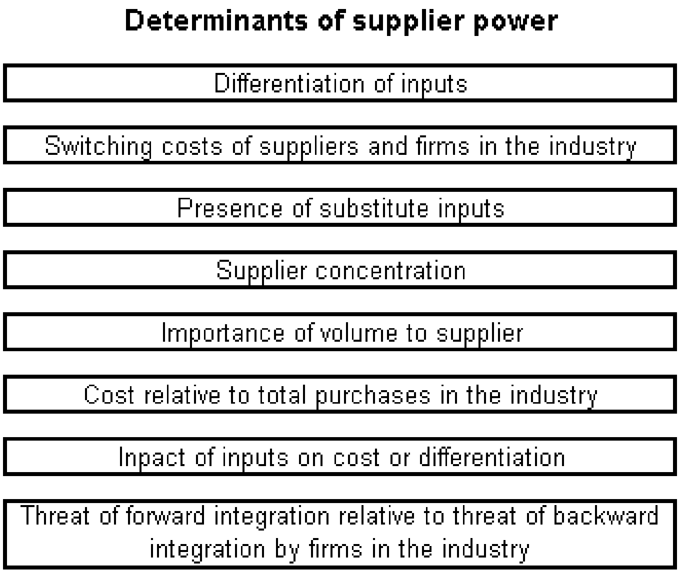

Figure 10. Determinants of supplier power (Porter, 1985)

Basically if suppliers have strong power in the industry, they are able to charge higher prices and set tighter purchase conditions. Therefore the company should maintain its independence over its suppliers to be able to retain a strong position when negotiating with suppliers. In energy efficiency investments the implications to suppliers become especially relevant when the investment has an effect on production inputs. An efficiency investment increasing production volume results in increased need of supply and might add supplier dependence. On the other hand, the investment might involve use of alternative production inputs, such as alternative energy sources, and thus change the company's supplier base significantly. Therefore the investment's effects on supplier power should be analyzed comprehensively in order to understand how they affect the company's competitive position in the industry.

Competitors

Rivalry among existing competitors in the market is one of the key factors determining whether a company can earn excess returns on its investments. Rivalry occurs because one or more competitors feel the pressure or see the opportunity to improve position in the market. Common tactics to improve position include price competition, advertising battles, product introductions or increased customer service. The competitive situation and intensity of rivalry in a market can depend e.g. on the following determinants:

- *Fragmented market:* When there are numerous equal players on the market, firms follow each other closely and tight price control is essential.
- *Concentrated market:* In this situation the market leader/leaders are often able to impose discipline as well as play a coordinative role through devices such as price leadership. However, smaller players may be willing to attack the industry leader.
- *Slow industry growth:* When the industry is growing slowly, the competition often turns into a market share game where players use all tactics to enable growth of their business.
- *High fixed/storage costs:* High fixed costs create strong pressures for firms to fill capacity, which often leads to excess price cutting when excess capacity is present.
- *Capacity augmented in large increments:* When economies of scale dictate that capacity must be added in large increments, there is a significant risk of bunching capacity additions. The industry may face recurring periods of overcapacity and price cutting, which has happened e.g. in the paper industry. (Porter, 1980)

When evaluating an energy efficiency investment, the company should consider its implications to the company's current competitive position in the market. For example, if the market participants are engaged in a tough price war, a cost-saving energy efficiency investment is likely to have a considerable contributing effect to company's competitive position. Additionally, potential entry barriers for new competitors should be considered. Increased economies of scale or acquisition of new, proprietary technology may make it more difficult for new players to enter the market, which ultimately enhances company's competitive position.

Regulators

It is evident that the government regulation of business activities has been increasing dramatically. The costs of complying with regulation are substantial and unpredictable changes in regulation constitute a major source of uncertainty especially for companies operating in the so-called "regulated industries" (Leone, 1977; Birnbaum, 1984). Government regulation can also have implications for competitive advantage. Regulation has often asymmetric impacts on competing firms and thus firms with superior capabilities for adapting to regulatory dictates may attain a position of competitive advantage over their rivals (Leone, 1995). Additionally, regulation is likely to create entry barriers to new firms. For example, environmental regulation may discourage new firm entry through increased capital requirements, added complexity involved in business operations and the expanded difficulties and costs in establishing new facilities (Dean & Brown, 1995). Such barriers enhance the competitive strength of existing market players by decreasing the threat of new potential entrants.

Especially companies' environmental liabilities have grown during the last years, which have resulted in the engagement of proactive corporate environmental management activities (Berry & Rondinelli, 1998). Consequently, pure adaptation to regulatory changes is no longer sufficient but companies must proactively meet the pressures set by their regulatory environment. Energy efficiency investments often provide several environmental benefits and hence they can be justified by the ability to cope with possible changes in environmental regulation. When assessing an energy efficiency investment from a regulatory point of view, the company should consider relative importance of current and prospective regulatory norms, the role of the investment in complying with them and the possible competitive advantage gained by having superior capabilities for adapting to regulatory dictates compared to competitors.

5.2.3 Conclusion

The discussed strategic compatibility factors are summarized in Figure 11. The framework takes into account company's internal strategic objectives as well as demands from the company's external business environment. The use of scorecards or other quantitative methods is recommended in analyzing each compatibility factor to enhance comparability between investment alternatives. An example of a scorecard method is presented in Appendix 6 and applied to the case investment in chapter seven.

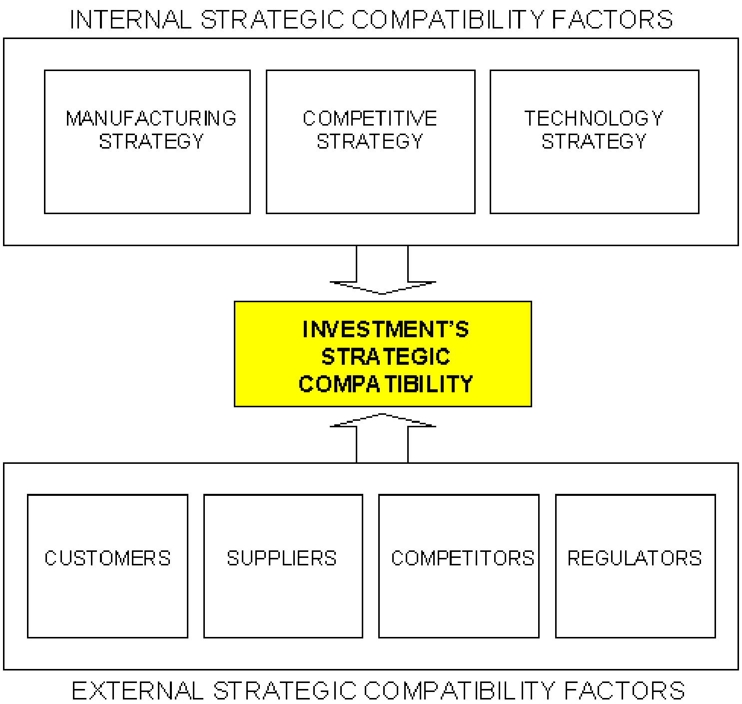

Figure 11. Framework for analyzing strategic compatibility of an investment.

5.3 Integrating financial and strategic analysis

Chapters three and four discussed the financial profitability of an investment by presenting several investment appraisal methods and incorporated risk analysis techniques in investment evaluation. The outcome from this analysis is the financial return of the investment, measured e.g. by the risk-adjusted NPV. This chapter extended the analysis to include the strategic compatibility of the investment by assessing the internal and external compatibility factors. However, the two perspectives cannot be assessed in isolation. To be able to make comprehensively justified investment decisions, financial and strategic analysis need to be integrated into a single framework. Figure 12 shows the financial and strategic investment analysis integration matrix, which can be used to take into account both the financial return and strategic compatibility of the investment. Based on these two dimensions, four investment categories are distinguished in the matrix and decision-making guidelines are given for each.

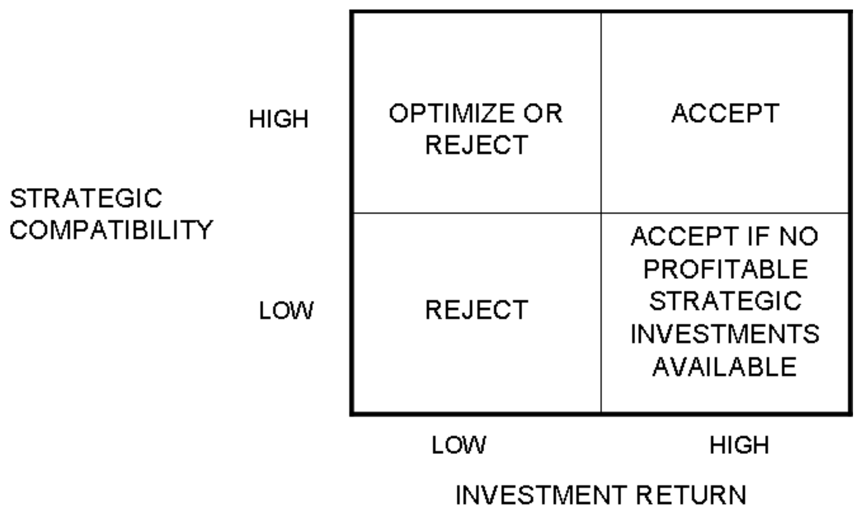

Figure 12. Financial and strategic investment analysis integration matrix.

When the financial profitability and strategic compatibility of the investment are both low, the investment should naturally be rejected. On the contrary, when the investment supports company's strategy and provides high returns, acceptance should be made without hesitation. Investments that are strategically compatible but lack adequate returns should be subjected to optimization. Optimization stands for attempts to increase the benefits or decrease the costs of the investment in order to improve the financial return to an adequate level. If optimization is not possible or does not lead to desired results, the investment should be rejected. High return investments incompatible with the company's strategy should typically be accepted as they increase the wealth of company's shareholders. However, if high return investments that support company's strategy exist, primary emphasis should be given to them as they contribute to the long-term competitive advantage of the company. The matrix is a valuable tool for evaluating a single investment per se but also for making comparison between different investment alternatives. The company should place all manufacturing investments in the matrix to see their relative position in the overall investment portfolio. This would enable a fair comparison between energy efficiency investments and other manufacturing investments.

6. CASE COMPANY PRESENTATION AND METHODOLOGY OF THE STUDY

This chapter introduces the case company of the study and describes the methodology and execution of the study.

6.1 Sachtleben Pigments Oy

In September 2008, Rockwood Holdings Inc. and Kemira Oyj established a joint venture under the name of Sachtleben. The venture was formed by pooling the titanium dioxide (TiO_2) production activities of their subsidiaries, Sachtleben Chemie GmbH and Kemira Pigments Oy. Rockwood Holdings Inc. has an ownership of 61 % of the joint venture and Kemira Oyj owns the remaining 39 %. Sachtleben produces titanium dioxide at two locations in Europe: Duisburg, Germany, and Pori, Finland. Titanium dioxide is used in a variety of markets, such as pharmaceuticals, cosmetics, packaging inks and coatings. In 2007, Sachtleben's sales amounted 555 million euros and the company had 1700 employees. Sachtleben has offices in Duisburg, New York, Shanghai and Helsinki. (Sachtleben, 2009)

The plant in Pori is currently operated under the name of Sachtleben Pigments Oy. The plant mainly produces rutile-based TiO_2 pigments by the sulphate process. The nominal production capacity of the plant is 130.000 tons of TiO_2 pigments per year. In addition to pigment production, there are sulphuric acid plant, water purification and wastewater treatment plants, copperas treatment plant and combined heat and power (CHP) plant at the production site. The CHP plant, owned by Porin Prosessivoima, produces electricity and steam for Sachtleben Pigments' needs as well as to the nearby industrial companies and to the district heating network of Pori.

6.2 Methodology of the study

The research method chosen for the purpose of this study was case study method. Case study is a description of a management situation and involves data collection through multiple sources such as verbal reports, personal interviews and observation as primary data sources. The choice of the research method should depend significantly on the research problem and the purpose of the research. (Ghauri & Groenhaug, 2005) Several factors can be identified that support the choice of case study as a research method for this study. First of all, the explanatory nature of the research question favours case study as a research method (Yin, 2003). Secondly, case study can be seen as preferred method when the research focuses on contemporary phenomenon in real-life context, which is clearly the case in studying energy efficiency investments. Thirdly, the difficulty in quantifying and understanding the phenomenon under study outside its natural setting refers to the suitability of case study as an appropriate research method. (Ghauri & Groenhaug, 2005)

The study can also be methodologically described as normative and constructive by nature, as the objective was to construct a comprehensive understanding of appropriate analysis tools for energy efficiency investment appraisal. The study focused on one specific energy efficiency investment in the case company, i.e. the installation of high pressure tube filters in the calcination section of a production line. The investment was used as a study example to provide the case company recommendations for best practices in analyzing energy efficiency investments, which should be generalized in the whole industry. Malmi et al. (2005) have highlighted the role of normative theories and constructive studies in developing management accounting research. The authors argue that the development and testing of normative theories is likely to produce research having more relevance in practice. Furthermore, constructive studies involve a significant potential of generating directly applicable, yet theoretically informed solutions to practitioners. (Malmi & Granlund, 2005)

Despite its advantages, the case study method has been also criticized in the academic literature. Traditional criticism against case study research stem from a perceived lack of generalizations and academic rigour (Scapens, 1990). The scientific status of case studies has been regarded as low because it has been argued that their findings apply to the studied cases only and cannot be generalized to a larger population (Lukka & Kasanen, 1995). However, Lukka et al. (1995) have argued that case studies and statistical studies are not that far from each other in terms of generalizability because considerable amount of real-world knowledge is needed to gain both generalizable and substantially relevant results. The analysis tools developed in this study are naturally created based on the needs of the case company but their general nature should enable their application also in other companies making energy efficiency investment analysis.

