

*Master Thesis*

***Decision Support for  
Energy Technology Investments  
in Built Environment***

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*Department for Industrial Economics and Technology Management*

*Accounting and Finance*

*NTNU 2006*



Department of Industrial Economics and Technology Management

MASTER THESIS

for

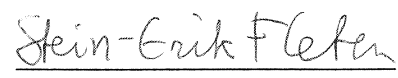
STUD. TECHN. MONIKA INDE ZSAK

<b>Field of study</b>	<b>Accounting and Finance</b> Investering, finans og økonomistyring
<b>Start date</b>	15.01.2006
<b>Title</b>	<b>Decision Support for Energy Technology Investments in Built Environments</b> Beslutningsstøtte for investeringer i energiløsninger i bygninger
<b>Purpose</b>	The purpose is to develop a decision support tool to enable developers, planners and designers to make technically and economically sound choices for energy use in built environments. In this context, a built environment means either a development or a redevelopment project within a specified geographic area. There is uncertainty in energy-related cost and benefit elements, and another purpose of this thesis is to increase the understanding of how uncertainty affects optimal development of energy systems in urban built environments.

**Main contents:**

1. Identification, analysis, modelling and estimation of uncertainty in important parameters such as electricity prices, oil and gas prices, demand growth and in the (development of) costs of alternative energy technologies in buildings. Costs include investment, operational and others, in order to enable a holistic view of economic, environmental, and social costs/benefits.
2. Develop a decision support model using appropriate software. The tool should include traditional profitability analyses such as net present value, but should also use methods that take into account the uncertainty identified in item 1 above.
3. Use the developed model to analyse case studies from Norway.

  
Olav Fagerlid  
Vice Dean

  
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## DECLARATION

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I hereby declare that I have written the above mentioned  
thesis without any kind of illegal assistance

\_\_\_\_\_  
Place

\_\_\_\_\_  
Date

\_\_\_\_\_  
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## **Preface**

This master thesis was performed during the spring of 2006 at the Norwegian University of Science and Technology, NTNU, Department of Industrial Economics and Technology Management.

Since there is little information regarding Energy Performance Contracting on the Norwegian market working with the topic has been challenging but thus more interesting and educational. I have gained valuable insight in financial theory and how to use theory on practical problems. A great challenge has been to combine several fields of study together with incorporating them in to computer software.

I would like to thank my supervisors Stein-Erik Fleten and Bjørn Bakken for good support and constructive feedback during the semester. I would also like to thank Einar Ståle Huse for valuable inputs regarding programming in VBA.

Trondheim, 12<sup>th</sup> of June, 2006

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Monika Inde Zsak

## Summary

This thesis investigates Energy Performance Contracting which is a financial technique to overcome barriers regarding energy investments in buildings. By letting an energy investor invest in energy efficient technologies for a client, the investments can be paid back, to the energy investor, out of the cost savings. In this thesis a decision support tool called the Energy Investment model is developed. All though the model is not yet commercial, it is a suggestion on how to model the investment decision for an energy investor. The model considers uncertainty towards energy investments in built environments. The investments will be those in relation with building envelope and the technology for four different energy carriers, namely pellets, electricity, heating oil and gas together with flexible energy systems combining these energy carriers.

The Energy Investment model is based on net a present value analysis together with methods such as value at risk and contracting structures to account for the different uncertainties that an energy investor faces while entering into Energy Performance contracts. The various risks will mainly be those regarding income, operating and maintenance -costs together with asymmetric information.

The uncertainty in income arises from the uncertainty in energy prices together with vagueness in defining the base line which the savings are measured against. The uncertainties are accounted for by creating stochastic price models for oil, gas and electricity in to the Energy Investment model. Further, the future prices of pellets are incorporated into the model using a scenario approach. In addition the price processes for the energy carriers are related through use of a correlation matrix.

The uncertainties in operating and maintenance costs arise from asymmetric information and uncertainties in technology costs. The last is also a reason for uncertainties in investment costs. Modelling technology can be done through use of learning curves but will be more important if real options are investigated. The use of real options will be less important when analysing the investment decision for an energy investor. This is due to the fact that an energy investor is rather concerned about getting paid in the period between the purchase date of an option and the options exercise date, and will therefore probably not give up margins for future income in the clients energy system.

By using the Energy Investment model on two different case studies from Norway, the results showed that variations in the baseline which the energy performance is measured against has the highest affect on the net present value for an energy investor. In addition it is difficult to measure accurate baselines and therefore a great amount of uncertainty is addressed to the issue. Measuring accurate baselines should therefore be given great amount of attention when conducting energy investments

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# 1 Introduction

Lack of financial funding and significant uncertainties in the costs and benefits related to energy use result in low willingness to conduct energy and heating related investments in buildings. In short, investing in an effective heating system can be very costly and therefore less “energy optimal” solutions are often selected. A way to overcome the barrier regarding energy related investments is by using Energy Performance Contracting. Energy Performance Contracting is a financing technique that uses cost savings from reduced energy consumption to repay the cost of installing effective energy technologies and energy conservation measures. An energy investor is a party offering such contracts. These types of contracts capture the benefits from energy savings without up front capital expenses on the part of the building owners. The reason for this is that the costs of the energy improvements are borne by the energy investor, or a third party, and paid back out of the energy savings. There can either be two or three main parties involved in an Energy Performance Contract. In most cases there are only two parties involved, namely the energy investor and the client. A third party can be drawn in if external funding is needed. This party will only provide economic funding and will in this thesis be referred to as the “third party”.

The energy investor will, when offering these types of contracts, operate as a developer, planner and designer for energy systems in built environments. Thus the investor bears uncertainties and risks. The concept of Energy Performance Contracting is not yet developed in Norway. One of the reasons may be the lack of a tool which helps to identify projects that are economically sound and, at the same time, communicates various risk factors that might arise when offering these types of contracts.

The risk factors that are most insidious for an energy investor are those risks which the investor is exposed to and have not yet been identified. The ones that are identified can almost always be managed to some extent by for example writing better contracts with the client. This thesis identifies and creates a support model for an energy investor with regard to investments in energy systems and the uncertainty that the investor might face. It is intended, that by using this model, the energy investor can make more technically and economically sound choices as well as avoid the biggest traps when investing in energy systems. The model is called the Energy Investment model and takes the uncertainties regarding prices of four different energy carriers- oil, gas, electricity and bio fuel- into consideration.

The thesis starts with an introduction of how Energy Performance Contracting works and the different services an energy investor can offer a client. The thesis then discusses the different types of technology investments that an energy investor might conduct before viewing the risk factors that are of importance when using Energy Performance Contracting. The risks that will be discussed are those regarding technology investments, price of energy carriers and the baseline which the energy savings are measured against. Additionally, there will be a short discussion regarding use of real options when conducting Energy Performance Contracting.

The second part of the thesis shows how to model the uncertainties in electricity, gas and heating oil prices using stochastic price models. In the following chapter a scenario approach is used to derive the prices for pellets. The thesis then explains how it is possible to construct a baseline when combining the several energy carriers in the Energy Investment model. Further a risk measure using Value at risk together with Conditional value at risk will be

presented. The risk measure will communicate the various risks an energy investor might face regarding energy prices.

The third main part of the thesis shows how the Energy Investment model works and demonstrates its use by analyzing two real cases in Norway. Subsequently, a sensitivity analysis for how the energy investor's profitability is affected by varying the uncertain variables will be conducted. The thesis will then show how uncertainties in energy prices affect the investment decision in energy systems. Lastly some concluding remarks are given together with suggestions for future work and improvements of the Energy Investment model.

## 2 Energy Performance Contracting

An energy investor is a party conducting energy related investments in a client's energy system, and receives profit through energy cost saving over a contract period. The contract used is called Energy Performance Contract (EPC). The Energy investor conducts energy related investments in a building to achieve cost savings. Regarding investment costs, the energy investor can either obtain the financial capital internally or externally. If a third party is involved, a bank for instance, the contract becomes more complicated and is called an "Energy Performance Contract with third party funding". When the contract period expires the client takes over the energy system and benefits from the cost savings.

Energy Performance Contracting bears additional advantages for the client, besides not paying the investment costs. Examples of such benefits are; the ability to use a single contractor to do necessary energy audits, retrofits and guaranteed energy savings from a selected series of conservation measures. In general some of the energy investor's main tasks (although they vary in each contract) are as follows:

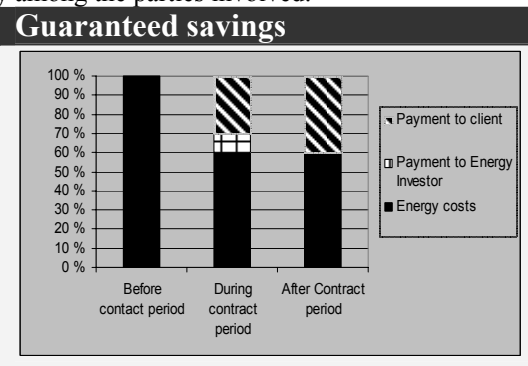
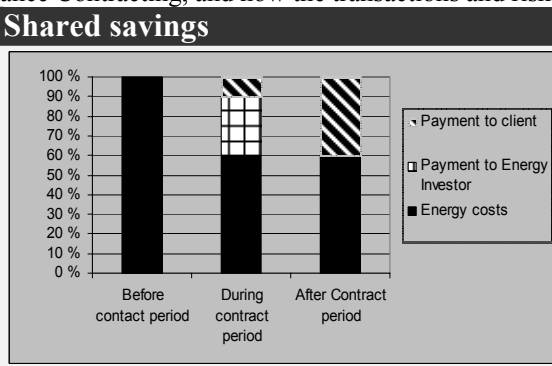
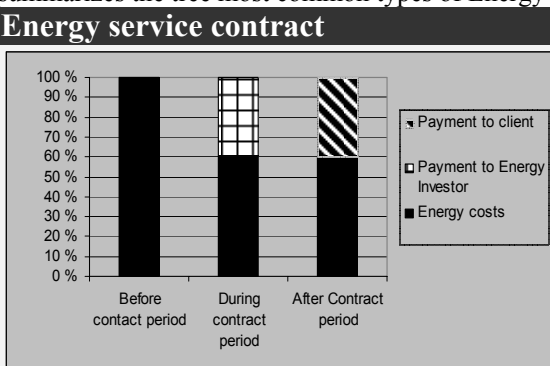
- Feasibility study of the clients existing building and energy system
- Plan and execute the optimal proposals from the feasibility analysis
- Provide funding
- Responsibility for maintenance
- Provide energy carrier(s) for the client
- Guidance in operating the new energy system, perhaps an alarm central for operational problems

As mentioned above, there are several ways to structure an Energy Performance Contract. The main difference is regarding the financial transactions between the involved parties. There exist three main forms of EPC, which are summarized in table 1. Within these main types of contracts there exist several methods on how the contracts can be structured. An example is regarding Shared Savings. In these types of contracts the energy savings are split between the energy investor, client and possibly a third party. There are several ways to share the savings. One way is that the parties can each get a fixed share during the contract period. Another way is that the energy investor gets the highest share of the savings until the investment costs are paid back. After the investments are paid back, the distribution of savings is altered so that the client receives a higher share than the energy investor. Further elaboration and discussion regarding the advantages and disadvantages of each type of EPC together with the types of buildings that are most suitable for such contracts, can be found in Zsak (2005). Besides a report written by PriceWaterHouseCoopers (2000) there has in general been little attention towards the use of Energy Performance Contracting in Norway. The main focus of the report by PriceWaterHouseCoopers is on marketing the concept of Energy Performance Contracting together with estimating an economic potential for the use of such contracts in Norway. However, the concept with Energy Performance Contracting has been studied in Europe and valuable references can be "A general introduction to EPC" written by The United States Department of Energy (1998) together with "Guidelines for success regarding EPC" written by Energieverwertungsagenturs (2000). In the mean time there has in general been minor effort devoted to how the uncertainty in costs of energy carriers and technologies affects the

profitability for an energy investor. The different types of risk an energy investor bears and how to model these risks are further discussed in the following chapters.