Scapens (1990) has identified three common problems in case study research. First, there is often a difficulty in drawing boundaries around the subject matter of the case. In the study this problem was addressed by limiting the scope of the study on investment analysis techniques and applying them to one specific investment. The second problem deals with the social reality being researched and the difficulty in making objective interpretations of the social system. The use of objective analysis techniques can be seen as a factor that decreased the effects of researcher's subjective interpretations and thus strengthened the objectivity of the study. The final difficulty stems from the fact that case studies require access to organizations and to confidential information. The researcher might therefore lack access to relevant information or damage relationships with the case company if confidential information is released. The research project was bound by a confidentiality contact in order to ensure open cooperation with the case company. (Scapens, 1990)

6.3 Execution of the study

The investment to be evaluated for the purpose of this study is the installation of high pressure tube filters to replace rotary vacuum filter of another production line in the calcination process. In the study several key executive personnel influencing energy efficiency investments in the case company were interviewed, including Senior Vice President, Energy Director, Technical Director, Financial Director and recently appointed Controller. Additionally, the Chief Executive Officer of the company was interviewed due to his considerable influence on investment approval. The purpose of the interviews was to establish an understanding of the state of energy efficiency investment appraisal in the case company and analyze the applicability of different investment analysis tools to the specific tube filter investment. The case company's investment proposals and instructions were also analyzed in developing investment appraisal methods. The objective was to use the tube filter installation investment as a concrete study example in order to provide results that can be generalized in the whole industry.

7. EMPIRICAL RESULTS AND DISCUSSION

7.1 Energy efficiency investment appraisal in the case company

7.1.1 Importance of energy efficiency

Sachtleben Pigments operates in the highly energy-intensive process industry, where energy costs comprise a substantial amount of total production costs. At the moment the annual energy costs of the company equal approximately 40 million euros, which represents a share of 25 % of the company's total production costs. The importance of energy efficiency becomes clear from a quote of the company's Financial Director:

> "Energy efficiency is definitely an issue which is strongly emphasized and followed in our organization as energy represents such a high proportion of our total costs." (Financial Director, 22.1.2009)

The Chief Executive Officer also recognizes high importance of energy efficiency in the whole industry:

> "Especially in Europe where energy costs are high, energy is of big importance and also our competitors have to have an eye on that. The one that manages energy efficiency best has a clear advantage in the market." (Chief Executive Officer, 27.5.2009)

Despite the various investments in energy efficiency, the company's energy costs have been constantly increasing due to increases in production capacity and energy prices. The energy consumption of TiO_2 pigment production at the plant site is 42 GJ/t (YVA, 2007). Primary energy sources used by the company are electricity, steam and propane. Steam and most of electricity are bought from Porin Prosessivoima (PPV), which is a non-profit organization selling energy at lower price than market actors. The power plant owned by PPV is located at the plant site, which uses peat, wood chips, recovered fuel, coal and oil to produce high-pressure steam for the needs of Sachtleben Pigments. Propane is acquired from Neste Markkinointi Oy, which supplies the gas by road transport to bunkers situated nearby the plant. The distribution of company's energy costs between different energy sources in 2005 is shown in Table 3. Propane represents the largest share of total energy costs, which has drawn attention in the company to a more efficient use of propane in the production process.

Energy source	%
Coal	18,2 %
Sulphur	6,9 %
Oil	15,1 %
Propane	39,1 %
Electricity	20,7 %
Total	**100,0 %**

Table 3. Energy procurement of Sachtleben pigments in 2005.

Sachtleben Pigments has signed the Energy Efficiency Agreement in Industries for the term 2008-2016, which obligates the company to reduce energy use by regularly identifying and implementing energy saving measures (EK, 2009b). The plant had participated also in the preceding Energy Saving Agreement program (1998-2007) as Kemira Pigments Oy. In order to meet the objectives for energy efficiency, the company has had an energy saving program since 1995, which has decreased the energy consumption per ton of pigment by 25 %. Energy efficiency is being measured with energy efficiency index (Figure 13), in which year 2005 has been set as new reference year for comparison.

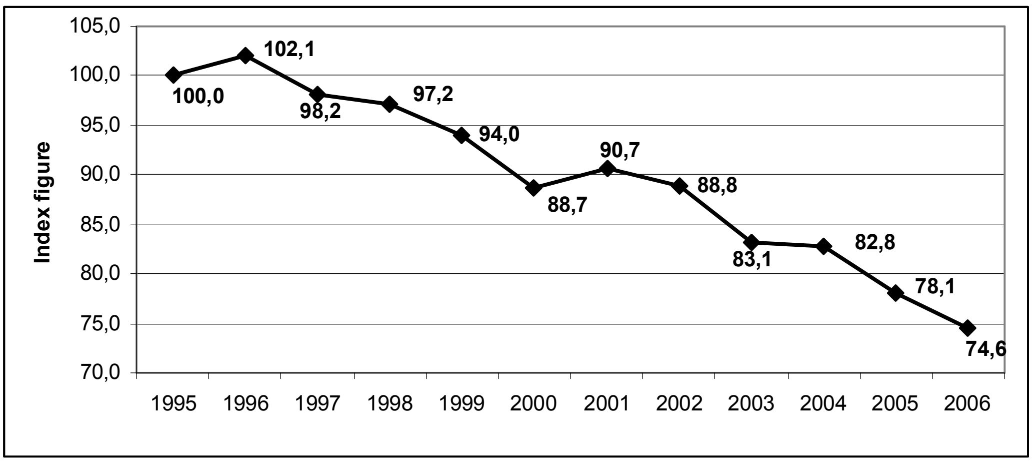

Figure 13. Development of energy efficiency index at Sachtleben Pigments Oy.

Improvements in the index figure depend significantly on the amount of energy efficiency investments implemented. On average a quarter of the company's total investments have been energy efficiency investments. A target level for the energy efficiency index is being set annually and reduction in the index figure is an essential goal for management. Energy efficiency is also being used as one basis for worker compensation and there is an ongoing planning on the possible ways to motivate workers on the operative level for more efficient use of energy.

7.1.2 Investment process

Every five years the company has conducted an energy analysis by using external consultants, in which the plant is reviewed by each process stage and the most prominent investment opportunities for improving energy efficiency are identified. The analysis is based on the Energy Efficiency Agreement in Industries and is partly subsidized by the government. The most recent analysis was conducted in 2006, which identified a total of 40 possible investment opportunities including process and equipment changes at various stages of the production process. The identified investment opportunities are subjected to initial profitability screening in order to determine the projects that should be taken further. Historically over half of the identified investment opportunities have been realized. The opportunities that have not been realized have typically not met the financial criteria or there has been a lack of appropriate technology for implementation. The unrealized projects are still being followed and reviewed in case of changes in their feasibility occur.

When an investment project has been selected in energy analysis for further processing, process development is responsible for preparing the investment proposal. Production engineers, Energy Director and project implementation team also participate in the preparation of the investment proposal. Surprisingly, the finance department has not traditionally been actively involved in the company's investment process. However, due to the establishment of joint venture, from the beginning of March 2009 a Controller has been responsible for the financial calculations in the investment planning process. The role of the new Controller is also to provide financial insight and criticality to the investment planning process:

> “Besides pure profitability calculations, I see my role in the investment process as an objective questioner. As people tend to become attached to investment projects, it is important that there is an unbiased person challenging the key assumptions behind the financial figures.” (Controller, 14.5.2009)

Typically the preparation phase takes time of one to six months. Ultimately the preparation group makes the decision of whether the investment will be proposed to the board of directors. Senior Vice President proposes the investment to the board, which consists of three members: Chief Executive Officer, Chief Financial Officer and Chief Commercial Officer of the company. The purpose of the board is to challenge and question the investment proposal, which sets high demands for the proposer to be able to make credible justifications and answer critical questions about the investment. Investments having especially high monetary value are proposed to the board of Rockwood Inc.

7.1.3 Decision-making criteria

The primary justification in the company for an energy efficiency investment is always financial; the investment project is conducted to save energy and improve the financial position of the company. In the preparation stage an Excel-form is being used that calculates the payback period, net present value and internal rate of return of the investment. The payback period method has a dominant role in decision-making. The payback requirement depends on the company’s financial situation; typical payback requirement for energy efficiency investments has been three years. Investments with higher paybacks are not usually considered further as the board’s general attitude towards such projects is negative:

> “In some cases there has been consideration of proposing an investment not meeting the payback requirement if the investment’s financial yield has been particularly high. However, the basic rule has been that such projects are not even worth proposing due to the general pessimism they face on the board.” (Energy Director, 22.1.2009)

The Chief Executive Officer appreciates the use of payback criterion as an initial screening tool for energy saving projects:

> "The payback criterion is a quick method that gives you a hint of whether the project makes good economic sense or not. If the payback period is highly unattractive, I would not consider the project further. If it's at adequate level, we will then take a deeper look at the project." (Chief Executive Officer, 27.5.2009)

The strict attitudes towards energy efficiency investments compared to other manufacturing investments are perceived eccentric by the company's Energy Director:

> "It seems odd that the criteria for energy efficiency investments are so tough. If you consider investments in producing new energy, the payback requirement might be 15 years. Now we are rejecting energy saving projects with paybacks of 3 years or higher. These two investment types are understood completely differently but I see no justification for unequal treatment." (Energy Director, 22.1.2009)

The Controller argues that the popularity of the payback period method stems at least partly from the fact that it is such a simple and easily understandable method:

> "Corporate managers still find NPV difficult to understand and prefer payback period as a concrete measure of investment profitability." (Controller, 14.5.2009)

The company classifies investment projects into three categories, which determines the required rate of return of the investment. First category is called "mandatory and maintenance" and pure energy efficiency investments have typically fallen into this category. The discount rate in NPV method applied to these projects has been 7 %, which is the weighted average cost of capital (WACC) of the company. Investments in the second category, "improvement", have a required rate of return of 10 % and the category has typically included capacity investments but also some of the energy saving projects. The third category, "new business", involves investments that radically change the nature of the business and therefore a discount rate of 13 % is applied in such projects; this category has not involved energy efficiency investments. The investment calculations are supported by sensitivity analysis, which considers energy price risk by examining the investment's profitability in a few price scenarios. Other risk analysis techniques are not being used in investment appraisal.

For the energy efficiency investments that derive from energy analysis, a government subsidy can be applied, which typically equals 10-15 % of total investment cost. The application has to be made after final investment approval but prior to the project implementation. As the subsidy is not paid until the equipment is fully in use and there is uncertainty involved in whether it's obtainable, the company has preferred not to include government subsidies in investment calculations.

Energy efficiency investments are also justified by other factors than their pure financial impact. All investment proposal forms include a section called "environmental impact", which describes the investment's possible effects on e.g. emissions and waste load. Some investment's have also been justified by safety factors or working conditions. Future outlooks and strategic considerations are also indirectly influencing investment appraisal:

> "Strategic planning may also have an impact in assessing and justifying an investment. Issues to be considered might be e.g. the future of energy sources, objectives for discharge level, worldwide trends and image issues." (Senior Vice President, 22.1.2009)

Despite the use of strategic planning in the process, the Chief Executive Officer views many of the energy efficiency investments as non-strategic:

> "Many of our energy efficiency investments are non-strategic in nature; that does not mean that they are not important but it means that they are driven by short-term thinking to save costs." (Chief Executive Officer, 27.5.2009)

Controller argues that the operative nature of energy efficiency investments generally weakens their ability to compete with other manufacturing investments:

> "Energy efficiency investments do not often do well in strategic evaluation, which means that they have to compete solely with their financial impact. Because of this, other more strategic investments outperform them in investment appraisal." (Controller, 14.5.2009)

The weak link between energy efficiency investments and corporate strategy might result from a lack of strategic evaluation tools. At Sachtleben Pigments, no systematic procedures are being used to evaluate qualitative issues and possible strategic implications of an investment. Consequently, financial figures play a key role in decision-making and as long as the other justifications cannot be quantified, their impact on final decision remains fairly limited:

> "It's the figures that count whether the investment will be accepted or not. Only in the case of mandatory environmental investments, qualitative justifications might have an impact." (Energy Director, 22.1.2009)

7.1.4 Perceived risk factors

The realization of energy savings from energy efficiency investments is often highly uncertain. Most uncertainty is related to fluctuations in energy price. An investment perceived highly prominent can turn out to be unprofitable in a different price scenario. On the other hand, an investment that would have yielded high returns may become rejected in the planning phase if the financial evaluation shows low returns with energy prices of that time. As the planning and installation of energy saving equipment usually takes one year at minimum, the ability to forecast future energy prices becomes crucial for making successful energy efficiency investment decisions. In one worst case scenario in the company's history the investment cost had doubled from planned amount and at the same time the price of energy had halved. This made the initially prominent investment extremely unprofitable.

The Chief Executive Officer highlights the unpredictability of political decisions as a key factor affecting energy price risk:

> "For example, in Germany during the last eight to nine years the energy price has tripled and one third of this price increase is only based on political decisions: energy taxes, CO_2 emissions etc. These political decisions are unpredictable and therefore you can never reliably forecast the development of energy price." (Chief Executive Officer, 27.5.2009)

Due to its unpredictability, the Chief Executive Officer emphasizes the role of strategic planning rather than financial modeling in managing the energy price risk:

> "I think that energy price risk is not a matter of financial calculations; it is a matter of strategic decisions. You have to base your energy portfolio on a mix of primary energy sources, which makes you to a certain extent independent from one source." (Chief Executive Officer, 27.5.2009)

The choice of technology represents another risk factor. In order to decrease the technology risk, the company prefers to choose such technology that has already been widely used by other companies in the industry. An extremely high risk is related to being the first in the world to introduce new technology and consequently such an approach is not preferred by the company. Energy savings are also influenced by possible production cuts as the variable energy cost savings do not fully materialize at lower levels of production. However, due to the capital intensiveness of the business, the main objective of the company is to operate at full capacity at all times. Additionally, changes in governmental regulation, such as energy taxes, is another risk factor that can significantly alter the profitability of energy saving projects.

7.1.5 Conclusion

The high amount of energy costs indicates that energy efficiency is clearly an important matter in the case company and the most effective way to improve the efficient use of energy are energy efficiency investments. However, the dominant use of the payback period method with extremely tight payback thresholds has discriminated energy efficiency investments in the company's investment planning process. It is likely that the popularity of payback method in the case company stems at least partly from the perceived risk of energy efficiency investments. The uncertainty related to realization of energy savings is now treated in a simplistic, risk-aversive manner, which ignores the investment's potential upsides and limits the perceived opportunities for energy saving projects. It can also be questioned if the discount rate should be determined by using strict investment categories instead of analyzing the risk of each investment project individually.