Table 1: The table summarizes the three most common types of Energy Performance Contracting, and how the transactions and risks vary among the parties involved.

	Energy service contract	Shared savings	Guaranteed savings
<b>Transactions between the involved parties</b>	<p><b>Investment:</b> The energy investor provides either internal or external (using a third party) funding and the client is free of all initial charges regarding the investment in the energy system.</p> <p><b>During the contract period:</b> The energy investor gets the whole benefit of the energy related cost reductions<sup>1</sup></p> <p><b>After the contract period:</b> The client owns the new energy system and gets full benefit of the energy-related cost reductions.</p>	<p><b>Investment:</b> Same conditions as in the Energy service contract</p> <p><b>During the contract period:</b> The benefit of energy related cost reduction is split between the energy investor and client according to a pre-arranged formula agreed in the contract. A common approach is that, in the beginning of the contract period, the energy investor gets substantially more of the savings than the client. During the end of the contract period the savings are shared more equally between the parties<sup>1</sup>.</p> <p><b>After the contract period:</b> The client owns the new energy system and gets full benefit of the energy-related cost reductions.</p>	<p><b>Investment:</b> The client provides funding for the investment<sup>2</sup>. The analysis, development and design of the new energy system are done by the Energy investor.</p> <p><b>During the contract period:</b> The client gets most of the energy related cost savings, although all costs related to analysis and design of the new energy system must be repaid to the energy investor.</p> <p><b>After the contract period:</b> The client owns the new energy system and gets full benefit of the energy-related cost reductions.</p>
<b>Risk</b>	The energy investor bears the credit risk, responsibility of savings in energy costs is agreed upon in each contract.	The energy investor bears the credit risk, responsibility of savings in energy costs is set in each contract.	The client bears the credit risk and the energy investor holds the risk of cost reduction being higher than the investment costs.
<b>Length</b>	Usually 3 – 7 years, needs to be specified in each contract.	Usually 5-10 years, needs to be specified in each contract.	Usually 5-10 years, needs to be specified in each contract.



<sup>1</sup> It is the energy investor's job to pass on the third Parties' share of the cost savings.

<sup>2</sup> If the client is a municipality this type contracting can be very useful since municipalities often get cheaper loan than private parties.

## 2.1 The process of performance contracting

To provide an understanding of how the process for an Energy Performance Contract works, which is necessary for understanding the model developed in this thesis, a short overview of the contract process is given in this subchapter. Although the process might vary from project to project it has, in this thesis, been endeavoured to divide the process into five general steps, namely Analysis & feasibility study, Revision, Implementation, Operation and Closure of contract. The steps are shown in figure 1.

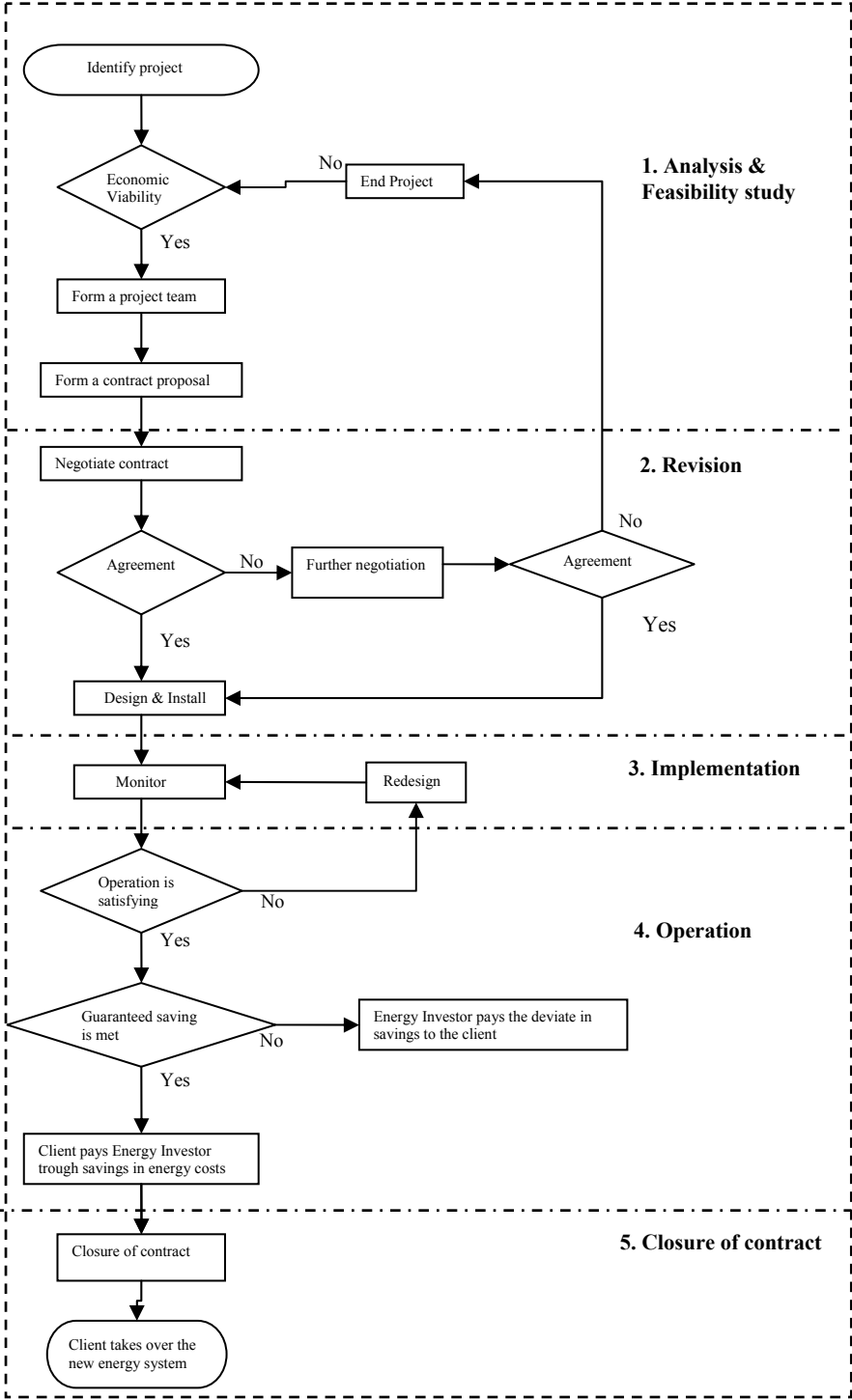


FIG 1: General steps in an energy performance contract.

As can be seen from figure 1, the first step is to conduct a *feasibility study*. The purpose of this study is to determine if a project is profitable or not. Several factors, such as the size of both the client's energy consumption and the possibility of cost savings regarding the energy consumption, are important. One downside regarding the use of energy service contracts is the possibility that the savings do not exceed the costs of carrying out and monitoring the project. If the analysis shows economic viability of a project, the next step is to form a project team. Since the process of designing, implementing and operating an energy system is a complex task, it could be useful to include different types of project team members with both operational background and financial training. Based on the analysis, a contract proposal is created. The second step in the process is *revision* of the contract proposal. If there is a disagreement between the energy investor and the client, negotiations may take place. If the negotiation does not lead to an agreement the project is ended. If the negotiations do lead to an agreement the next phase is *implementation*. This phase mainly concerns installing the proposed energy system although some technical designing may be needed. The last phase is *operation* of the implemented energy system. This phase can include maintenance and monitoring as well as providing the energy carrier(s) for the client. The degree of involvement of the energy investor is specified in each contract. There is a chance that the operation may not turn out as expected. In such cases the energy investor may need to install extra technology or redesign some of the energy solutions. If there is a deviation from the savings guaranteed by the energy investor, the energy investor must pay the deficit to the client. In cases where the expected cost savings are reached, the client pays the energy investor using the cost reductions acquired through the new energy system. When the contract period is over, the last phase; *closure of contract*, is reached. From this time onward the client takes over the new energy system and fully exploits the savings in energy related costs.





### **3. Energy system investments**

There are basically two main investment categories of energy investments in buildings. The first are investments related to the building envelope. This can for example be isolation of walls and windows. The second category is related to how the heat demand in the building is served. Although both categories are modelled in the Energy Investment model only the second category will be discussed. Further elaboration on building related investments can be found in Zsak (2005).

However, there are several different heating systems and technologies to choose from when constructing a building. If the building already exists, there may be some limitations as to which heating systems are appropriate. The reason for this is that each heating system needs an infrastructure. For example, switching from an energy system based on direct electrical heating to an energy system based on water heating, once the building already exists, can be quite a large and expensive project. Pipes in the floor or radiators need to be installed which can require extensive renovation. Furthermore, the energy system chosen should also be in alignment with the energy supply in the particular area. If there are no pellets providers in the area, a heating system with a bio mass fired boiler would probably not be the best choice. When choosing heating systems based on several energy carriers, the cost structure of the different energy systems are the main decision parameters for which energy carriers to choose, and how to combine them in the heating system.

#### ***3.1 Cost structures for the different energy systems***

The various energy systems have different cost structures. For some energy systems the investment costs are relatively low compared to others, but the cost for the energy carrier(s) might be higher. Therefore the future costs and income are highly dependent on the heating system chosen for the particular building. It is a known fact that investing in technology for renewable energies are often more expensive but in return the price paid for energy consumption (the price of the energy carrier) is mostly cheaper than for non-renewable energies. As the reader might have realised, it is exactly these differences among the energy carriers that can make investments profitable for an energy investor.

#### ***3.2 Energy flexibility***

There is a growing amount of attention being directed towards combining several energy carriers to achieve energy flexibility and water-based heating systems are especially suitable for this purpose. Here, energy flexibility refers to the possibility to switch between at least two energy carriers in a way that is preferable for the user. There are several reasons both from the long term and short term perspective, for combining energy carriers to gain flexibility and reduce costs. From the long term perspective, combining several energy carriers may for example increase security of energy supply. From the short term perspective, the different energy carriers are used in a way such that the different energy efficiencies and energy prices for the heating systems are combined in order to minimize the operating costs. Since the heat demand varies throughout the year, there will be a corresponding variation as to which energy carrier that will be the most optimal to use in each time interval.

### 3.2.1 Duration curve

When installing a flexible heating system, two definitions are important; peak load and base load. The peak load will occur when the heat demand is at its highest. The energy carriers used for peak load have different cost characteristics than the energy carriers used to serve the base load. The typical case is that the energy carrier serving the peak load has relatively low investment costs but higher energy costs and vice versa for the energy carrier serving the base load. According to Holen, Owren, Ulseth and Dahl (2003) the percentage distribution between the peak load (PL) and base load (BL) can be calculated using the below Equation for the particular energy system that is considered

$$(I_{BL} - I_{PL})a = T \left( \frac{e_{PL}}{\eta_{PL}} - \frac{e_{BL}}{\eta_{BL}} \right) \quad (3.1)$$

$I$  is the marginal investment cost for the peak load and the base load [NOK/kW] and  $a$  represents the annuity factor. Further  $e$  is the energy price [NOK/kWh] for the peak load and the base load.  $\eta$  represents the efficiency of the two energy carriers and  $T$  is the time interval where the peak load is used. When the distribution between the peak load and base load is calculated, a duration curve is required in order to separate the peak load and base load. The duration curve is constructed by ranking the heat demand from the highest to the lowest, together with the time usage for the different demands throughout the year. An example of a duration curve is shown below.