Another problem is that qualitative justifications and strategic implications have minor influence on investment decision despite their considerable significance. The enhancement of qualitative and strategic issues in investment appraisal might provide fair comparison between energy efficiency and other manufacturing investments:

> "The main problem is that our investment evaluation criteria in use are not treating energy efficiency investments and other manufacturing investments equally. If there would exist some other grounds for energy saving projects, it would be easier to justify them to decision-makers." (Energy Director, 22.1.2009)

The Controller of the company confirms that the discrimination of energy efficiency investments stems from the lack of appropriate analysis tools:

> "I believe that companies are generally better at evaluating the financial impacts of capacity investments than energy efficiency investments. It is not a question of intentional discrimination; if the benefits of energy efficiency

investments cannot be reliably expressed in investment calculations, they will not become accepted.” (Controller, 14.5.2009)

It can be concluded that more sophisticated and comprehensive investment analysis tools can enable a fair comparison between energy efficiency investments and other manufacturing investments in the case company. The sources of investment risk, such as fluctuating energy prices, should be modeled by using risk analysis techniques instead of applying tight payback requirements. A comprehensive strategic perspective should be included in the investment evaluation to place value for investment compatibility with strategy and investment’s qualitative effects. When all the company’s manufacturing investments are evaluated by using this kind of approach, equal treatment of different types of investments is possible and the most profitable investments are eventually chosen. In the following section this approach will be applied to a specific energy efficiency investment in the case company to illustrate its implications.

7.2 Analyzing an energy efficiency investment

7.2.1 Description of investment

One of the most energy intensive process stages in TiO_2 pigment production is calcination. In the calcination process, the hydrated titanium dioxide slurry is first filtered and then fed to a calcination kiln, where it is fired directly by a gas burner in countercurrent flow. Sachtleben Pigments has five kilns in the calcination section and there is a filtration process for each (Figure 14). Traditionally the feed slurry is filtered by a rotary vacuum filter but in recent years the company has introduced high pressure tube filters (tube presses) for two production lines, 21 and 31. The investment under evaluation is the installation of high pressure tube filters in production line 41. Installation of high pressure filters is an investment directly affecting the energy efficiency of the calcination process. By installing high pressure tube filters, the solids content of the feed slurry can be raised to 65 % from 40 % achieved by rotary vacuum filter. The corresponding saving in propane consumption is assumed to equal 0.74 MWh/t TiO_2, which is an immense 52 % improvement in energy efficiency based on the kiln’s energy efficiency index.

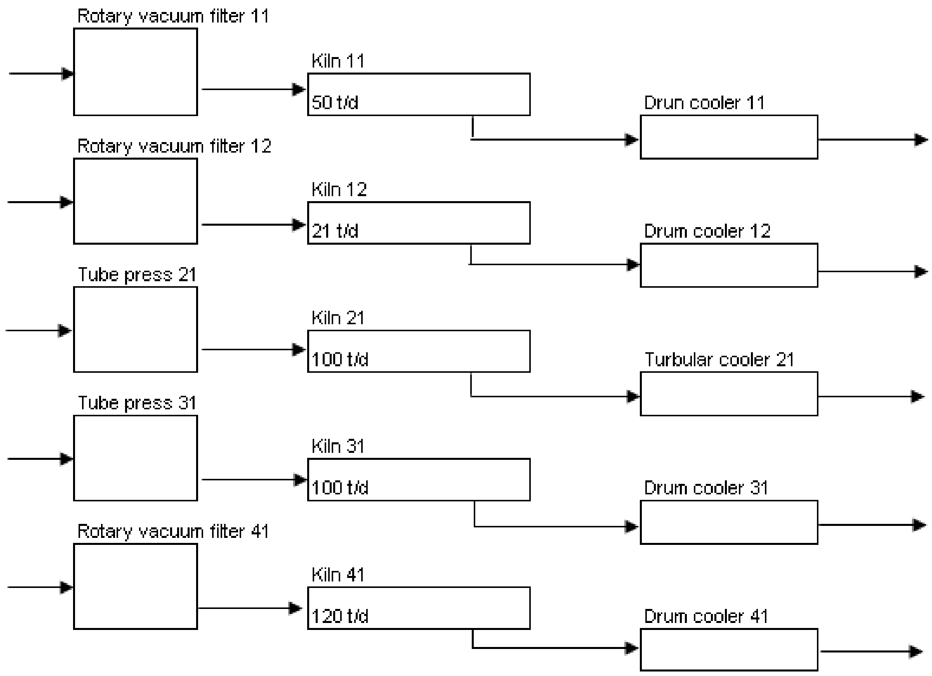

Figure 14. Calcination process at Sachtleben Pigments (Laitinen & Honko, 2008).

The investment enables approximately 25 % increase in the maximum throughput of the kiln (120 t/d → 150 t/d). To meet the capacity increase, a more efficient cooler is required for the kiln. Additionally, the increase in throughput of kiln 41 would make the production line 11 redundant, which has the highest SEC (i.e. lowest energy efficiency) among all lines.

Besides lowering propane consumption, the investment also causes changes in electricity consumption. High pressure tube filters consume more electricity than rotary vacuum filter but on the other hand, electricity is also saved by turning off the production line 11. The same goes for maintenance costs; maintenance requirements of high pressure filters are higher than that of rotary vacuum filter but the maintenance savings from line 11 practically offset its effects. Additionally, the amount of CO_2 emission through off-gas is reduced as a result of reduction in propane consumption.

7.2.2 Profitability calculation

Quantifiable effects of the investment are summarized in Table 4. The utilization rate used in the calculations was 90 %. The initial investment costs include the equipment and installation costs of tube filters as well as the required cooler for production line 41. Possible effects of government subsidy are not considered in the calculations. The total investment cost equals 9.9 million euros. Propane savings comprise of lower propane use in line 41 and propane savings from shutting down the production line 11. Electricity savings equaled the savings from shutting down the production line 11; higher electricity consumption of tube filters was assumed negligible. Energy prices were estimated based on current price levels; price of propane was assumed 40 €/MWh and electricity 50 €/MWh. The increase in the maintenance cost of tube filters is almost compensated by the reduced maintenance from shutting down one production line. The total estimated annual savings of the investment equal slightly below 2.5 million euros.

Estimated costs of investment	**€**
High pressure filters (incl. installation, building works)	-8 000 000
Revolving shell-and-tube cooler (incl. Installation, bulding works)	-1 900 000
Turning off of calcination line 11	0
Total investment cost	***-9 900 000***
Estimated changes in operating margin	**€/a**
Propane savings	**2 429 192**
Calcination line 41	604 703
Calcination line 11	1 824 489
Electricity savings	**85 000**
Calcination line 11	85 000
Maintenance, utilities etc.	**-17 500**
Calcination line 41 Maintenance and utilities of HP filter compared to RV filter	-175 000
Calcination line 41 Annual saving in revision costs	25 000
Calcination line 11 Maintenance and utilities (incl. revision costs)	132 500
Total changes in operating margin	**2 496 692**

Table 4. Estimated costs and changes in annual operating margin of the tube filter investment.

Based on the above data, the profitability of the investment was calculated by using common investment appraisal methods: payback period, net present value (NPV), internal rate of return

(IRR) and profitability index (PI). The results of profitability calculation and calculation assumptions are summarized in Table 5.

PROFITABILITY RESULTS	
Payback period	4,0 years
NPV	7 398 748 €
IRR	21 %
PI	1,75
Calculation assumptions	
Evaluation term	10 years
Discount rate	7 %
Residual value	0 €

Table 5. Profitability calculation results and used assumptions.

Calculations were based on operating margin before tax. The economic lifetime of the investment was assumed ten years and a discount rate of 7 % was used. Residual value of the equipment was assumed zero. With the applied assumptions, the net present value of the investment is over seven million euros. Based on basic NPV calculation, the investment should hence be definitely accepted. However, as shown above, the result was obtained by making several assumptions about energy prices, equipment costs and other critical variables. Therefore it is critical to examine the investment's risk and sensitivity of investment return to changes in those variables. In the next section, different techniques for assessing and responding to investment's risk are examined.

7.2.3 Application of risk analysis techniques

Adjusting the payback period

As discussed in chapter four, the simplest method to cope with investment risk is to require shorter paybacks for riskier projects. A common payback requirement for energy efficiency investments at Sachtleben Pigments is three years, which means that the tube filter investment with a payback period of four years would be rejected by using this criterion. When considering the fact that the profitability calculation indicated an expected return of over seven million euros, the strict payback criterion seems unreasonable. The use of such a tight payback threshold would also require further risk analysis procedures to justify that the investment truly is riskier than average. By applying the payback requirement, the investment's sources of risk remain unrecognized and an actual understanding of the extent of uncertainty cannot be captured.

The main problems with the payback method in analyzing the tube filter investment are illustrated in Figure 15. Firstly, the tube filter investment can be considered exceedingly long-term in nature; the benefits of greater process efficiency are likely to last at least ten years or even longer. Overemphasizing near-future cash flows and unrecognizing the whole investment period can be hence considered especially weak in this kind of investment having long-term impacts. Secondly, the payback period method assumes a stable environment as the calculation is based on single estimates of investment variables. However, when considering the fluctuating energy prices, the investment's cash flows are highly unlikely to remain at a stable level. The payback period fails to acknowledge the extent of uncertainty related to variance in investment's cash flows, which leads to ignorance of potential downsides and upsides in investment return. When also taking into account that the current energy prices used in calculations are at historically low levels, it can be concluded that the adjusted payback method as risk analysis technique clearly underestimates the return of the tube filter investment.

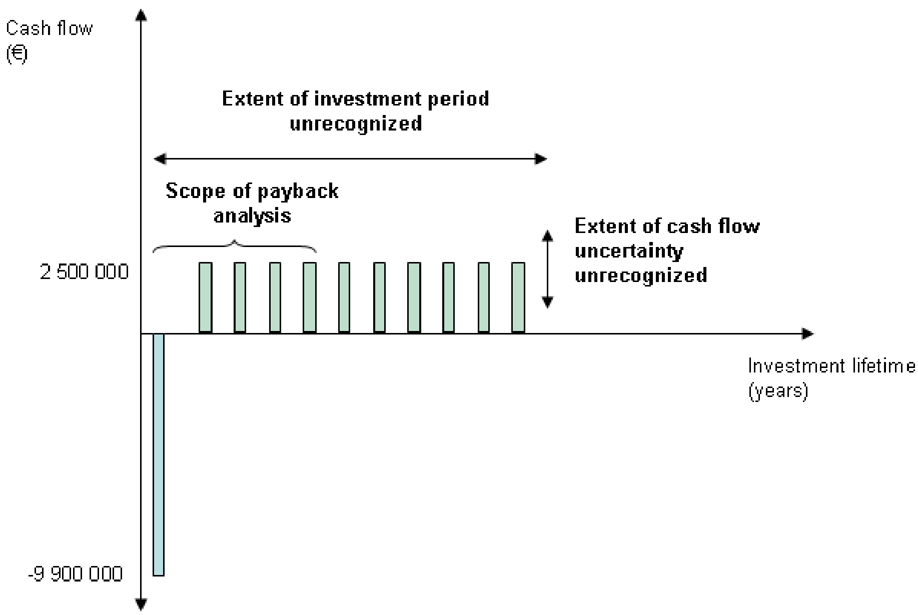

Figure 15. Main problems with payback method in analyzing the tube filter investment.

Adjusting the discount rate

It was concluded in chapter four that energy efficiency investments should earn a discount rate equal to or even lower than the company's cost of capital. The weighted average cost of capital (WACC) applied at Sachtleben Pigments is 7 %, which has been used in evaluating many energy efficiency investments. For capacity investments, the required rate of return has been 10 %. Thus, when it comes to NPV analysis, the company has perceived energy efficiency investments as average risk-projects and less risky than capacity investments.

The tube filter investment is a pure energy efficiency investment; i.e. it does not increase total production capacity. The investment lowers variable costs of energy, which means that it basically has the same risk characteristics as a capacity investment. The company cannot produce more than market demand and therefore the investment return is similarly market-dependent as the return of a capacity investment. For this reason there is actually no justification for applying lower required rate of return to it than to capacity investment. However, if we consider the current low interest rate level and the fact that previous two tube filter investments turned out very profitable, the low discount rate of 7 % seems suitable.

The possible effects of adjusting the discount rate on investment NPV are shown in Table 6. The calculation shows that even with a considerably high required rate of return of 15 % the investment remains profitable and provides a return of over 2.4 million euros. The calculations strongly support the investment as it appears highly profitable even in a high-risk scenario.

Discount rate	5 %	7 %	9 %	12 %	15 %
Investment NPV	9 137 308 €	7 398 748 €	5 890 291 €	3 980 474 €	2 409 833 €

Table 6. Effects of discount rate adjustment on tube filter investment return.

The benefits of discount rate adjustment as a risk analysis tool are that it doesn't take much effort and its implications are rather easily understandable. However, the method has its limitations (Figure 16). Firstly, it can be questioned if the discount rate is truly capable of reflecting the risk characteristics of the tube filter investment. The discount rate does not distinguish different types of cash flows and their individual risk characteristics. By solely adjusting the rate the perspective to investment risk remains fairly limited.

Secondly, the method takes the assumptions made in the profitability calculation as granted. If the profitability calculation is based on overoptimistic assumptions, the corresponding cash flows are likely to be overestimated. In such case even an overly high discount rate isn’t adequate in turning the project’s NPV negative. Thirdly, investment flexibility is ignored in pure NPV calculation. The possible new possibilities provided by the investment and the flexibility in its implementation are not considered by just examining its direct cash flow effects. Solutions to overcome these problems include cash flow adjustment, simulation analysis, sensitivity analysis and real options, which will be discussed in the next sections.