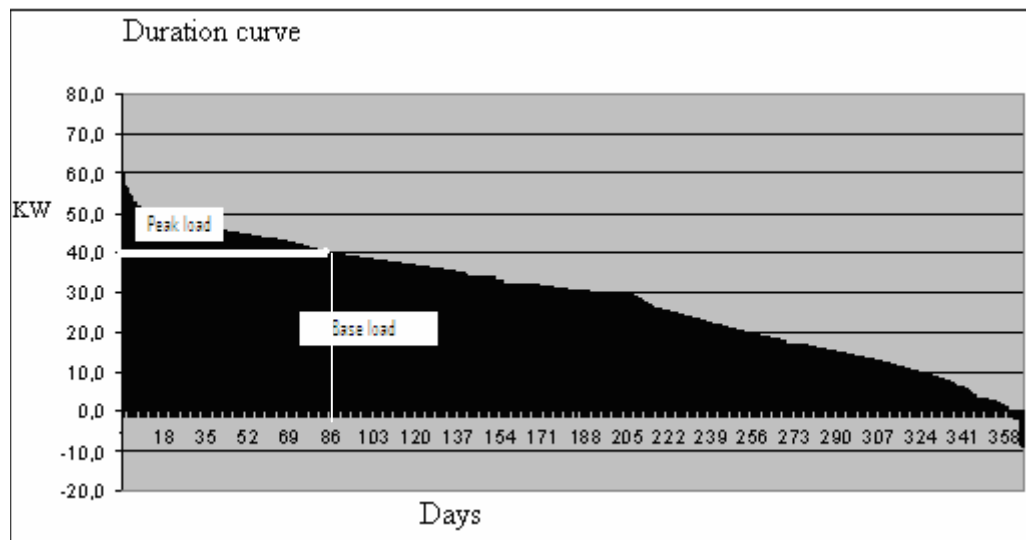


Fig 2: Duration curve for an industry building Holen et al (2003)

In the figure a white line separates the peak load from the base load, derived by finding  $T$  using Equation 3.1 and drawing a line vertical to the the x-axis until it intersects with the duration curve. The peak load is then the area above the horizontal line between the intersection and the y-axis. As can be seen from figure 2, the base load has a maximum power of 60-70% of the peak demand. This implies that the peak load runs approximately 86 days a year. The energy carrier for the peak load serves the demand above 60% of the max capacity needed during these days. The figure shows that when the demand exceeds the base load, the demand for the peak load energy carrier varies with time but use of the base load energy carrier is constant and the base load runs at maximum capacity during the time interval.

Further, when the heat demand is below the base load level, the base load energy carrier serves the whole load. There are many factors that affect how the heat demand for a building varies throughout the year. Some of them are building type and isolation thickness, but according to Holen et al (2003) the most decisive factor is the weather. This fact will be used in this thesis when modelling the base line to which the energy savings are measured against. The discussion of how to create baselines will be done in chapter 11. In the meantime an overview of the different risk factor affecting the profitability for an energy investor will be given.



## 4. Risk factors for an Energy investor

An energy investor is exposed to a variety of different issues regarding risk and uncertainty when investing in a project. The information available to the energy investor may for example be incomplete or contain errors. In this thesis risk refers to the possibility that an unexpected event can adversely affect the value of the investment in improvement of a building envelope or an energy system<sup>3</sup>. To identify the different risk factors of importance, an analysis of net present value for an energy investor has been conducted. Further the cost drivers and the parts that are value-additive to the net present value are identified. The three main categories that will be considered are investment costs, income and expenses.

The first category considered are the investment costs, which are mainly driven by the cost of technology. Although the fact that lesser degrees of freedom regarding choice of technology<sup>4</sup> and time delays can severely affect the need for higher investment costs, these themes will not be discussed in this thesis but can rather be read in Zsak (2005). As mentioned renewable energies often bear larger investment costs for the technology and infrastructure, but in return the renewable energy carriers are mostly cheaper to use than non renewable energy carriers. How these cost structures will develop in the future is difficult to predict, especially regarding technology costs for renewable energies. The difficulties are mainly due to uncertainty in how new technology will develop and the unknown speed of market penetration.

During the contract period of an EPC the energy investor can also experience a variety of uncertainties in expenses. Operational expenses, maintenance and training expenses can all deviate from the forecasts. If the energy system is not operated correctly it can lead to higher energy consumption than expected. Depending on the terms of a contract the energy system can either be operated by the energy investor, by the client or as cooperation between the two. If the client chooses to operate the system himself, it can cause extra uncertainties for the energy investor due to a client's possible lack of operational knowledge or the presence of asymmetric information. Since the energy investor has guaranteed a certain amount of savings, and thus will pay the deviation to the client, the client can view the deviation as "free energy" and Asymmetric information can arise. In opposite if a client receives a share of energy savings exceeding the agreed up on level it may drive the client to endeavour energy savings. Therefore how the contract is structured regarding operational tasks and share of future income can be decisive for an energy investor's uncertainty regarding operational costs. Additionally, maintenance costs may also be needed if unforeseen breakdowns or outages of the energy system happen. Further uncertainties may also arise with the use of new technology on the market which should also be taken into consideration when decisions regarding a new energy system for the client are made. Lastly, if the energy investor provides the energy carrier(s) for the client he will pay the market price for the energy. Deviations between the agreed upon price, that the energy investor receives from the client and the market price, which the energy investor pays when providing the energy carrier for the client, will affect the profit for an energy investor.

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<sup>3</sup> At this stage it can be valuable to realize that uncertainty is not the same as risk. Uncertainty is just the concept that limited knowledge and understanding of the future simply prevents us from forecasting the future and predicting the consequences of our decisions with 100 % accuracy.

<sup>4</sup> See chapter 3

Income represents the third main category of risk and uncertainty for an energy investor. Since the energy investor receives payment through savings in energy related costs for the client, the baseline, which the performance is measured against, needs to be clearly defined in the contract. Normally, if it is a redevelopment project regarding an existing building, a mean value of previous year's energy bills can be used as the baseline. Alternatively, if the project considers a new building normative values for energy use in that particular building category can be used instead. The Energy Investment model in this thesis is made flexible so that both methods can be used, how this is done will be further elaborated in chapter 14. The measure of the baseline can be a risk factor itself. Previous bills may not include future rise of energy use, and costs for energy may have been extra high or low, in the period of measurement, compared to previous years. Figure 3 summarize the above risk factors together with showing a simple overview of the various cash flows that create uncertainty for the energy investor

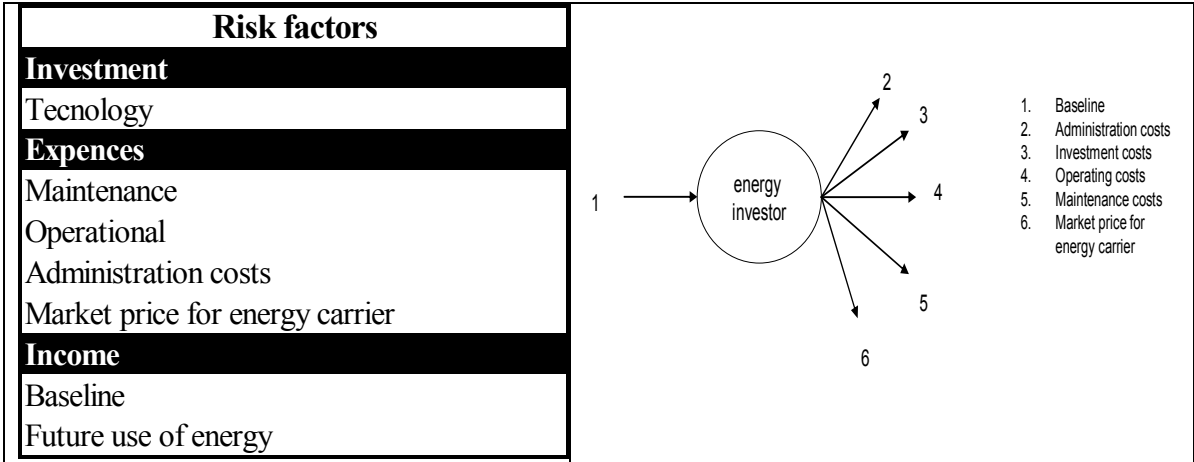


FIG 3: Overview of the risk factors for an energy investor

In the following chapters there will be a further discussion of the risk factors related to the cost of technology together with risks due to the baseline, future energy demand and market price of the energy carrier(s) chosen. These risk factors are the most convenient and easy to measure among the above mentioned. Hence these will be further discussed and modelled in this thesis.

## 5. Risk and uncertainty in development of technology cost

Both uncertainty in cost of technology and maintenance will affect the profitability for an energy investor. Uncertainties regarding maintenance costs are mainly in connection with the lack of experience regarding previous use of the technology. In this thesis it is assumed that these uncertainties are reflected, through learning curves, in the investment costs of the particular technology in consideration.

### 5.1 Learning curves

Despite cost reductions accompanying the technical upgrading and deployment of renewable energy technologies on the Norwegian market, most of them are still more expensive than competing technologies for heat and electricity generation. It can be difficult to predict future developments and how technology will drive down the cost of investments, especially regarding renewable energies. Additionally, it is difficult to foresee the time it will take before market penetration allows the prices to drop to the level of conventional technology for energy use. One way of approaching the challenge is by using Causal loop diagrams (CLDs), which is a way of system thinking. Using CLDs gives the benefit of holistic overviews on how changes in connected variables affect each other. Figure 4 gives a simple demonstration on how investments and decisions regarding new technologies affect future scenarios on prices of the technologies related to the energy carriers discussed in the thesis.

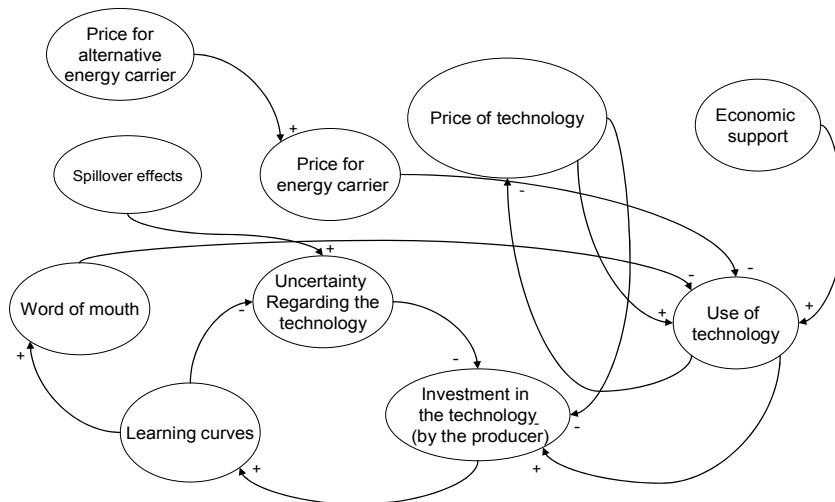


FIG 4: A causal loop diagram regarding technology costs

In this Causal loop diagram, the short descriptive phrases represent the elements which make up the sector and the arrows represent the causal influences between these elements. Each link between the elements includes a sign (either + or -). If a causal link from one element A to another element B is *positive* (+) then a change in A produces a change in B in the *same*

direction. If a causal link from one element A to another element B is *negative* (-) then a change in A produces a change in B in the *opposite* direction.