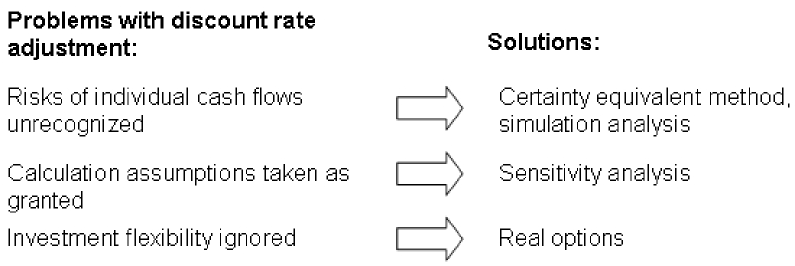

Figure 16. Problems with discount rate adjustment and solutions.

Adjusting cash flows

Instead of reflecting the investment risk in the discount rate, the cash flows can be adjusted based on their riskiness and thus the risk-free rate can be used as a discount rate. This approach requires identification of separate investment cash flows and their corresponding risks. Figure 17 depicts the key cash flows and underlying risks behind these cash flows. The investment costs consist of equipment and installation costs, which are highly dependent on the supplier of the equipment and its pricing power. Energy savings derive from three variables: energy price, utilization rate and investment lifetime. Maintenance cash flow results from both additional maintenance costs of kiln 41 and maintenance savings of kiln 11. When assessing the riskiness of each cash flow, the likelihood of occurrence of the risk factors should be analyzed.

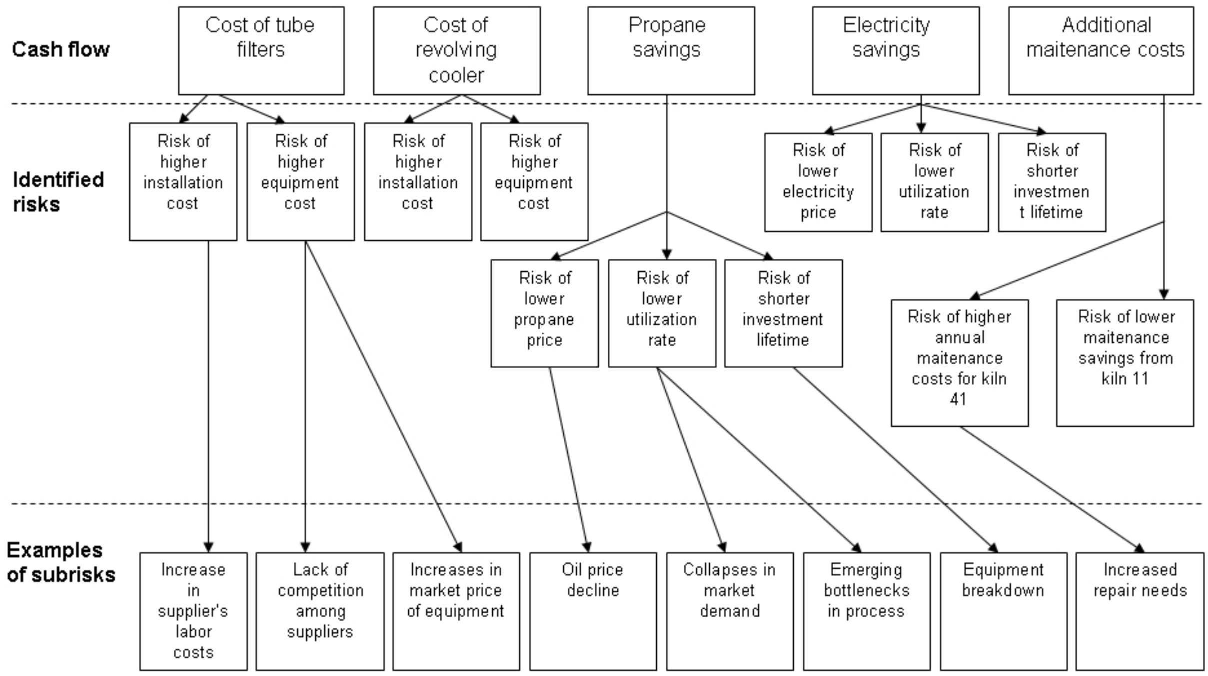

Figure 17. Identification of individual cash flows and risks of the tube filter investment.

Certainty equivalent method has been considered in the academic literature as a favorable technique in adjusting investment's cash flows. The method is implemented by converting each risky cash flow into its certainty equivalent amount, which is the amount of money the decision-maker would just be willing to accept instead of the risky amount. However, the Energy Director of the company did not perceive the certainty equivalent method suitable for analyzing the risk of the tube filter investment. The risk related to energy savings is not solely negative; there is also a considerable positive risk involved, i.e. that energy prices will rise and savings will increase. Therefore it seemed unreasonable that by reducing the cash flows to certain level the risk would somehow be removed. As energy prices are expected to rise in the long run, the potential upsides would totally be ignored by just reducing the expected cash flows to a so-called lower "certain level". Additionally, the determination of certainty equivalent factors seemed highly vague and thus the correctness of the results would have been extremely questionable. Consequently, the certainty equivalent method was not further considered in analyzing the risk of the tube filter investment.

Sensitivity analysis

The risk identification conducted in the previous section showed that the profitability of the tube filter investment is dependent on several variables and the variables are subject to different types of risks. Sensitivity analysis is a useful tool in understanding which variables bear the highest risk and how critical they are in determining investment profitability. In the first step of sensitivity analysis, key investment variables should be identified and pessimistic, most likely and optimistic values estimated for them (Table 7). The estimations of variable values were made by the Energy Director of Sachtleben Pigments and they were basically based on his past experience and professional judgment.

Variable	Pessimistic estimate	Most likely estimate	Optimistic estimate
Installation of high pressure tube filters (€)	9 600 000	8 000 000	6 400 000
Installation of revolving shell-and-tube cooler (€)	2 280 000	1 900 000	1 520 000
Additional maintenance costs (€)	21 000	17 500	14 000
Utilization rate (%)	60 %	90 %	95 %
Investment lifetime (years)	7	10	15
Price of propane (€/MWh)	30	40	60
Price of electricity (€/MWh)	37,5	50	75
Discount rate (%)	12 %	7 %	5 %

Table 7. Possible values of key investment variables of the tube filter investment.

Based on the variable values, series of project NPV's were calculated by setting one variable at its pessimistic or optimistic value while holding the others constant. The results from the sensitivity analysis are illustrated in Figure 18. The analysis shows that propane price is clearly the riskiest investment variable; at its pessimistic value the investment NPV falls down to less than 4 million euros where as at its optimistic value the NPV can rise above 16 million euros. Other risky investment variables include utilization rate and investment lifetime. Price of electricity, additional maintenance costs and installation of revolving shell-and tube-cooler have extremely minor influence on investment profitability; the NPV holds rather constant despite of changes in these investment variables. One of the strengths of sensitivity analysis is the possibility to discover reasons why the investment project might fail. Figure 18 indicates that basically four variables can have strong negative influence on investment NPV: utilization rate, propane price, investment lifetime and discount rate. However, none of these variables is solely risky enough to turn the project NPV negative.

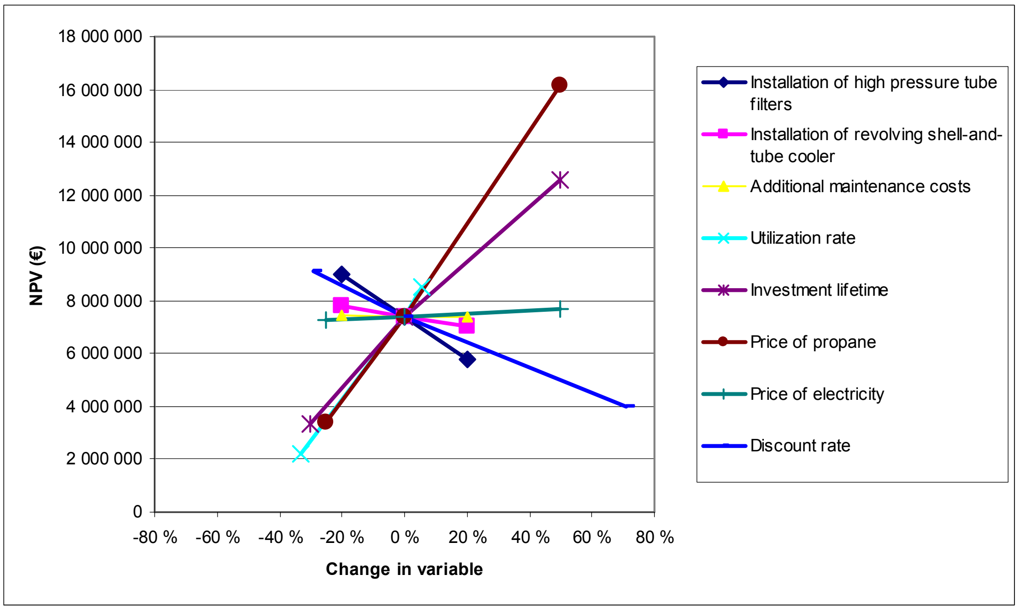

Figure 18. Sensitivity of investment variables to tube investment return.

The riskiness of investment variables is further depicted in Figure 19. The figure shows the range of NPV for each variable; i.e. the difference between optimistic and pessimistic NPV value of each variable. The figure illustrates more clearly the relative importance of each variable. Price of propane is clearly the variable that causes largest variance in investment NPV.

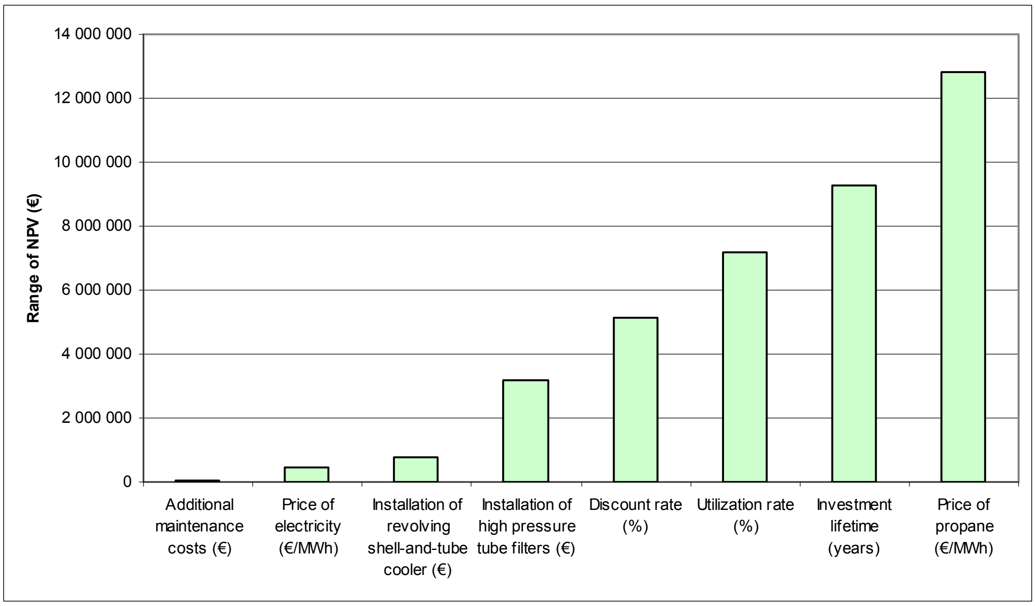

Figure 19. Range of NPV of each tube filter investment variable.

It is also notable that even though utilization rate is more sensitive variable in nature than investment lifetime (the slope is sharper in Figure 18), the range of NPV is higher for investment lifetime because the effects of utilization rate on investment NPV are mainly negative.

Additionally, as suggested by Hull (1980), the combinations of pessimistic, most likely and optimistic variables were calculated (Figure 20). Two main conclusions can be derived from the results. Firstly, the risk involved in the investment is considerably high; the investment NPV can range from a loss of over 6 million to a return of over 33 million euros. The second conclusion is that most of this risk is fortunately positive; the upside in investment return is substantially higher than downside. Figure 18 illustrated that most of this positive risk is derived from two variables: propane price and investment lifetime.

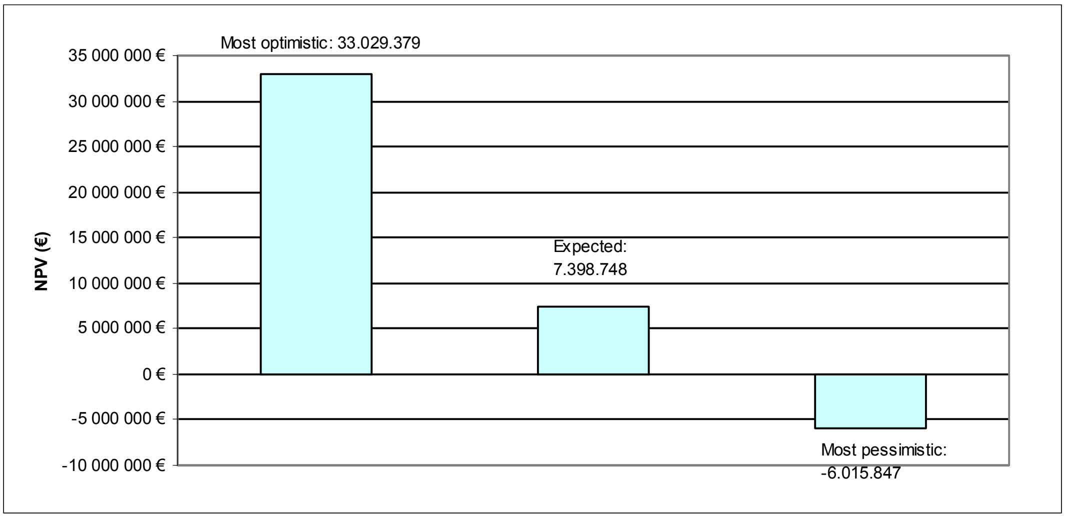

Figure 20. Most optimistic, likely and pessimistic scenarios for the tube filter investment.