Figure 4 illustrates that there are several elements that both directly and indirectly influences the price and uncertainty in connection with the technology. Probably the most known phenomenon is decreasing uncertainty to scale, and learning or experience curves can be a representation of such processes. As more experience is gained with a particular technology, the larger are the improvements in performance, costs and other important technology characteristics. How rapidly costs fall due to improvement, or in other words how high the improvement rates are, often depends on how mature the technology is. Some technologies, for instance fuel cells, are in the “pre-commercial” phase. The cost of such technology is very high, however the improvement rates are high as well. After the “pre-commercial” phase the improvement rates tend to decline due to, among other factors, an establishment of infrastructure and support systems for the respective technology. The technologies considered in this thesis are all beyond the pre-commercial stage, but each have different improvement rates that are partly determined by how well the technology is developed. The learning effects are also influenced by the investment in a technology. Often, the more resources that goes in to R&D, the steeper the learning curve becomes. Further, use of the technology can be stimulated with some kind of economic support, rules or restrictions that favours the technology, but also *price* and *word of mouth* are important. Finally, lower energy price will most likely stimulate the use of the belonging technology.

Technologies can often be related to each other. Stoves for bio fuel and boilers for heating oil can be considered as an example. Improvement for minimizing heat loss in a bio fuel can also often be used on a boiler for heating oil. The two technologies have the same end-user application but use different fuels or energy carriers. This means that improvement in one technology can be transferred to other related technologies. This is often referred to as spillover effects. Spillover effects would influence lower prices and uncertainty for a particular technology. Modelling spillover effects can be a complex task, and since relations among the technologies are difficult to predict, it will not be covered in this thesis. Further reading on modelling these effects, and how to group technologies in to clusters, can be found in Forray and Grubler (2000).

The discussion above is an overview on what characterizes the pricing process for a particular technology. How to use the above characteristics to model a price process for a technology will be considered is further elaborated in Appendix 1.

## **5.2 The investment decision and flexibility**

In relation to energy investments, option analyses are sometimes made. The reason for this is that these investments, which include major decisions on whether to invest now or wait, utilize operational flexibility or not, replace now or wait, can be rather expensive and are in most cases irreversible. When doing a discounted cash flow analysis one assumes that the strategic decisions are made initially with no recourse to choose other pathways or options in the future. In contrast, when using real option theory, instead of setting up a passive strategy with net present value, one takes the strategic decision-making process into consideration. Hence makes it is possible to include the value of flexibility. The flexibility in this thesis represents the possibility to switch between energy carriers or technologies to increase the profit for an energy investor. In this context the discussion is regarding created options which,



in contrast to inherent options<sup>5</sup>, are not free of costs. Although using option theory is one way to overcome risk, this chapter shows that combining real options with the concept of using an Energy Performance Contract will in most cases be unfavourable for the energy investor.

There are several reasons for an energy investor not being interested in buying real options. The main reason is that the energy investor gets the repayment through energy savings in the client's energy system. By introducing a created option this would reduce the margin between the costs of an investment and the savings due to the energy installations and therefore reduce the income or cash flow for an energy investor. Since an energy investor considered in this thesis is a private investor the concern will firstly be to profit or get paid back from the investments in the client's energy system during the projects lifetime. To put it in another way, buying an option is to give up an amount today in order to get future potential profit. In contradiction, the energy investors are concerned about getting paid in the time between the date for purchase of the option and the exercise date of the option. Further, the structure of energy system investments in buildings are such that once investments are made in infrastructure for a flexible energy system, not using it would only reduce profits. This fact is better understood in view of a practical case. Consider the option of flexibility, which means that there are investments made such that the user of an energy system can switch between several energy carriers or technologies<sup>6</sup>. This is an example of a created option. To be able to have this flexibility the building has to have a water based heating system, or major changes has to be done with the building almost every time the user wants to switch from one energy carrier to another, which again will be far too costly. Once investments in infrastructure (or pipes for a water based heating system) are made, not using them would only lower the profit margin for an energy investor. Investing in pipes and not using the water based heating system but rather heating with electric ovens, will be a sort of worst case scenario. Heating with electric ovens involves high energy costs and in addition the infrastructure for water based heating system is more expensive than investing in non water based heating systems. Therefore when investing in water based heating system it should also be used by for example heating with a pellets-fired boiler if the heating costs are lower than heating with electric ovens. The above thoughts also apply to the option of expanding an investment. Investing in the infrastructure today and not using it is far too costly.

Some might ask whether it is possible to separate, in time, the investments regarding building envelope improvements and investing in the energy system for a client. An energy investor would then have the option to wait and see what happens to technology costs before investing in an energy system. The problem can be considered as an option to expand where the energy investor already has a contract with the client and has the possibility to expand the investments. When investing in improvements in a client's building envelope, this will be done with the objective to minimize the heat demand so that the energy investor can benefit from as much cost savings as possible<sup>7</sup>. However this collides with investing in a water based heating system later on. A water based heating system is more profitable the higher the heat demand is. The dilemma, whether it is viable to invest in a water based heating system if a building is built with a very low heat demand, is a major discussion in the business today.

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<sup>5</sup> Inherent options are free and one just needs to be aware of their presence. Inherent options can for example be stopping project or business activities, although their exercise price may be very high

<sup>6</sup> Here, switching between technologies can either be switching energy carrier for example from an oil-fired boiler to a pellets-fired boiler or simply without change in energy carrier for example from an electricity boiler to a heat pump.

<sup>7</sup> Since there is an upper limit where the costs for investment in building related improvements exceeds the potential savings. There is made a presumption that this limit is not reached when presenting the statement.

Due to the above discussion, option analysis can be said to be less important when analysing the energy investment problem, and will therefore not be considered further in this thesis. Instead the net present value will be used to derive the economic value of an investment for the energy investor together with other methods, such as value at risk and structuring contracts in a way that minimizes asymmetric information to overcome risks are introduced.

## 6 Uncertainties in the cost of the energy carrier

As discussed in previous chapters, the energy investor gets its payment through the savings in the client's energy system measured against a baseline. When this is done the energy investor and client agrees on a price for the new energy carrier or the heat used by the client after the investment. The total savings using an Energy Performance Contract can therefore be described by Equation 6.1;

$$TS = \sum_{y=1}^T \sum_{m=1}^{12} \left( CB_m - AEP_{m,y} * OEC_m * \left( \frac{1-REC}{100} \right) \right) \quad (6.1)$$

m - Number of month<sup>8</sup> in a year (Jan = 1, ..., Dec = 12)

y - Number of year in a contract, [years]

T - Total project period [years]

TS - Total savings during the contract period [NOK]

CB<sub>m</sub> - Cost of client's old consumption in month m [NOK]

OEC<sub>m,y</sub> - The client's old energy consumption, in month m [kWh]

REC - Reduced energy consumption after investment [%]

AEP - Agreed upon price for energy consumption during month m in year y of the contract period [NOK/kWh]

How the total share is allocated among the involved parties is agreed in each individual contract. If the energy investor provides the energy carrier(s) for the client, the cash flow from the client to the energy investor would be the investors share of financial savings plus the agreed up on price for energy consumption after investment. However the energy investor will pay the market price for the energy carrier provided for the client. By incorporating the market price of energy into the cash flow received from the client the profit before operating, maintenance and administration costs are paid will be as in Equation 6.2;

$$P = \sum_{y=1}^T \sum_{m=1}^{12} \left( SE_{m,y} + (AEP_{m,y} - MEP_{m,y}) * OEC_m * \left( \frac{1-REC}{100} \right) \right) \quad (6.2)$$

P - Energy investors profit before operating, maintenance and administration costs [NOK]

MEP<sub>m,y</sub> - Market price for energy carrier during month m in year y [NOK/kWh]

SE<sub>m,y</sub> - Savings for an energy investor during month m in year y [NOK]

Equation 6.2 illustrates the uncertainties due to the deviations between the agreed upon energy price and the market price for the energy carrier. The uncertainties can therefore be represented with two possible outcomes.

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<sup>8</sup> The reason for considering energy consumptions as a function of time is that it can vary severely during the different months and seasons. However, commercial or industry buildings will have a more stable energy use than residential buildings.

- $AEP_{m,y} < MEP_{m,y}$  ; when the agreed upon price for energy is below the market price for energy
- $AEP_{m,y} > MEP_{m,y}$  ; when the agreed upon price for an energy carrier is above the market price for energy

If the agreed upon energy price is below the market price, the guaranteed energy saving may not be reached and the energy investor has to pay the deviation to the client. If the market price for the energy carrier is below the agreed upon price, the result would be savings beyond the agreement. How the margin is to be allocated between the energy investor, client and possibly a third party, depends on the allocation of the risk between the parties and has to be settled in each individual contract.

In the Energy Investment model agreed upon energy price will be modelled using stochastic variables.

## **6.1 Characteristics in energy prices**

When considering prices of energy carriers it is important to be aware of the dynamic interplay between producing and using; transferring and storing together with buying and selling. Thus some special characteristics for prices of energy carriers are described below.

### **Delivery**

Commodities are based on actual delivery. Fuel oil and pellets are often delivered by tank car. Electric energy requires a power grid and in some places natural gas, if not delivered by tank cars, is delivered in pipes. However, transfers of the commodities can be relatively troublesome since great resources are needed. Therefore temporary delivery problems might occur. Further, such problems can often affect the commodity prices.

### **Storability and storage costs**

Some of the energy carriers can be stored over a time period but for electricity the only efficient storage method is by using hydro storage dams. Due to lack of capacity in connection with hydro storage dams, electricity is often said to be non-storable<sup>9</sup>. The lack of storability leads to the fact that the normal arbitrage cash-and-carry strategy is not applicable for pricing electricity commodities and a leasing market does not exist Unger (2001). Although gas, bio fuel and heating oil are also subject to storage costs these are still only a fraction of the costs for storage of electricity and hence are negligible in this context.

### **Volatility and price jumps**

The risk of temporary shortages causes energy prices to be far more volatile than ordinary asset prices. A jump is a phenomenon that occurs in the energy market. This happens when extreme situations of price shifts occur, and can for example be caused by the entry of a new competitor into a market with few firms, so that price suddenly drops. This situation can occur in the market for pellets. If there is only one local provider of pellets, the entry of a new could cause the prices to drop considerably. This is especially due to the fact that

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<sup>9</sup> The word non-storability can sometimes be misleading since electric energy can be transformed into other stable energy forms, and then, when needed, re-transformed back to electrical energy. Due to high costs and big losses in the transforming process, this form of storability is precluded due to economical reasons

transportation of pellets is rather expensive so the cost for pellets in each area is set by the local provider(s).

### **Non normal distribution**

Non-normal price distributions are usual for energy commodities. They exhibit what is typically called fat tails (kurtosis), further elaboration can be found in Appendix 7. This means that the probability for price changes with extreme or very high magnitude compared to the normal distribution are much higher. Therefore, when using models based on normal distribution for modelling energy prices one must be aware of the under-estimation of the risk factors, or the possibilities for extreme price developments

In addition to the characteristics above, decentralization and short maturity of the market together with low market activity (liquidity) distinguish the prices of energy carriers compared to investment assets from regular money markets. These facts affect the quality of the price models that is constructed and makes the prices more uncertain.



## 7. Uncertainty in baseline and future energy savings

Constructing an accurate baseline requires large quantity of data form several years back in time. The reason for such a requirement is both the uncertainty in the cost of an energy carrier and the unpredictable weather. If the baseline is calculated, based on bills dating only a few years back, the numbers may not be as accurate due to, for instance, energy prices being particularly high during the period, or unusually low temperatures resulting in an above average heat demand. If a baseline for energy use is constructed using measurements of energy consumption over several years it might look like figure 6.

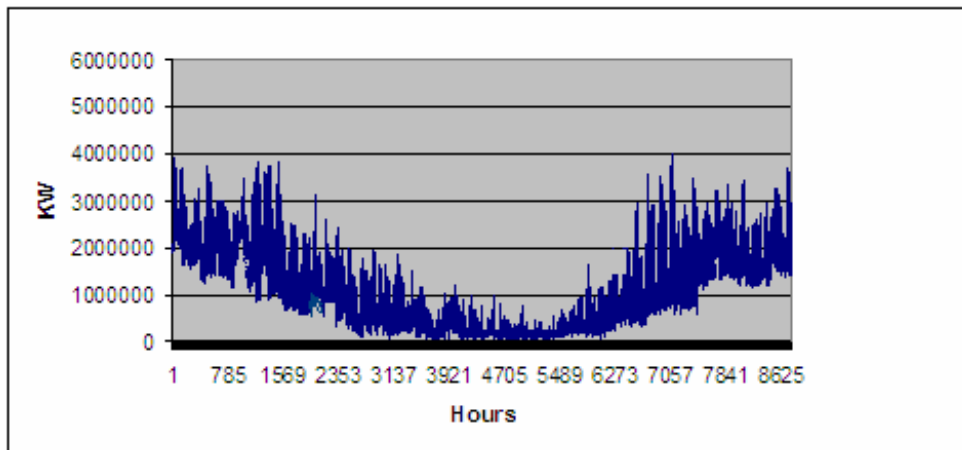


FIG 5: Shows how the heat demand varies trough the year with an hourly time resolution<sup>10</sup>

Since the heat demand in a building through the year is very dependent on the weather, a design reference year curve (DRY-curve) could be used for more accurate predictions. The curve for the design reference year shows how the temperature may vary throughout the year as an average of the last thirty years. Figure 6 shows a design reference year curve for Oslo constructed in 2005 Pedersen (2006).

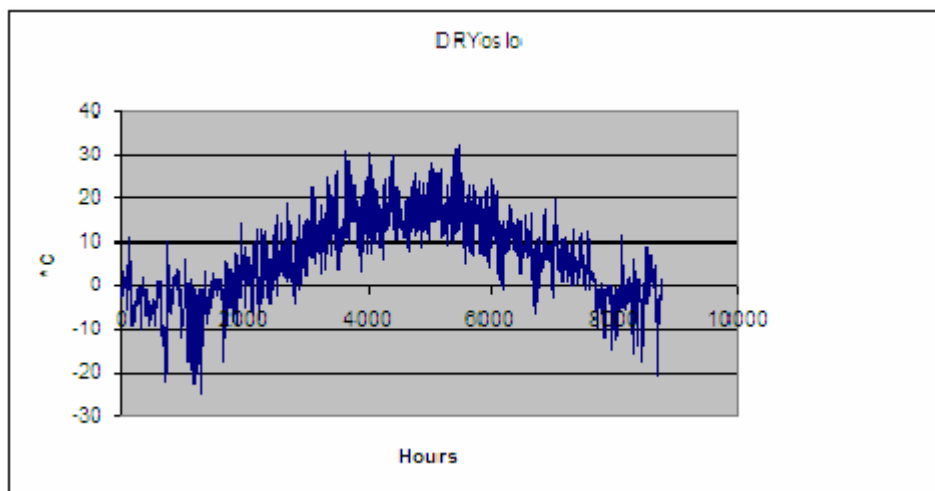


Fig 6 DRY- curve for Oslo, constructed in 2005, based on measurements regarding the weather for the last 30 years.

<sup>10</sup> Pedersen (2006)

It can be noticed that when comparing the two curves the DRY-curve is almost a mirror reflection of the heat demand. Therefore figure 6 might be used for more accurate predictions regarding the baseline.

Regarding the future energy use the client might take out more energy than predicted to increase comfort which would decrease the level of energy savings and asymmetric information might occur. The uncertainty can be controlled, to some extent, if the energy investor operates the client's energy system. Another scenario of increased energy demand might occur if the client's building is an industrial building where the expected production rises in the future. Therefore the contract between the parties should be constructed with the awareness that these scenarios might occur.

Due to the increased focus on energy management, measurements of energy use for different buildings have been more common during the past years. This will make construction of baselines more convenient in the future. The more measurements that are available, the better baselines can be constructed.



## 8. Energy prices and stochastic modelling

This chapter will explore the main stochastic price processes applied to model future energy prices for heating fuel, gas and electricity. The prices for gas and heating oil were modelled using a simple mean reverting model found in Lucia and Schwartz (2000). The electricity prices were modelled using a short term-long term model suggested by Schwartz and Smith (2000). Regarding modelling of future pellets prices, three different scenarios were assumed and a price prediction for each scenario was made. The scenarios will be discussed in the next chapter.

The excessive number of fundamental price drivers, presented in chapter 6, cause extremely complex price behaviour and thus makes the price for energies difficult to model. There exist several models for commodity price evolution dependent on which factor or price driver one wishes to consider or emphasize in the model. However, this chapter will be limited to a short discussion of the two models used in the Energy Investment Model and other models will only be referenced for greater detail. Due to the requirement of combining several energy carriers in the Energy Investment Model, computational viability is also considered when choosing the models. Further, basic theory on price models together with reasons for choosing the two models used this thesis can be found in Appendix 2.

### 8.1 One factor-Mean Reverting model (Gas & heating fuel)

The mean reverting model ensures that prices gravitate over time toward the mean reversion price levels. One way of modelling mean reversion can be as shown in Equation 8.1

$$dX_t = \kappa(X^* - X_t)dt + \sigma dW \quad (8.1)$$

$\kappa > 0$  and  $X(0) = X_0$ .  $X_t$  represents the logarithm of the prices. Further,  $X^*$  operates as the mean of the logarithms of spot price in time  $t$  and is the element which the price tends to revert. Equation 8.1 shows that the expected change in  $X$  depends on the difference between  $X_t$  and  $X^*$ . If  $X_t$  is greater (less) than  $X^*$  then the price is more likely to fall (rise) over the next short interval of time.  $X^*$  is often set to be the long run marginal cost of production for the particular commodity modelled. Further  $\kappa$  is the mean reversion rate which represents the speed at which prices revert. As mentioned above, the mean reversion rate is always greater than, or equal to, zero. Higher numbers of  $\kappa$  correspond to faster mean reversion.

In this thesis the prices also include a deterministic function, namely  $f(t)$ , in addition to the simple mean reverting process described above. The additional function represents the seasonal variations in the energy prices. For cold seasons the prices tend to be higher than for the warm seasons which is accounted for by using the cosine function<sup>11</sup> shown in the below Equation Lucia and Schwartz (2000)

$$f(t) = \gamma \cos((t - \tau)2\pi) \quad (8.2)$$

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<sup>11</sup> The seasonal pattern can also be modeled by using a constant piece-wise function. The use of such dummy variables can give flexibility all though they suffer from the fact that they are very sensitive to anomalies in the sample analyzed. Further information can be found in Pilipovic(1997)

The cosine is measured in radians and  $\gamma$  is the strength of the annual seasonal factor. Further  $\tau$  represents the displacement factor or in other words the time of annual peak. By including the seasonal pattern the total price process will be

$$S_t = EXP(X_t + f(t)) \quad (8.3)$$

## 8.2 Long term-Short term model (Electricity)

In the Energy Investment model the electricity power prices will be modelled with the Long-term/ short-term model suggested by Schwartz and Smith (2000). As indicated by its name, the price process has two stochastic variables which allows for both mean reversion in short-time prices together with uncertainties in the long-time equilibrium level to which the prices revert. The two factor price process is as follows;

$$\ln(S_t) = X_t + \varepsilon_t \quad (8.4)$$

The factor  $X_t$  refers to the short term deviations that are defined as the difference between spot price and equilibrium price and represents the changes that are not expected to persist. The process is expected to follow a mean reversion processes as described in Equation (8.1) above, which in this case reverts towards zero (also called an Ornstein-Uhlenbeck process) instead of  $X_t^*$ . The Short-term process is described by

$$dX_t = -\kappa X_t dt + \sigma_x dW_x \quad (8.5)$$

As before  $\kappa$  represents the rate at which the short-term deviations are expected to disappear. The long-term process, also called the equilibrium level, follows a Brownian motion and is described by

$$d\varepsilon_t = \mu_\varepsilon dt + \sigma_\varepsilon dW_\varepsilon \quad (8.6)$$

The drift in the Equation above represents the certain long-term aspects that are considered to be important for the evolution of the price. Further  $dW_\varepsilon$  and  $dW_x$  are increments of pure wiener process and are correlated as;

$$dW_\varepsilon dW_x = \rho_{x\varepsilon} dt \quad (8.7)$$

The short-term and long-term factors can not be observed directly, but are estimated from analysis of spot and future prices.

In addition to the factors described above, the two-factor model will also have a seasonal component described Equation 8.2 The total price will therefore be given by

$$S_t = EXP(X_t + \varepsilon_t + f(t)) \quad (8.8)$$

### 8.3 Energy markets and forecasts of energy prices

The energy markets vary a great deal among the energy carriers in Norway. Due to the fact that some of the energy carriers do not have a deregulated and open market, prices often vary between the regions and suppliers in Norway. For the energy carriers that do not have a deregulated central market in Norway, it is common that the local distributor and end user agrees on a contract where the price and quantity are set for a particular time horizon, often one year. The terms can vary considerably between the contracts, and are mostly dependent on the end-user's heating alternatives. If the end-user owns a flexible heating system it gives higher power when bargaining since the local distributors then need to out-compete the alternative energy carriers both in price and comfort.

To calibrate the different parameters in the above price models, future quotes, if available, were used. Therefore the future quotes for the three energy carriers will be discussed below. For the future beyond 5 years, where there are no forward quotes traded, predictions, based on macro economic models was used. The predictions are made by *The International Energy Agency* and *Markedskraft*. It is appropriate to remind the reader that the predictions are not the same as future or forward prices; they only reflect the opinion/predictions of the single analyst or company doing the analysis, and not the market as a whole. In addition forward prices are also risk adjusted.