As a conclusion, sensitivity analysis identified the riskiest investment variables and also showed that the investment return is subject to both high negative and positive risk. Overall the results were prominent as none of the variables was solely risky enough to turn the project NPV negative. However, the method has its weaknesses, which considerably deteriorate its implications to final investment decision-making. The analysis did not take into account all the possible combinations of variables and lacked the consideration of probabilities. Simple optimistic and pessimistic values can be considered inadequate in describing the behavior of different investment variables. Additionally, optimistic and pessimistic investment NPV's are hardly appropriate as clear-cut decision-making rules. Rather, information about the likelihood of different return scenarios would be needed in order to assess the magnitude of investment risk. By knowing the probability of investment failure the company could make the investment decision based on attitudes and preferences towards risk. Such an approach can be taken by using Monte Carlo simulation analysis, which will be applied next in analyzing the tube filter investment.

Monte Carlo simulation

The previous risk analysis tools provided valuable insights but still a comprehensive view of the tube filter investment's risk was not attained. Monte Carlo simulation might address this problem by considering the entire range of outcomes and their probabilities. In the first stage of the method, a forecasting model should be prepared. In this case study a basic NPV model was used as a forecasting model, which included all the cash flow components identified already in Table 4 of section 7.2.2. In the second stage the model's risk variables were selected. Based on sensitivity analysis, propane price, utilization rate, cost of high pressure tube filters and cost of revolving cooler were selected as risk variables. In order to assure the validity of the results, the investment period was assumed stable and investment lifetime was not included as risk variable.

In the next stage the probability density functions for the risk variables were generated (Figure 21). All other variables were assumed to vary according to normal distribution except for utilization rate, in which an exponential distribution was applied. Propane price probability function was based on historical data from past 5 years; other distributions were developed based on the company's energy director's subjective assessment. The subjective distributions were generated in line with sensitivity analysis assumptions so that approximately 2 % of observations fell beyond the pessimistic and optimistic estimates for variable values. Correlation between variables was assumed non-existent.

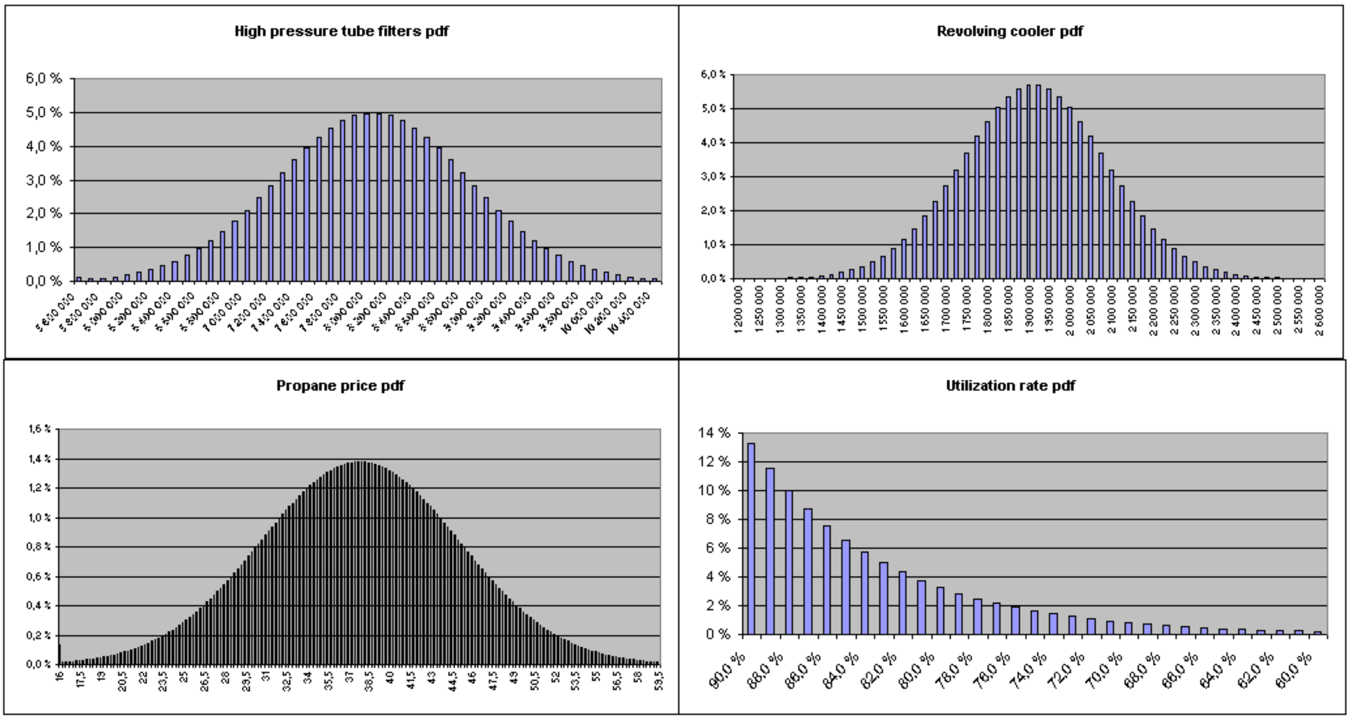

Figure 21. Probability density functions of tube filter investment risk variables.

The generated probability functions were then used to run the simulation. The simulated NPV's were calculated with a risk-free rate of 3.5 %. At 500 simulation runs the expected NPV still varied greatly and therefore a total of 10.000 simulation runs were conducted to enhance the accuracy of the results. The results are depicted in the form of normal distribution in Figure 22.

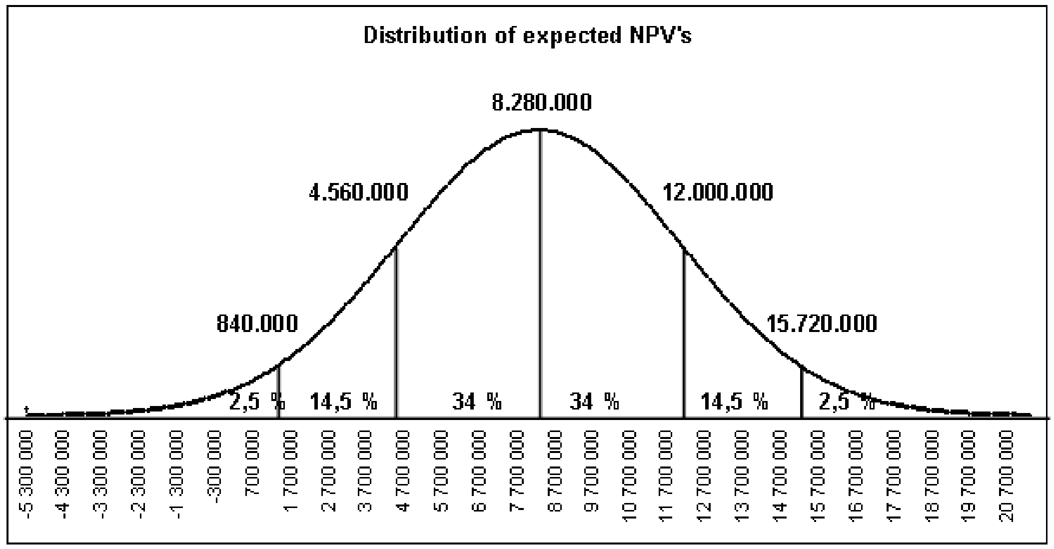

Figure 22. Probability distribution of expected NPV's for the tube filter investment.

At 10.000 runs, the expected NPV of the tube filter investment varies between 8.200.000 and 8.400.000 euros and standard deviation of NPV varies between 3.600.000 and 3.800.000 euros. At a probability of 68 % the investment NPV will turn out somewhere between 4.560.000 and 12.000.000 euros. There is an approximately 1.5 % probability that the NPV of the investment will be negative.

The probability of investment outcomes can be also depicted by using cumulative probability distribution (Figure 23). The figure shows that NPV of 4 million or less occurs at a probability of approximately 15 %, NPV of 3 million or less at a probability of 10 % and NPV of 2 million or less at a probability of 5 %.

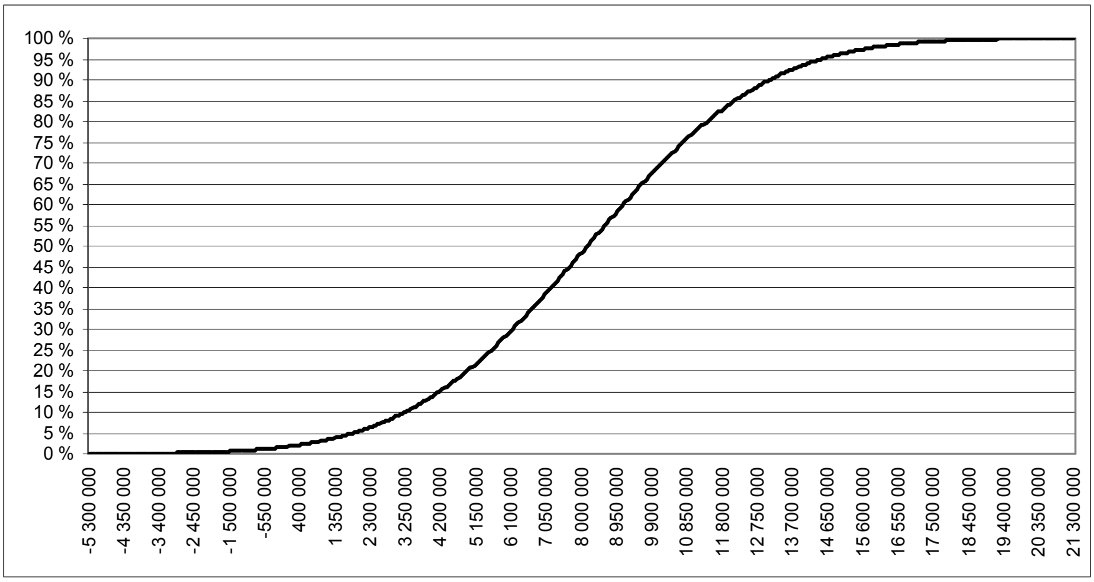

Figure 23. Cumulative probability distribution of expected NPV's for the tube filter investment.

The results from the Monte Carlo simulation analysis strengthen especially the decision-maker's understanding of the investment's negative risk. The standard deviation of the investment is above 3.5 million euros, which shows the high riskiness of the project discovered also in the sensitivity analysis process. However, by knowing that that probability of negative investment NPV is at a substantially low level of 1.5 % and while still taking into account the potential upside in return, the investment seems definitely worth accepting. The information provided by simulation analysis is much more accurate and comprehensive than that of any other previously applied risk analysis method. As the model was kept simple by analyzing only the most critical variables and the existence of correlation between variables appeared remote, the results seem fairly reliable. In the future the model could be enhanced by adjusting the probability density functions of risk variables by using actual data on investment costs and realized utilization rates.

Real options

As the tube filter investment clearly involves high uncertainty and is irreversible in nature, real options approach might reveal additional information about the investment's flexibility and the possibilities it provides. Chapter four presented four types of real options: abandonment option, postponement option, expansion option and operating options. The tube filter investment is now analyzed from the perspective of each real option category.

The abandonment option would come in question if there would be an opportunity to withdraw from the project somewhere in the implementation phase in order to prevent possible future losses. The tube filter investment is conducted by first making a preliminary investment, which takes only up to 3-4 % of the total project cost. At the preliminary investment stage the investment project can still be cancelled. However, as the preliminary investment basically adds no new information about the project's profitability and the share of committed costs in the preliminary phase is so low, no concrete value can be placed for this abandonment option.

Postponement options can sometimes add value in energy efficiency investments if the waiting of more favorable technology or energy price conditions might improve investment profitability. However, the company's Energy Director perceives such options rather negligible:

> "In terms of technology, I see no value in waiting for better conditions. We are actually a worldwide technology pioneer in tube filter investments and in order to keep this position, we do not want to wait for our competitors to follow. Energy price changes, on the other hand, are so unpredictable that no matter how long you wait, the uncertainty is still there." (Energy Director, 27.4.2009)

The installation of tube filters in kiln 41 increases throughput of the kiln and thus makes production line 11 redundant, which is the least energy efficient production line. The remaining four production lines are sufficient with the current level of production and thus the overall production capacity remains constant. However, as the four remaining kilns are annually subject to four weeks of maintenance downtime, there exists a possibility to use kiln 11 during these downtime hours and keep the production running. This possibility can be treated as an expansion option. The downtime production option value can be calculated by using the estimated production of kiln 11 per year and the gross margin per ton of pigment, which give the profit per year obtained from the option. These figures are not expressed here due to confidentiality issues. The production would be kept running during downtime only when the plant is producing at full capacity; during restrictions of production the downtime option would probably not be used. Therefore the annual profit has to be adjusted by the probability of maximum utilization rate, which equals 13 % according to the probability distribution generated in simulation analysis (Figure 20). By adjusting the annual profit with the utilization rate probability, an annual cash flow of 166.854 euros is obtained, which is then subjected to NPV analysis. As the cash flows are market-dependent and have the same characteristics as capacity investment, a discount rate of 10 % was used. The investment period was assumed five years as it can be expected that in the near future total production capacity is increased, which means that kiln 11 has to be turned on and downtime production option is eliminated. The calculation indicates that the value of downtime production option for kiln 11 is 632.507 euros.

Operating options are related to operative flexibility in using the equipment. The nature of titanium dioxide production is not very flexible; the objective is basically to produce at full capacity at all times. Even if production would be adjusted to meet lower demand, the profitability of the tube filter investment would only be lower as the amount of energy savings would be reduced. Therefore the option for production flexibility has no value in the tube filter investment. Raw material flexibility is also inexistent as the investment only reduces use of raw material (energy) but does not increase the variety of raw materials.