#### 8.3.1 Electricity

Electricity is the energy carrier which has the most developed and deregulated market in the Nordic countries. The Nordic Power exchange is called Nordpool. The spot market at Nordpool is divided in two parts, namely Elbas and Elspot. In addition, there is also a financial market with futures, forwards and options on forwards. The figure below gives an idea of some of the markets and the products traded at each market

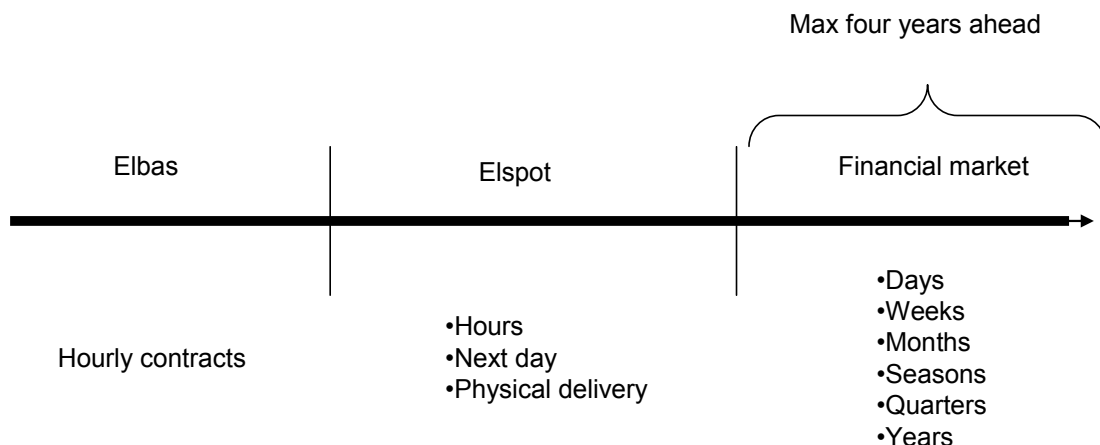


FIG 7; The various contracts traded at Nordpool

Elbas is a market for balancing contracts and the contracts are traded each hour at the market. The spot price is traded each hour for actual physical delivery, and the power is delivered the

day following the day of purchase. The different prices are set by participants handing in bids before noon on the previous day. The bids contain prices and volumes for each of the 24 hours over the next day. Nordpool then creates demand and production curves for the following day. The equilibrium of the curves is set to the system prices which are the reference prices for the futures traded. Due to congestion (non-perfect transmission lines), different area prices are derived. All the electricity prices used in this thesis originate from Nordpool's database.

It is a challenging task to predict the future electricity price in the Nordic area due to the fact that input variables have been highly volatile in the past. Also the outcome depends on several political decisions that have not yet been finalised. By using the Kalman filter, a forward curve for electricity was generated. The forward curve is solely based on market data. Since market prices are only available for three years forward, the Kalman filter automatically takes the drift for the three years and assumes the same trend for the following years. Therefore the values, from the Kalman filter, can be uncertain in the distant future. This chapter will therefore elaborate some of the predictions based on a market analysis done by Markedskraft (2005)<sup>12</sup>. The forecasts are used for comparison to, and analysis of, the numbers that were calculated from the Kalman filter.

The development in electricity prices can not be considered independently from the price development in other energy carriers. As will be discussed in the following chapters, the fuel prices are assumed to come down from today's high levels. Further, some general assumptions on future capacity for electricity in the long-run are made. It is assumed that most of Norway's future marginal electricity production will originate from Combined-cycle gas turbines (CCGTs). At the present time there is a planned gas-fired power plant at Kårstø, which is projected to be 420MW and 3,5 TWh/year in power production. The project is supposed to be realised by the end of 2007. In addition, a new CHP gas-fired plant is assumed to start up at Mongstad in 2008 with a production of 3.2 TWh/year. In Norway there are also discussions whether to invest in gas-fired power plants with CO<sub>2</sub> handling. Though, due to extra costs of around 12-18 €/MWh it is still at this stage only an issue for discussion. In addition to investing in gas-fired power plant, renewable electricity is being considered, and there are presently applications for a total of 10 TWh at the Norwegian regulator (NVE). Despite the rapid cost reductions for windmills, it is difficult to give exact numbers of expansion in capacity because extension of the technology is highly dependent on political forces and local acceptance. Markedskraft has (based on future predictions of cost falls for wind mills of around 10% from 2005 to 2010 and another 10% reduction from 2010 to 2020) assumed that there will be a significant expansion of wind power of 0,6 TWh each year. Building new micro and mini hydro plants in Norway is dependent on NVE's processing of applications and concessions since many of them will be profitable with today's electricity prices. Markedskraft has therefore assumed 0,4 TWh new hydro power per year. CO<sub>2</sub> prices will have a great influence on the price forecasts. According to predictions from Markedskraft, it can be seen that the price for CO<sub>2</sub> is assumed high for the first few years, which is probably because of the high gas prices together with shortage of allowances. However it then comes down to a lower level in 2008, when the Kyoto mechanisms come in to action, Figure 8 shows Markedskrafts predictions of the CO<sub>2</sub> price.

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<sup>12</sup> Markedskraft is an independent company that offers consultancy and analyses to market participants on the Nordic and European electricity markets.

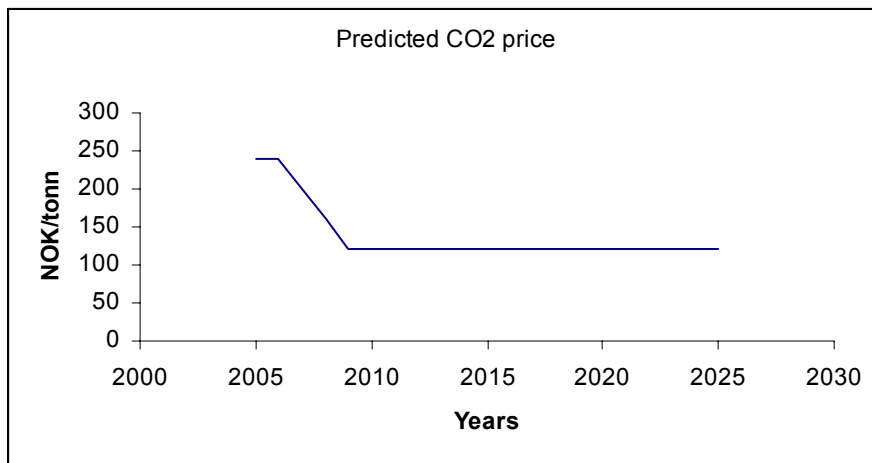


FIG 8; Predictions of future CO<sub>2</sub> price by Markedskraft(2005)

That the CO<sub>2</sub> prices are very unstable; therefore predicting future trends can be very uncertain. Based on the above assumptions together with a total increase of 1% in demand every year, Markedskraft's prediction for the future electricity prices at Nordpool is shown in the figure below.

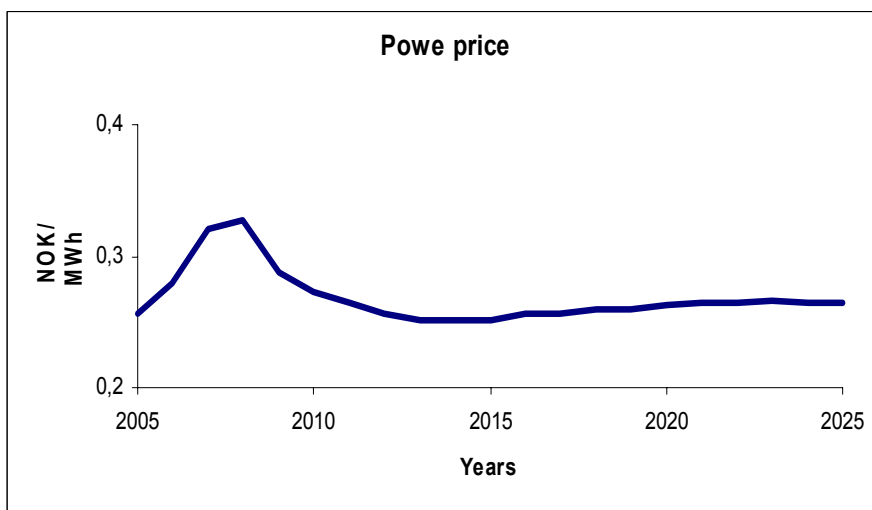


FIG 9; Price prediction for electricity (yearly mean) by Markedskraft, Prices are converted from euro/MWh to NOK/MWh

As one can see from the above figure, Markedskraft predicts that the electricity prices will first rise in 2006-2008 but then come down to a lower level around 32-33 euro/MWh (250-255 NOK/MWh) from 2012. The reason for the rise in electricity prices is probably the cost of CO<sub>2</sub> allowances, which will increase the cost of electricity production from power plants based on fossil fuels. After 2008 the prices for fuels such as gas and oil are expected to decline from the high levels. This together with new capacity and building combined-cycle gas turbines (CCGT) are probably some of the reasons why Markedskraft predicts lower electricity prices after 2008.

### 8.3.2 Heating oil

According to the Oil and gas Journal of 2005, the in-land productions of heating oil in Norway are from two refineries. The two refineries are facilitated at Mongstad close to

Bergen and at Slagen near Oslo. Their total capacity is 310 000 barrels per day where Mongstad has roughly twice the capacity as Slagen. About 30% of the production of heating oil is sold to the domestic market and the rest is exported to Europe. Price data used for modelling heating oil prices in the Energy Investment model were collected from Norsk Petroluimsinstitutt (2006). Figure 10 shows that the prices have increased greatly over the past years.

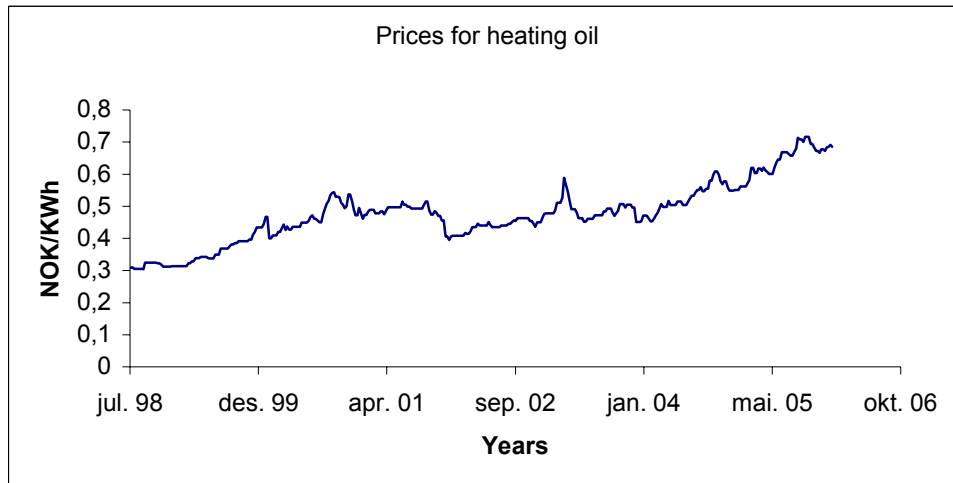


FIG 10; Prices for heating oil in Norway, taxes are not included<sup>13</sup>.

Heating oil is a refined product of crude oil, therefore the development of the prices for crude oil affects the prices for heating oil. According to IEA(2005), the price paid by the consumers for heating oil is derived from the cost of crude oil, the cost to produce the product and the cost to market and distribute the product as well as the profits demanded by the refineries, whole- sellers and dealers. In addition to this, taxes are added to the prices described by IEA. How each of the price drivers affect the heating oil varies among the markets around the world.

Due to the fact that heating oil is solely used for heating purposes, the price varies among the seasons. Refineries can increase production but only by a moderate degree because they quickly reach a point where, to produce more heating oil, they would also have to increase the production of other petroleum products. Inventories that are built during the summer and fall are therefore used to help meet the demand in the winter season.

As has been elaborated above, the crude oil prices affect the price for heating oil, but one must bear in mind the there is a mutual influence between prices for crude oil and heating oil. Hence the demand for heating oil is also reflected in the crude oil prices. Since there is no spot or future price for heating oil in Norway<sup>14</sup>, an approach based on the above relationship is used to predict the future development of heating oil prices. Futures on crude oil prices from IPE were therefore analyzed. The crude oil prices are probably the price driver among the price drivers for heating oil that differs or varies the most with time. Because of this, using the approximation discussed is considered as satisfying in this thesis. The graph below shows the prices for heating oil and prices for crude oil from January 1996 to December 2005 and by doing a correlation analysis on the historical *return* on both heating oil and crude oil, a

<sup>13</sup> Calculated with a Heat value of 10 KWh/l Enøksenteret i Møre og Romsdal (2006)

<sup>14</sup> There exists future contracts on heating oil at NYMEX, but this is heating oil 2, which is used as engine fuel, and not heating oil which is a more pure product used for heating in households

correlation coefficient of 0,19 was found. On average, the price of crude oil was around 30% of the heating oil price.

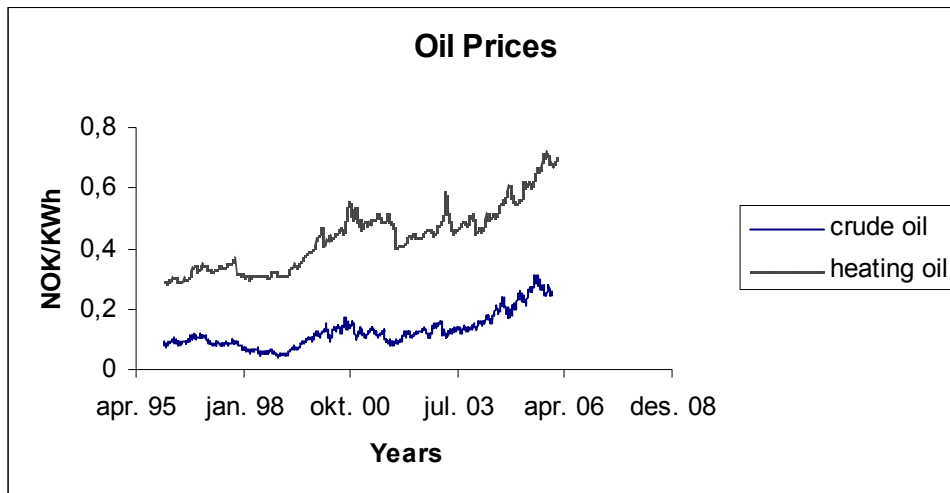


FIG 11 Crude oil prices (Brent) from IPE and heating oil, data's received from Norsk Petroliumsinstutt (2006).

Both IEA and Markedskraft predict the crude oil price to stay high for a short period in the future, before falling to a lower level around the years 2010-2012. Markedskraft shows that the price will be around 60 \$/barrel (270 NOK/MWh)<sup>15</sup> in 2006-2007 and drop to prices around 35 \$/barrel (170 NOK/MWh) from year 2012 onward. How the parameters are adjusted or approximated to fit future predictions will be discussed below when considering the result for the modelling parameters. Further, the relationship between crude oil and heating oil prices is used when setting the future level for mean reversion of the heating oil prices. The fact that the crude oil prices are expected to fall will be assumed to also affect the prices for heating oil, and reduce them to a lower level. Assuming the same level between heating oil and crude oil in the future, the heating oil prices are expected to come down to a level of about 62% of the today's prices. Using this to approximate the mean reversion level for heating oil prices gives a result of 400 NOK/MWh.

### 8.3.3 Gas

There exists no open central market place for inland consumption of gas, therefore a large part of the Norwegian gas production is sent to the UK and the European continent through an extensive net of gas pipes. Furthermore, the International Petroleum Exchange (IPE) is the only fully deregulated spot market in Europe. In addition to spot prices, financial contracts are also traded at the IPE. The three main contract types are seasons, quarters and months. The contracts for seasons are either summer strips (April-September) or winter strips (October-March). Quarterly contracts are contracts for the three following months, for instance strips January-March, April-June etc. The monthly contracts are for delivery in each calendar month (January to December). The figure below illustrates the different contracts available at IPE.

<sup>15</sup> The exchange rate of 5,96 NOK/\$ together with conversion of 1327,2 KWh/barrel was used in the conversion Oanda (2006) Norsk Petroliumsinstutt (2006)

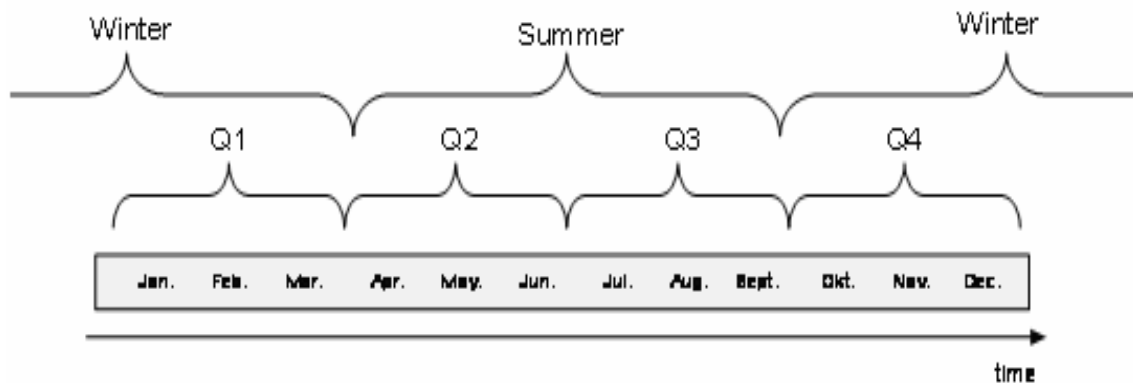


FIG 12: The different contracts available at IPE

Due to the lack of a Norwegian market, the prices at IPE are used for modelling and approximation of the prices paid for natural gas delivery in Norway. By doing this there are some adjustments of the IPE prices that need to be done. Firstly the transport costs between the UK and Norway are accounted for by subtracting them from the spot prices analysed. The transportation costs used in this thesis are the ones predicted by Markedskraft, 13 NOK/MWh Markedskraft 2005. Next, the prices at IPE <sup>16</sup> are wholesale prices so they need to be adjusted to the prices that are actually paid by the end user. To be able to adjust the prices, one has to consider the value chain and how the different profit margins are added to the wholesale prices for gas delivery in Norway. The figure below shows how the whole sale prices are connected to the price paid by the end-user.

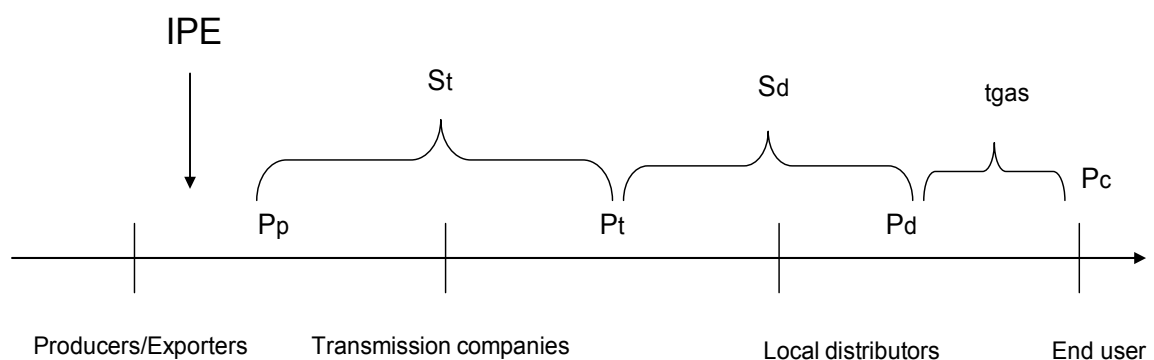


FIG 13: The value chain for gas from production to end user

In Figure 13  $P_p$  represents the price between the producers/exporters (big oil companies such as Statoil and Hydro), or in this case the IPE prices (not including transport costs from UK to Norway) and the transmission companies. Further  $P_t$  represents the price between the

<sup>16</sup> Since the prices at IPE are quoted in £/therm these are converted to NOK/MWh, an exchange rate of 11,67 NOK/£ (10.03.2006) Oanda (2006) was used together with the conversion factor between therm and electricity which is 0,023071 MWh/therm Alstad and Foss(2002)



transmission company (Gassco) and the local distribution companies (Gasnor and Lyse Energi).  $P_d$  is the price received by the local distributors from costumers.  $P_c$  is the gas price paid by the end-users and  $P_d$  is the gas price paid by the end-user minus taxes,  $t_{gas}$ , on the use of gas.  $S_t$  and  $S_d$  represent the gross margins for the transmission and distribution companies. The margins for distribution companies are often set with relation to prices of alternative energy carriers. Further, as can be seen from the figure  $S_t = P_t - P_p$  and  $S_d = P_d - P_t$ . The taxes on gas can then be written as  $t_{gas} = P_c - P_d$ . According to Austvik (2003) the total price paid by the end-user can then be written as a function of  $P_p$ .

$$P_c = P_p + S_t + S_d + t_{gas} \quad (8.9)$$

$P_p$  from the Norwegian producers will probably be priced relative to the alternative, which is to export the gas. In this thesis it will be assumed that there are no constraints in transport, and therefore this price will be set as the IPE price, but with the transport costs subtracted. Since the relevant prices in this thesis are the consumer prices, the prices from IPE need to be adjusted according to Equation (8.9) ( $P_p$  needs to be adjusted to  $P_c$ ). In the thesis, this is done by incorporating the trend in the prices from the IPE (since these only reflect the change in price) into the Energy Investment model, and then adjusting them up to the level of the prices paid by the end-users to the local distribution companies. As can be seen above, there are two local gas distributors in Norway, namely Gasnor and Lyse Energi, and their average price is used for adjustments from  $P_p$  to  $P_c$ <sup>17</sup>. Today the price for natural gas delivered to households is in average 0,45 NOK/KWh<sup>18</sup>, and hence will be the starting point for the future gas price simulations in the Energy Investment model.

Investment costs for natural gas are generally much higher than for oil, especially regarding transportation, such as investments in gas pipes. Because of this, natural gas is less mobile over long distances than oil, therefore there are often “regional” gas markets with pricing mechanisms somewhat independent from each other. How these markets will develop in the future is dependent on the degree of liberalization of the future markets. In the past years transportation of natural gas has become somewhat cheaper due to new technology, with Liquefied Natural Gas (LNG) transported by ships. Also new gas pipes and storage halls are being built which makes transportation of natural gas between the regions easier. A liberalization of the market will probably alter the market structure from being “regional” with differing prices, to more central markets with less price differentials. However, in the central markets the price fluctuations may be higher.

Today’s prices are high, following oil prices. Both Markedskraft and IEA predict that the natural gas price will drop after a peak price in 2008. Markedskraft predicts the peak to be at 135 NOK/MWh in 2007 before the price drops almost linearly to a price level of 80 NOK/MWh in 2012. IEA’s price predictions are somewhat higher with a peak of 200 NOK/MWh in 2006, dropping to a lower level of 120 NOK/MWh from 2010 onward. It should be noted that the prices discussed above are the average prices for gas between all the market segments; the prices for the residential market will be somewhat higher. The prices predicted by Markedskraft are for gas delivery at Kollsnes, while the price forecast from IEA is a mean for the *whole world*. This might account for some of the price differences. By

<sup>17</sup> The price paid by the industry will be somewhat lower than prices paid by households, and are more case specific. The prices paid by households is therefore taken as the starting point when adjusting the level of the wholesale prices from IPE.