Besides the aforementioned real options, two more options need to be distinguished in the tube filter investment. The investment project can be backed by a government subsidy, which typically equals 10-15 % of investment cost. At Sachtleben Pigments government subsidies are not generally recognized in investment calculations because it is often uncertain whether a subsidy becomes approved by the government. However, ignoring a subsidy of such substantial amount misjudges investment profitability; the implications of the subsidy should undoubtedly be quantified rather than ignored. The option value of obtaining the government subsidy for the tube filter investment can be calculated as follows:

Investment cost	9 900 000
Government subsidy	990 000
Likelihood of occurrence	80 %
Value of subsidy in year 2	792 000
Risk-free rate	3,5 %
Value of subsidy in year 0	**739 340**

The subsidy was assumed 10 % of investment cost and the energy director of the company estimated the likelihood of its occurrence at 80 %. As the subsidy is obtained after two years from implementation, it has to be discounted to attain its present value in the beginning of the investment period. Risk-free rate was applied as discount rate as risk is already included by recognizing the likelihood of occurrence. In this way the value of subsidy equals 739.340 euros.

The final option to be considered is the possible future value of reductions in CO_2 emissions. The investment reduces plant level CO_2 emission by over 15 % but the reduction currently has no financial value as TiO_2 production is not currently in the ETS (Emissions Trading Scheme) program. However, in 2013 chemical industry will be included in ETS and it is likely that ETS will be applied also to calcination kilns of TiO_2 production. The option value of CO_2 emission trade savings can be calculated as follows:

Expected price of CO2 emission (€/t)	20
Annual CO2 emission savings (€/a)	283 001
Change in investment NPV (€)	1 244 996
Likelihood of occurrence	70 %
Value of CO2 option (€)	**871 497**

Expected price of CO2 emission was estimated at 20 €/t based on current price level and future outlooks. Energy director estimated that the likelihood that chemical industry will be included in ETS is 70 %. In this scenario the NPV of the investment would increase by 871.497 euros. As the effect on investment NPV is considerable, it is worth conducting sensitivity analysis on the two critical assumptions: price of CO_2 emission and the likelihood that ETS will be applied to TiO_2 production (Table 8). The sensitivity analysis shows that CO_2 savings can increase the investment NPV up to 2.5 million euros.

	CO2 emission price (€/t)			
Likelihood of occurrence	**10**	**20**	**30**	**40**
30 %	186 749 €	373 499 €	560 248 €	746 998 €
40 %	248 999 €	497 998 €	746 998 €	995 997 €
50 %	311 249 €	622 498 €	933 747 €	1 244 996 €
60 %	373 499 €	746 998 €	1 120 496 €	1 493 995 €
70 %	435 749 €	**871 497 €**	1 307 246 €	1 742 994 €
80 %	497 998 €	995 997 €	1 493 995 €	1 991 993 €
90 %	560 248 €	1 120 496 €	1 680 744 €	2 240 993 €
100 %	622 498 €	1 244 996 €	1 867 494 €	2 489 992 €

Table 8. Sensitivity of CO_2 option value to CO_2 price and likelihood of option realization.

To conclude, the real options approach identified three additional value-adding factors, which should be included in investment calculations: downtime production option, government subsidy option and CO_2 emission savings option. By adding the value of these three options to the basic NPV of the investment, the real options -adjusted NPV is obtained:

Basic NPV	7 398 748
+ Value of downtime production option	632 507
+ Value of government subsidy option	739 340
+ Value of CO2 emission savings option	871 497
Real options -adjusted NPV	**9 642 092**

The real options -adjusted NPV equals 9.642.092 euros and is considerably higher than the basic NPV, which ignored the flexibilities and possibilities attached to the investment. Consequently, real options approach should be considered as a fundamental part of risk analysis as the value of options can sometimes make a valuable difference in assessing investment’s profitability.

Conclusion

The application of different risk analysis tools provided substantially deeper and more concrete information about the return of the tube filter investment. Of all the techniques, sensitivity analysis, simulation analysis and real options approaches proved out most valuable in determining investment's risk-adjusted return. Payback period, discount rate adjustment and cash flow adjustment added low value to the analysis by lacking the characteristics of a comprehensive and objective analysis method. Nevertheless, the results obtained from the superior methods were also based on several assumptions, which should be subject to critical assessment. Still, the fear of making false assumptions should not guide the choice of risk analysis method and lead to the dominant use of less sophisticated methods, such as the payback period method. Rather, sensitivity analysis should be used to critically assess the assumptions in order to ensure the objectivity of simulation results. By attaching the identification of investment flexibilities to the analysis with the real options approach, these three methods constitute a solid combination for the risk analysis of energy efficiency investments.

7.2.4 Strategic compatibility analysis

In order to analyze the strategic compatibility of the tube filter investment from the perspective of the strategic framework introduced in chapter five, a scorecard model was developed (Appendix 6). The model follows the logic of the framework by assessing each compatibility factor through a series of questions. The respondents were asked evaluate the tube filter investment by giving a rating from 1 to 3 (1 = low compatibility, 3 = high compatibility) to each question with the help of rating descriptions expressed in the form. The respondent group consisted of Energy Director, Senior Vice President, Financial Director and Technical Director of Sachtleben Pigments. In this section the overall ratings to each question and their central justifications are presented.

Competitive strategy

Do we have a clearly identified and communicated competitive strategy? (2.25 / 3.00)

The first thing in evaluating investment's strategic compatibility is the fact how well the company actually knows its strategic objectives. Despite the organizational restructuring, overall the respondents argued that the company had reasonably well identified its competitive strategy. The company's strategy has characteristics from both cost leadership and differentiation strategy:

> "We are strongly focused on afdc-, uv-titanium and printing inks product categories, in which quality is aimed at keeping on a high level. The rest is basically bulk production, where cost stands as main priority." (Energy Director, 14.5.2009)

> "We have acknowledged the fact that with pure bulk products, we are not going to be able to compete on the market. Therefore we need to have advantage in cost or quality to manage in competition; this has been reflected in our product strategies." (Senior Vice President, 14.5.2009)

Technical Director of the company had a more pessimistic view on the identification of the company's strategy and even perceived the company's strategic position to be missing:

> "Earlier we had a strategic goal to be the best of the world in product quality. Now the situation is quite different as the importance of quality as a competitive priority has diminished due to increasing price competition. This has ruined the foundations from our quality strategy and we are actually a bit lost with our strategic position." (Technical Director, 14.5.2009)

Has the investment emerged from a comprehensive strategic planning process? (2.13 / 3.00)

The purpose of this question was to find out whether there exists a link between company's strategy and the investment or is has the investment emerged strictly from operational needs. The respondents identified a link between cost savings and competitive strategy but also argued that the link is stronger in product-related investments:

> "The tube filter investment has only minor effects on our products and thus the investment cannot be said to derive directly from our product- or competitive strategy. However, cost advantage is an important competitive factor because in the majority of our products we are obliged to engage in price competition." (Senior Vice President, 14.5.2009)

How important is the investment in implementing our competitive strategy? (2.67 / 3.00)
In this question the relative importance of the investment in implementing competitive strategy was tested. The high rating was justified by pressures in long-term cost reduction and emission trade:

> "The titanium dioxide business is moving more and more towards price competition and cost effectiveness is an essential issue in maintaining our competitive advantage. This highlights the importance of the tube filter investment." (Energy Director, 14.5.2009)

> "The investment has extensive impact on our business as third of our production goes through kiln 41. Besides pure cost reduction, I see the ability to lower CO_2 emissions as a strong competitive factor in the future." (Senior Vice President, 14.5.2009)

How unique is the competitive advantage provided by the investment? (2.75 / 3.00)
The uniqueness of the competitive advantage determines how easy it is for the company's competitors to imitate and gain similar benefits. In the case of the tube filter investment, uniqueness of the advantage proved out highly valuable:

> "The technology used in the investment is a result of our persistent R&D efforts and we believe that we have unique knowledge in this area. At the

> moment we are the world-leader in this technology and competitors have a long way forward to be able to create cost advantage in a similar manner." (Energy Director, 14.5.2009)

> "This is an extremely efficient way to lower costs, which is not directly available to our competitors. It will take years or even decades for the competitors to follow us." (Technical Director, 14.5.2009)

<u>Manufacturing strategy</u>

Does the investment decrease our production costs? (2.67 / 3.00)
It is clear that the tube filter investment has an impact on cost as a competitive priority. The respondents perceived the costs savings of the investment substantial also on a plant scale:

> "This is the largest cost saving that can be achieved anywhere in our production process." (Senior Vice President, 14.5.2009)

> "At the moment the focus on is lowering our variable costs of production and this investment is a key measure in attaining our saving targets." (Energy Director, 14.5.2009)

Does the investment improve the reliability of delivery? (1.50 / 3.00)
Delivery as a competitive priority was evaluated based on its reliability and speed. The investment was projected to have some positive influence on the reliability of delivery:

> "As there will be a smaller likelihood of the kiln becoming a bottleneck of the process, the reliability of delivery may improve slightly." (Energy Director, 14.5.2009)

> "When producing at full capacity, the investment helps us in producing the required output and hence indirectly improves the reliability of delivery." (Technical Director, 14.5.2009)

However, the improvement was not seen significant and the Senior Vice President argued that the investment could even deteriorate the reliability of delivery:

> "The tube filters operate with such a sensitive process that the susceptibility to malfunction may increase in the process, which would actually decrease our reliability of delivery." (Senior Vice President, 14.5.2009)

Does the investment improve the speed of delivery? (1.33 / 3.00)
The respondents recognized no considerable effects on speed of delivery and from a customer's point of view the effects were seen negligible:

> "Improved process fluency may accelerate delivery speed slightly but as basically all our products are sold from stock, the customer does not receive the products any earlier." (Technical Director, 14.5.2009)

Does the investment improve the quality of our product? (2.00 / 3.00)
All respondents agreed that the tube filter investment improves the quality of the product with improved milling in the process:

> "The investment has a clear positive impact on the milling of the pigment in later process stages. As we do not have to mill the product so much, it becomes easier for us to produce a product that meets the quality standards of our customers." (Energy Director, 14.5.2009)

Despite the customers' tight quality control, the enhanced quality was still not seen as an appropriate justification for price increases:

> “Our customers have certain expectations for quality which have to be met but they are not willing to pay any extra for exceeding those expectations.” (Senior Vice President, 14.5.2009)

Does the investment increase the variety of process inputs? (1.00 / 3.00)

The flexibility priority was evaluated on a three-dimensional basis: process input- , product- and production flexibility. The tube filter investment’s impact on process input flexibility was viewed inexistent by the respondents. The investment reduces propane consumption but no new energy sources or raw materials become available.

Does the investment increase the variety of product options or variants? (1.83 / 3.00)

The respondents identified improvements in key strategic products but actual new product options providing product flexibility were not recognized:

> “The core production process remains unchanged so the investment does not actually provide any new products or product variants.” (Technical Director, 14.5.2009)

Does the investment improve production flexibility? (2.67 / 3.00)

Finally, the investment’s effects on production flexibility were assessed. The positive influence on production flexibility was seen as a central beneficial attribute of the tube filter investment:

> “The investment enables us to produce a wider scale of products and improves our ability to quickly change the rate of production. This is extremely important for the sake of process fluency and efficiency.” (Senior Vice President, 14.5.2009)

> “With the new technique we are able to adjust production better, which is especially important now when the market demand has collapsed. Additionally, kiln 11 provides several flexibility options: we can produce during

> maintenance, produce a whole new product or make trial production runs." (Technical Director, 14.5.2009)

Technology strategy

Do we have the required internal resources and capabilities to implement the new technology? (3.00 / 3.00)

Technology implementation involves always a risk, which is highly dependent on the company's internal resources and capabilities. Due to the prior experience of Sachtleben Pigments in similar technology, the respondents saw no problems with introducing the technology in terms of internal capabilities:

> "We have already conducted two similar investments, which involved a lot of training to our personnel. I would say that the technicians here possess a good deal of in-depth knowledge of this technology." (Energy Director, 14.5.2009)

> "Overall we have all the required know-how needed in this investment. We have acquired the technology and have prior experience in using it. Only the users of the equipment need to be trained." (Technical Director, 14.5.2009)

Is the investment compatible with the existing production process? (2.50 / 3.00)

This question was posed to find out whether major changes are needed in the existing production process to implement the investment. Technical Director perceived the compatibility with process exceedingly favorable:

> "Separate building has to be constructed for the equipment but no substantial changes are needed in our existing production process. It can be said that the technical compatibility with process is in this investment exceptionally high." (Technical Director, 14.5.2009)

Energy Director's view on the compatibility with process was slightly more pessimistic:

> "Existing equipment does not have to be relocated because the new equipment is installed to an empty space. However, from the perspective of process fluency it has to be made sure that the old equipment fits to the new situation. Besides the installation of tube filters, coolers and conveyors are required which involve small changes in the process. " (Energy Director, 14.5.2009)

Is there a possibility that more feasible technologies for the same purpose become available in the future? (2.67 / 3.00)

Rapid technological change may quickly alter the relative superiority of a given technology and shorten the durability of competitive advantage. However, the respondents assessed the risk of more feasible technologies rather low:

> "The technological development in this industry is amazingly slow. I consider it highly unlikely that there would emerge more feasible technologies for water filtration of titanium slurry in the near future." (Technical Director, 14.5.2009)

> "I believe that it will take several years or even decades before any new methods can be discovered in the calcination technology." (Senior Vice President, 14.5.2009)

Is the chosen technological leadership/followership strategy for the investment appropriate? (3.00 / 3.00)

The advantages of the chosen technological leadership strategy in the tube filter investment were judged to clearly outweigh the disadvantages of the strategy:

> "We are a clear technological leader in this investment as our competitors do not have this kind of technology in use. The risks of leadership are low as we have already conducted two similar investments." (Energy Director, 14.5.2009)

> "This is best available technology (= BAT) in the market but our competitors have not dared to introduce it in order to avoid risks. The advantages of

leadership are obvious because even if our competitors would follow us, we are already in the lead, have paid off the investment cost and have at the same time replaced old technology in our production process." (Technical Director, 14.5.2009)

Customers

Does the investment lower customer's costs? (1.83 / 3.00)

The first external evaluation factor dealt with the investment's implications to company's customers by examining possible improvements in e.g. customer satisfaction and loyalty. The investment's reflections on the customer side were basically limited to improved milling quality of the pigment:

> "When the customers don't need to mill the product so much, their costs can be lowered. Customers follow product quality carefully so they can clearly see the benefit." (Senior Vice President, 14.5.2009)

> "In paint products the improved milling of the product should be visible to our customers and customer satisfaction should be improved as we can provide them better products at the same price. However, I see no considerable significance in this advantage." (Technical Director, 14.5.2009)

Does the investment raise customer's performance? (1.50 / 3.00)

The previously mentioned milling effects were also believed to have a slight effect on customer's performance:

> "As the product does not need to be milled so much, the customer is able to even increase the quality of the product by milling it further." (Senior Vice President, 14.5.2009)

Suppliers

Does the investment decrease our dependence on suppliers? (1.17 / 3.00)
Reduced dependence on suppliers might provide improved negotiation position in terms of price and delivery. However, such benefits were seen rather far-fetched due to the lack of other alternatives for the propane supplier:

> "The investment decreases slightly our dependence on our propane supplier but on the other hand we are still extremely dependent on it because no alternatives for this supplier exist." (Energy Director, 14.5.2009)

> "Dependence on our propane suppliers remains high; we only buy a bit less but it is still very difficult to change the supplier." (Technical Director, 14.5.2009)

Does the investment require an establishment of new supplier relationships? (2.00 / 2.00)
In this question the changes in supplier base were analyzed, which could have both positive and negative effects. The tube filter investment does not require new supplier relationships and therefore all the respondents were naturally unanimous in their answers.

Competitors

How does the investment enhance the company's current competitive position in the market? (1.67 / 3.00)
The purpose of the question was to examine the current competitive situation in the market and investment's fit to ongoing competitive pressures. The economic downswing deteriorated considerably the tube filters investment's compatibility with the current competitive situation:

> "Because the investment cost is so high, the investment doesn't really fit to current situation. In this economic downturn the key thing is to keep the plant running and maintain our customer relationships. A large energy efficiency

> investment does not contribute to our survival in the market." (Senior Vice President, 14.5.2009)

> "At the moment the key issue is to take care of short-term cash needs and therefore a long-term investment of such a high monetary value is not the optimal way to save costs in this situation." (Energy Director, 14.5.2009)

Does the investment create entry barriers to potential new competitors? (1.33 / 3.00)
Especially when the threat of new competitors is high, the creation of entry barriers can enhance the company's competitive position on the market. However, the value of these barriers was not regarded as important as the risk of new entrants was considered very low:

> "Five biggest players on the market represent a share of 70 % of the world pigment market and new entrants arise extremely seldom. Because of the risk of new entrants being so low, these entry barriers basically have no real significance." (Senior Vice President, 14.5.2009)

Nevertheless, the Technical Director identified some value in creating entry barriers by having additional capacity:

> "If we have additional capacity that can be offered to new markets, we make it more difficult for the new players to enter the market." (Technical Director, 14.5.2009)

Regulators

What is the investment's role in complying with current regulation? (2.50 / 3.00)
Besides its pure financial impact, the tube filter investment can be justified by its environmental effects. Especially adherence to the energy agreement was seen as important factor:

> "In order to achieve the energy saving targets expressed in our energy agreement, this investment has to be conducted. Additionally, our environmental permissions oblige us to save energy." (Energy Director, 14.5.2009)

Does the investment enhance the company's ability to adapt to future regulatory changes? (2.67 / 3.00)

In this question the perspective was moved from current regulation to future regulatory norms. The respondents highlighted the pressure for CO_2 emission reduction in their answers:

> "New regulation is emerging constantly and especially the reduction of CO_2 emissions is a clear worldwide trend. We believe that the calcination kilns will be subject to CO_2 emission trade in 2013." (Senior Vice President, 14.5.2009)

> "I see no other future scenario than tightening environmental- and emission control. In this respect the tube filter investment enhances considerably our ability to cope with these changes." (Technical Director, 14.5.2009)

Conclusion

The overall results of the strategic compatibility analysis of the tube filter investment are shown in Table 9. It can be concluded that the investment's internal strategic compatibility is considerably higher than external; this is mainly because the investment's positive implications to customers, suppliers and competitors are minor. It is likely that capacity investments generally outperform energy efficiency investments in these factors. However, the investment clearly supports the company's internal strategies and is especially feasible from a technological point of view. The overall strategic compatibility rating equals 2.26, which stands for moderate strategic compatibility. Now having determined the strategic compatibility of the tube filter investment, it is time to combine these results with the risk-adjusted financial analysis results in order to obtain a comprehensive view of whether the investment should be accepted or not.

STRATEGIC COMPATIBILITY RESULTS	
Compatibility factor	Total rating
Internal compatibility factors	2,64
Competitive strategy	2,45
Manufacturing strategy	2,67
Technology strategy	2,79
External compatibility factors	1,88
Customers	1,83
Suppliers	1,58
Competitors	1,50
Regulators	2,58
Strategic compatibility rating	2,26

Interpretation of results:	
1,0 - 1,65	*Low compatibility*
1,66- 2,35	*Moderate compatibility*
2,36 - 3,0	*High compatibility*

Table 9. Strategic compatibility analysis results of the tube filter investment.

7.2.5 Integrating strategic and financial analysis

It was concluded in section 5.3 that financial and strategic analysis can be combined by using the financial and strategic investment analysis integration matrix. The matrix has been used to analyze the tube filter investment in Figure 24. For the sake of comparability between investments of different monetary value, the real options -adjusted internal rate of return was chosen as a measure of investment's financial return. The company's cost of capital 7 % was chosen as a threshold level drawing the line between financially profitable and unprofitable projects. Strategic compatibility was measured by the strategic compatibility rating obtained in the previous section. The analysis shows that the tube filter investment is especially feasible from the financial point of view but also has reasonable strategic compatibility. Hence, the investment should be accepted. By placing all manufacturing investments to the matrix the company can make strategic decisions on what investment to accept and guarantee fair comparison between energy efficiency investments and other manufacturing investments.

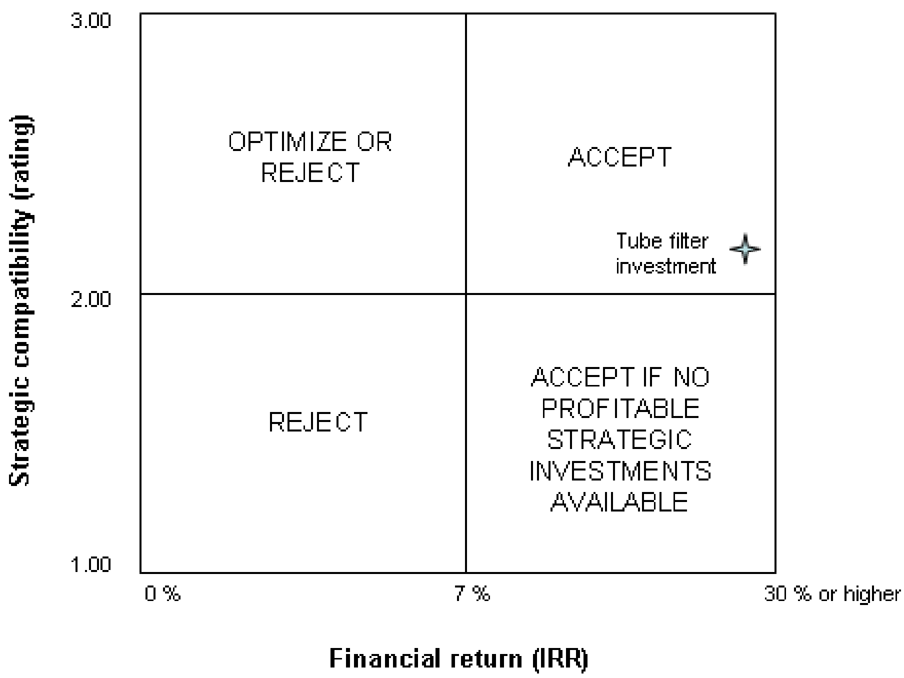

Figure 24. Analyzing the tube filter investment with the financial and strategic investment analysis integration matrix.

8. CONCLUSIONS

Energy issues are becoming more and more important, which creates pressures for industrial companies to improve their energy efficiency. Having energy efficient manufacturing processes is not anymore a question of good will, but has serious implications for the company's cost position and competitive advantage. Still several research studies have shown that industrial firms do not always implement their profitable energy saving projects, which has implied the existence of a so-called energy efficiency gap. The researchers have argued that there are several barriers that prevent energy efficiency investments from being accepted in the companies' capital budgeting process. This study focused on one specific barrier to energy efficiency investments; namely the lack of appropriate investment analysis tools. It was believed that by improving the investment evaluation tools the benefits of energy efficiency investments could be brought more explicitly forth and a fair comparison between energy efficiency investments and other manufacturing investments could be made possible.

The theoretical part of the study identified two main areas of improvement in energy efficiency investment analysis. Firstly, more sophisticated financial analysis techniques should be applied to include the specific risks, such as energy price risk, in investment calculations. The dominant use of the payback period method was recognized as a fundamental problem in the investment analysis and it was concluded that the payback method should be replaced by risk-adjusted discounted cash flow methods. The risk analysis techniques were presented and their general applicability to energy efficiency investment analysis was discussed. Secondly, a strategic perspective was introduced to analyze the strategic nature and qualitative implications of energy efficiency investments. A strategic compatibility framework was developed to identify key factors determining investment's strategic attractiveness. Instead of using strict categorizations to operative and strategic investments, the framework was established to evaluate all manufacturing investments with the same strategic criteria. Finally, the financial and strategic perspectives were integrated into a single matrix showing the relative position of an investment in the company's investment portfolio. With the help of the matrix the company can make decisions on what investments to accept and which of them should be given priority in acceptance.

The empirical part of the study supported the conclusions made in the theoretical part. Firstly, the state of energy efficiency investment appraisal in the case company was analyzed. As expected, the payback period method had a dominant role in investment decision-making with extremely tight payback thresholds. The risks of energy efficiency investments were well known in the company but no systematic risk analysis procedures were being used to analyze the risks related to investment return. There was also a lack of strategic considerations in investment evaluation as energy efficiency investments were rather seen as operative in nature. Due to the dominant role of financial figures in investment appraisal, qualitative aspects rarely had an impact on the final investment decisions. Investment proposers seemed to lack appropriate justifications for energy efficiency investments and were startled by the tough requirements energy saving projects faced in the company's board of directors. It was also notable that the CEO as a member of the board did not recognize any discrimination between energy efficiency investments and other manufacturing investments and actually supported the use of payback as an initial screening tool for investment projects.

Secondly, a specific energy efficiency investment was analyzed as case study example to illustrate the implications of the theoretical part of the study. Different risk analysis techniques were applied to analyze the investment's risk and the applicability and usefulness of each method in energy efficiency investment appraisal. Sensitivity analysis, simulation analysis and real options approach were recognized as superior methods in analyzing the risks of energy efficiency investments. The results of these three methods indicated a high investment return with extremely low probability of making a financial loss by conducting the investment. Interestingly, with the use of simple payback method the investment would most likely have been rejected as the investment's payback period clearly exceeded the company's general payback requirement. Additionally, the strategic framework from the theoretical part was applied to analyze the investment. The strategic evaluation was based on a scorecard model which indicated moderate strategic compatibility for the investment. Finally, the financial and strategic perspectives were integrated by using the financial and strategic investment analysis integration matrix, which supported the investment's acceptance as the final decision. To summarize, the new, more sophisticated analysis tools provided a more comprehensive view of the investment's financial return and strategic compatibility. By using the simple payback rule, much information would have been ignored in the analysis and the clearly profitable energy efficiency investment project would have been unfairly rejected. The study also concluded that the classification to different investment types is actually unnecessary; by using the same comprehensive evaluation criteria to all investments, an equal treatment is guaranteed.

Recapitulation of the study has been depicted in Figure 25. The study clearly showed that lack of appropriate investment analysis tools constitutes one significant barrier to energy efficiency investments, which can be overcome by improving both the financial and strategic investment evaluation methods. Several methods were proposed for improving the analysis, which in simultaneous use provide basis for equal treatment between manufacturing investments and lead on to an increased acceptance of energy saving projects.

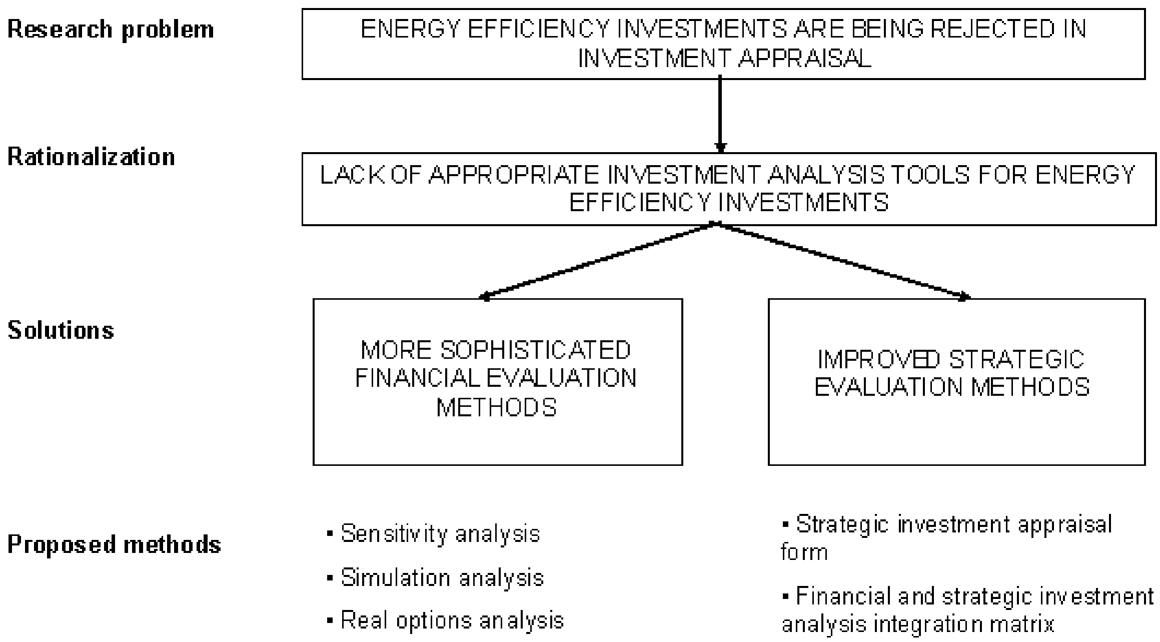

Figure 25. Recapitulation of the study.

The importance of energy efficiency investment analysis is emphasized in the emergence of companies focusing solely on planning and implementing energy saving projects. Energy service companies (ESCO's) are professional businesses providing the design and implementation of energy saving projects. Two important conclusions can be derived from the ESCO business.

Firstly, the existence and high growth of these companies shows that a pure expertise in analyzing energy efficiency investments can create enormous business opportunities. Secondly, energy efficiency investment analysis being the core business of these companies, it is likely that these companies possess unique knowledge of how energy efficiency investments should be analyzed. Consequently, with the help of training events and written reports provided by ESCO's, information about best practices in energy efficiency investment analysis could be distributed to the industrial companies' capital budgeting processes as well.

The popularity of inadequate and simple investment analysis tools, such as the payback period method, can stem from several factors. First of all, the use of payback has been built as a tradition to industrial companies' investment practices and therefore changes in this behavior require extensive change processes in the companies. Secondly, corporate managers still seem to prefer the payback method over NPV because of its simplicity and understandability. Consequently, managerial training would be required to make managers more aware of the serious weaknesses of the method and the lost investment opportunities caused by the use of these simple appraisal methods. Thirdly, industrial companies' investment processes are often dominated by engineers and the involvement of the finance department has typically been relatively minor. Thus, the lack of economic perspective in investment process may have also contributed to the use of simple financial methods. Therefore the engagement of the finance and also strategic department in investment appraisal is also a critical factor in improving the quality of energy efficiency investment analysis.

Several limitations have to be noted when considering the implications of this study. The study focused solely on the financial barriers to energy efficiency investments; obviously there are also other causes behind the energy efficiency gap, such as organizational and human factors barriers. This study provided no information about the influence of these other barriers on energy efficiency investment decisions. Additionally, some limitations can be distinguished that arise from the research method. The research findings were based interviews and observations in a single case company, which can deteriorate the generalizability of results. Consequently, the proposed methods may not be as applicable in other companies and with other types of energy efficiency investments. It is possible that the interviewees' awareness of the research may have had an effect on their answers. Also the effect of researcher's own interpretation and understanding should be acknowledged when considering the proposed solutions. The analysis and suggested improvements were based on the researcher's view of the current practices and theories, which means that they should not be taken as the absolute truth.

Further research should be conducted to discover how big of a barrier the inadequate analysis tools actually are to energy efficiency investments' acceptance. Also other barriers, such as organizational and human factors issues, should be subjected to further research. The analysis methods proposed in the study should be applied in other companies operating in other industries and to other types of energy efficiency investments to determine whether they in fact constitute a generally superior approach to energy efficiency investment analysis. Investment post-completion auditing should also be applied to the analyzed energy efficiency investments to evaluate how well the proposed methods succeeded in forecasting investments' profitability. By overcoming the financial barriers to energy efficiency investments, companies would not only make better investment decisions but also support the achievement of the worldwide goals for energy efficiency.

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APPENDICES

Appendix 1. Case study interviews

1. Identification of research problem

22.1.2009, Sachtleben Pigments Oy, Pori

Interviewees: Energy Director, Senior Vice President, Technical Director, Financial Director

2. Tube filter investment risk analysis

27.4.2009 Helsinki School of Economics, Helsinki

Interviewees: Energy Director

3. Risk analysis results and strategic compatibility assessment

14.5.2009 Sachtleben Pigments, Pori

Interviewees: Energy Director, Controller, Financial Director, Senior Vice President, Technical Director

4. Upper management view on energy efficiency investments

27.5.2009 Sachtleben Pigments, Pori

Interviewee: Chief Executive Officer

Appendix 2. Theme interview form 22.1.2009
Interviewer: Niklas Härus

Analyzing energy efficiency investments in the process industry
– Case Sachtleben Pigments Oy

Questions:

1. **Personal background**
- Responsibilities, work tasks, reporting relations
- Work history

2. **Energy efficiency at Sachtleben Pigments**
- Monetary amount of energy costs and proportion total costs
- The role of energy efficiency in strategy and values
- Measures of energy efficiency

3. **Energy efficiency investments**
- Annual monetary amount of proportion of total investment budget
- Investment types, typical characteristics
- Investment process

4. **Analyzing energy efficiency investments**
- Quantitative methods (NPV, IRR, payback period)
- Qualitative methods (e.g. compatibility with strategy)
- Investment post-completion auditing

5. **Risks in energy efficiency investments**
- What are the essential uncertainties in energy efficiency investments (energy price, use of energy, labor costs, maintenance costs, interest rate etc.)?
- How are these uncertainties taken into account in investment analysis? (e.g. higher discount rate, sensitivity analysis)

Appendix 3. Theme interview form 27.4.2009
Interviewer: Niklas Härus

Analyzing energy efficiency investments in the process industry
– Case Sachtleben Pigments Oy

Questions:

1. Based on preliminary interviews, *productional investments* are always prioritized over *energy efficiency investments*. What is exactly meant by production investment compared to energy efficiency investment?

2. Risk of energy efficiency investment vs. productional investment
    - In assessing the capacity investment (to 130.000 tons) a discount rate of 10 % was used, in tube filter investments 7 % → is the tube filter investment less risky than capacity investment?
    - How successful were the previous two tube filter investments? Did the energy savings materialize?
    - How will the tube filter investment be financed?

3. Can a government subsidy be applied to the tube filter investment? Has this been taken into account in the calculations?

4. Propane price is the most important variable determining the profitability of the tube filter investment. Where could I obtain data on historical prices of propane?

5. Tube filter investment and real options
    a. Can the investment still be cancelled in the implementation phase to cut future losses?
    b. Does the investment provide expansion options (e.g. later introduction of kiln 11)?
    c. Is there a benefit to be gained by postponing the investment? (e.g. wait for better technology or more feasible energy price conditions)

Appendix 4. Theme interview form 14.5.2009
Interviewer: Niklas Härus

Analyzing energy efficiency investments in the process industry
– Case Sachtleben Pigments Oy

Questions:

1. How do you see your role in the company's investment process?

2. It has been argued in the academic research that energy efficiency investments are being discriminated in the investment decision-making process. Do you agree? Why?

3. The payback period method is still widely used as primary method in investment evaluation in the industry despite its obvious weaknesses (does not consider the entire investment period, ignores the time value of money). Why is this?

4. The highest risk in energy efficiency investments is related to energy price fluctuations. How suitable are the following methods in taking into account this risk?

    a. Shorter payback period thresholds
    b. Higher discount rate
    c. Sensitivity analysis on optimistic and pessimistic price scenarios
    d. Simulation analysis based on historical energy prices

5. Strategic investments are often defined as investments that have long-term impact on company's competitive position in the market.
    a. Can energy efficiency investments be considered as strategic investments?
    b. Should strategic investments be prioritized in the investment process?

Appendix 5. Theme interview form 27.5.2009
Interviewer: Niklas Härus

Analyzing energy efficiency investment in the process industry
– Case Sachtleben Pigments Oy

Questions:

1. How do you see the importance of energy efficiency in your business?

2. It has been argued in the academic research that energy efficiency investments are being discriminated in the investment decision-making process. Do you agree? Why?

3. The payback period method is still widely used as primary method in investment evaluation in the industry despite its obvious weaknesses (does not consider the entire investment period, ignores the time value of money). Why is this?

4. On a general level, can energy efficiency investments be perceived riskier or less risky than investments in manufacturing capacity?

5. Can energy efficiency investments be considered as strategic investments? Is there a link between energy efficiency and corporate strategy?

Appendix 6. Strategic compatibility form.

STRATEGIC COMPATIBILITY FORM FOR CAPITAL INVESTMENT APPRAISAL

Project manager: please fill in the yellow cells based on your assessment of investment's strategic compatiblity.

Project Name:	
Project manager:	
Date:	

STRATEGIC COMPATIBILITY RESULTS		
Compatibility factor	Total rating	
Internal compatibility factors	*0,00*	
Competitive strategy	*0,00*	(average of cells D25-D28)
Manufacturing strategy	*0,00*	(maximum of cells D30-D36)
Technology strategy	*0,00*	(average of cells D38-D41)
External compatibility factors	*0,00*	
Customers	*0,00*	(maximum of cells D43-D44)
Suppliers	*0,00*	(average of cells D46-D47)
Competitors	*0,00*	(maximum of cells D49-D50)
Regulators	*0,00*	(average of cells D52-D53)
Strategic compatibility rating	*0,00*	

Interpretation of results:	
1,0 - 1,65	*Low compatibility*
1,66 - 2,35	*Moderate compatibility*
2,36 - 3,0	*High compatibility*

Comments:

Appendix 6. Strategic compatibility form (continued).

	COMPATIBILITY FACTOR			RATING DESCRIPTIONS		
	Subfactor to be evaluated	**Question**	**Rating (1-3)**	**1**	**2**	**3**
	COMPETITIVE STRATEGY					
	The role of competitive strategy	Do we have a clearly identified and communicated competitive strategy?		No strategy identified/communicated	Some sort of competitive position has been identified and communicated	Competitive strategy has been identified and communicated throughout the organization
	Link to competitive strategy	Has the investment proposal emerged from strategic planning process?		No connection between the investment and strategic planning	Some strategic considerations involved when planning the investment	The investment opportunity was discovered in comprehensive strategic plannig process
	Strategic significance	How important is the investment in implementing our competitive strategy?		Irrelevant/only minor significance	Supports the strategy but not necessary for maintaining/enhancing competitive position	Critical for the company's long-term competitive position in the market
	Uniqueness of competitive advantage	How unique is the competitive advantage provided by the investment?		The advantage is known in the whole industry/can easily be imitated by competitors	The advantage is not widely known but competitors might be able to follow	The uniqueness and/or proprietary nature of the advantage provide a sustainable competitive advantage
	MANUFACTURING STRATEGY					
	Cost	Does the investment decrease our production costs?		No effects on production costs	Only relatively low cost reductions to be achieved	The investment provides considerable cost reductions
	Product delivery	Does the investment improve reliability of delivery?		No effect on reliability of delivery	Reliability of delivery improved but not highly valued by customers	Reliability of delivery improved and appreciated by customers
		Does the investment improve speed of delivery?		No effect on speed of delivery	Speed of delivery improved but not highly valued by customers	Speed of delivery improved and appreciated by customers
	Quality	Does the investment improve the quality of our product?		No effect on product quality	Quality improved but price increases difficult to justify	Quality improved and corresponding price increases justified
	Flexibility	Does the investment increase the variety of process inputs (raw materials or energy inputs)?		No changes variety of inputs	Increases variety of inputs in process areas that have only minor significance	Increases variety of inputs in critical process areas
		Does the investment increase the variety of product options or variants?		No changes variety of products	Changes in products that have only minor significance	New options or variants in key strategic products
		Does the investment improve production flexibility?		No improvements in production flexibility	Improvements in flexibility but market demand rather stable	Improvements in flexibility and highly volatile market demand

Appendix 6. Strategic compatibility form (continued).

	TECHNOLOGY STRATEGY					
	Internal resources and capabilities	Do we have the required internal resources and capabilities to implement the new technology?		There is a lack of appropriate capabilities and succesful implementation is uncertain	New resources and capabilities have to be acquired to implement the technology	Required resources and capabilities are in place and succesful implementation is guaranteed
	Compatibility with process	Is the new technology compatible with the existing production process?		Major changes needed in the process to implement the new technology	Only minor changes needed in the process to implement the new technology	The new technolgoy is fully compatible with the existing production process
	Technological trends	Is there a possibility that more feasible technologies for the same purpose become available in the future?		Due to rapid technological change in the industry new superior technologies are likely to emerge	There is a possibility that more feasible technologies for the same purpose become available in the future	The emergence of more feasible technologies for the same purpose seems highly unlikely
	Technological leadership/followership	Is the chosen technological leadership/followership strategy for the investment appropriate?		The chosen leadership strategy involves high risks/followership strategy not able to provide major competitive advantage	The advantages of the chosen leadership/followership slightly outweigh the disadvantages of the strategy	The advantages of the chosen leadership/followership clearly outweigh the disadvantages of the strategy
	CUSTOMERS					
	Lowering customer's cost	Does the investment lower customer's costs?		No reductions in customer's costs	Customer's costs are lowered but no changes in the customer's perceived value	Customer's costs are lowered and enhanced customer satisfaction attained
	Raising customer's performance	Does the investment raise customer's performance?		No raise in customer's performance	Customer's performance raised but no changes in customer's perceived value	Customer's performance raised and enhanced customer satisfaction attained
	SUPPLIERS (raw materials, partners, energy providers)					
	Supplier dependence	Does the investment decrease our dependence on suppliers?		No effects on supplier dependence/dependence increased	The investment decreases supplier dependence but does not provide negotiation power over suppliers	The investment decreases supplier dependence and provides negotiation power over suppliers

Appendix 6. Strategic compatibility form (continued).

	Supplier base changes	Does the investment require establishment of new supplier relationships?		New, highly risky suppliers relationships need to be established	No major changes in existing supplier base/new suppliers have only minor significance	Establishes new, more reliable supplier relationships
	COMPETITORS					
	Existing competitors	How does the investment enhance the company's current competitive position on the market?		No considerable effect on company's position/unsuitable for current situation	Enhances competitive position but does not fully meet the competitive pressures that prevail in the market	Enhances competitive position and meets the competitive pressures that prevail in the market
	New entrants	Does the investment create entry barriers to potential new competitors?		No entry barriers created	Creates only weak barriers and threat of new competitors low	Creates strong barriers and threat of new competitors is considerable
	REGULATORS (government, environmental organizations etc.)					
	Current regulation	What is the investment's role in complying with current regulation?		No contributing effect	The investment slighly enhances compliance	Regulation creates high pressure for implementation
	Prospective regulation	Does the investment enhance the company's capability to adapt to future regulatory changes?		No enhancing effect on adaptability	Investment enhances adaptability but likelihood of major regulatory changes low	Investment enhances adaptability and likelihood of major regulatory changes high