<sup>18</sup> Due to the lack of infrastructure, Haugesund and Stavanger are the only area in Norway where gas is delivered by pipe for heating purposes to households

looking at future contracts traded at IPE the trend is in alignment with Markedskraft’s predictions, although IEA predicts a small increase in prices beyond year 2012. Monthly futures indicate that the price for March 2007 will be 7363 pence/therm which is around 145 NOK/MWh when transportation costs are accounted for. Seasonal future contracts give a price at 4605 pence/thermal, which is around 50 NOK/MWh when the transport costs are subtracted. Although it is uncertain whether transport costs will be the same in the future, it shows once again that the gas prices are expected to decline. Based on the prices forecasted by Markedskraft the Price at IPE beyond 2012 would be around 93 NOK/MWh. The long-term mean factor that prices revert to in the price process is set to be 0,38 NOK/ MWh. This is 15% under 0,45 NOK/KWh, which is the same percentage reduction assumed at Kollsnes.

**8.4 Finding the state Variables**

To derive the parameters and state variables for the different price models a Kalman filter and a non linear least square method was used. The Kalman filter approach was used for deriving the parameters and state variables in the two factor model for electricity prices. Further, a non linear least square method was used for deriving the model parameters for heating oil and gas. The chapter will be limited to a brief explanation of the Kalman filter, further theory together with how it was used to derive the state variables in this thesis can be found in Appendix 3.

**8.4.1 The Kalman filter**

The state variable  $X_t$  and  $\varepsilon_t$ , discussed in section 8.2, are not directly observable, but can be estimated by using price datas, in this case the spot and forward data from Nordpool. The purpose of the Kalman filter is to separate the useful and valuable information form noise in the datas analyzed, therefore the name “filter”. The Equations for the process will not be derived here but can be found in Alstad and Foss (2004). The Kalman filter is programmed in Matlab and the model parameters are derived by defining a likelihood function  $L(\Theta)$ , where  $\Theta$  is the vector of the parameters that are to be estimated and can be written as  $(\Theta(\kappa, \mu_\varepsilon, \sigma_x, \sigma_\varepsilon, \gamma, \tau, \varepsilon_0, \rho_{x\varepsilon}))$ . The recursive procedure starts with an initial  $\Theta$ , and the parameters are updated every time the filter runs which is until the likelihood function  $\Theta$  converges to a given level.

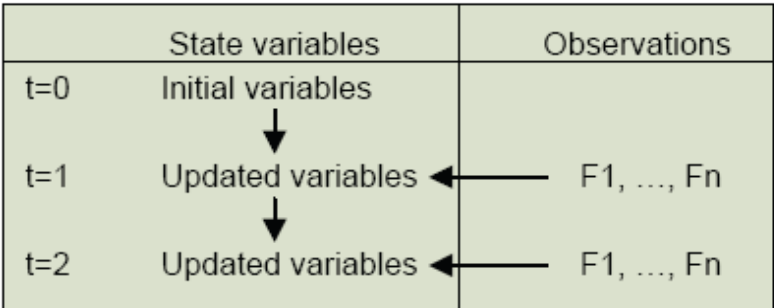


FIG 14 Given an initial state in step 0 and a set of observations in step 1, the filter calculates state variables for step 1 that minimizes RMSE for a given set of parameters Alstad and Foss (2002)

**8.4.2 Least square method**

The method is based on a discretization of Equation 8.1 and 8.2 describing the mean reversion process. The discretization can be written as

$$\begin{aligned}\ln S_t &= f(t) + X_t \\ X_t &= (1 - \kappa)X_t + \kappa X^* + u_t\end{aligned}\tag{8.10}$$

Where  $t=1,2,\dots,N$ ,  $\kappa$  is the speed of mean reversion and  $X^*$  is the level that the prices revert to.  $u_t$  represent i.i.d normal random variables with mean zero and variance  $\sigma^2$ . Further  $f(t)$  is the seasonal variation of the prices. All the parameters are estimated simultaneously using a least square method. By substituting  $X_t$  in the first line of Equation 8.10 in to the second line the expression below is obtained

$$\ln S_t = (1 - \kappa) \ln S_{t-1} + f(t) - (1 - \kappa)f(t) + \kappa X^* + u_t\tag{8.11}$$

Hence this is the Equation used in the non linear least square procedure. By doing this  $\gamma$ ,  $\kappa$ , and  $\tau$  are simultaneously derived. Further the standard error of the regression is the estimated value of  $\sigma$ .

## 8.5 Modelling results and calibration of parameters and state variables

This subchapter will give the estimation results for the parameters together with the state variables derived by using the Kalman filter for electricity prices together with the simple least square method for heating oil and gas prices. The chapter will also consider the different results for the modelling parameters and analyse them according to the discussions made in above chapters regarding future energy prices. Calibrations can be especially important for the one factor models which are based on historical spot prices. Since some assumptions are made due to scarce data, there will be a sensitivity analysis in later chapters that explores how changes in some of the price parameters affect the decision to invest in the different energy systems. Further information on the modelling result can be found in Appendix 3

### 8.5.1 Electricity parameter results

To calculate the parameters and the state variables for electricity, spot prices together with futures with one, two and three years to maturity were used. The time period for observations was weekly in the period from 7<sup>th</sup> of January 2000 until 2<sup>nd</sup> of January 2006.

The parameters obtained from running the Kalman filter are shown in the below table.

Table 3; Parameter result for the electricity price process.

$\kappa$	$\gamma$	$\tau$	$\rho_{x\varepsilon}$	$\sigma_x$	$\sigma_\varepsilon$	$\mu_\varepsilon$	$X_0$	$\varepsilon_0$
1,24 year <sup>-1</sup>	8,55%	0,43 Year	0,0073	54,6%	11,5%	1,24%	0,0635	5,63

When using the Kalman filter the short -term and long-term factor,  $X$  and  $\varepsilon$ , for the historical prices were also constructed, and can be viewed in appendix 3, The forward curve suggests a small decrease in the prices followed by a continuous price increase as is shown in the below graph

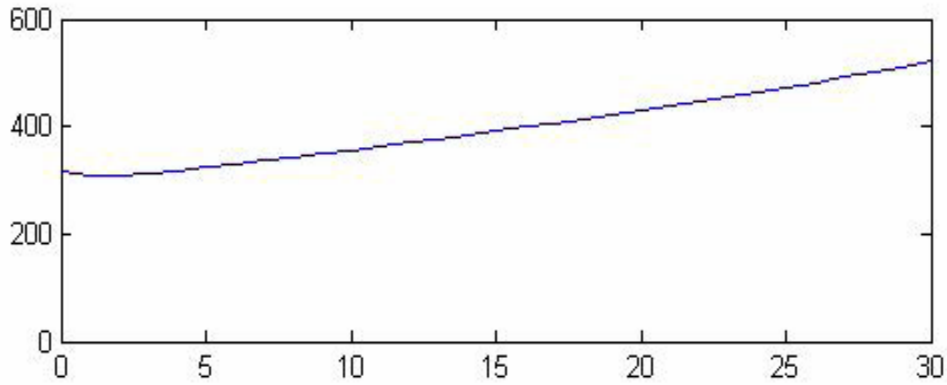


FIG 15: Forward curve for electricity prices, constructed by the Kalman filter, The values on the Y-axis are NOK/MWh and the values on the x axis are weeks from January 2006.

The Kalman filter suggests a drift of 1,24 %, by applying this rate the expected price for electricity in January 2008 is 296 NOK/MWh and the expected price in 2012 is predicted to be 250 NOK/MWh. According to Ollmar (2004) the risk premium in the electricity market is very small in the long term<sup>19</sup>. This will account for the risk difference between the predicted prices on the market and the future prices in the long term. Based on the above facts and the market predictions a decision to use all the parameters provided by the Kalman filter was made.

### 8.5.2 Gas parameter results

The gas parameter results were based on spot prices at IPE in the period from September 2000 to 2<sup>nd</sup> of January 2006. By doing the least square method, the variables were as shown in the below table.

Table 4: Parameter results for the Gas price model. \* means that this parameter was not obtained from the least square procedure but rather set in advance, as discussed in former chapters.

$\tau$	$\kappa$	$\gamma$	$\sigma$	$X^*$
0,41 year	0,078 year <sup>-1</sup>	30 %	20 %	-0,967

By using these parameters, together with the scaling from  $P_p$  to  $P_c$ , the prices will have the same changes as the IPE gas prices suggest for the mean reversion model but at a higher level, namely the end user price where the margins in the value chain for the gas prices are added. The prices will fall with around 27% from 2007 to 2012 when incorporating the model parameters. This is close to Markedskrafts predictions of a 28% fall in the gas price at Kollsnes from 2007 to 2012. Based on the above information and predictions, future quotes and the spot price at IPE, the decision has been made to use all the parameters in table 4 for future modelling of gas prices. Sensitivity analysis regarding price changes for the Energy Investment model will be preformed later on in the thesis.

<sup>19</sup> Ollmar's studies are restricted to a time horizon of three years in to the future, but show that the risk premium in the electricity market moves closer towards zero the further in to the future one considers. It is therefore taken as a satisfying assumption that the risk premium will move even closer to zero beyond three years.

### 8.5.3 Heating oil parameter results

Parameters for heating oil are based on prices from 1<sup>st</sup> January 1996 until 2<sup>nd</sup> of January 2006, and the results are shown in the table below

Table5 Parameters obtained from least square analysis of heating oil prices, \* means that this parameter was set in advance.

$\tau$	$\kappa$	$\gamma$	$\sigma$	$X^*$
0,41 year	0,0010 year <sup>-1</sup>	-2,4 %	4 %	-0,91*

As can be seen from the price data in Figure 11, the rise in price has been large over the past years, and it is unlikely that the rise in price will follow this trend. If prices were to follow this trend it would be too high and not able to compete with the alternative energy carriers for heating of buildings. The fact that the mean reversion level is set lower than the starting price will reduce the heating oil prices to a lower level in the future, which is in alignment with the future crude oil prices. How fast they decline depends on the value of  $\kappa$ . Since the value for  $\kappa$  was rather low from the simulations, a decision to adjust this factor so that the prices are reduced to a lower level around 2012, as predicted by Markedskraft and IEA, was done<sup>20</sup>.

How the different energy prices, discussed above, deviate from the future prices on the market will decide the extent of deviations from the forecasted values regarding the income for an energy investor

### 8.6 Performing a Monte Carlo analysis

To be able to use the stated variables and estimate future prices, a Monte Carlo analysis was used. A Monte Carlo analysis involves randomly generating uncertain variables and using these to generate several price paths for each time period. The expected price path is then the average of all the calculated prices for each period. The more simulations that are done the more accurate the value estimates will be<sup>21</sup>. The different price paths are used for creating several samples of possible NPVs in the following value at risk analysis.

<sup>20</sup> When calibrating the model the new  $\kappa$  was set to 0,02 year<sup>-1</sup>.

<sup>21</sup> For a result to be sufficient several thousand simulations are often needed. All though since Excel, which is used in this thesis, is not powerful enough as a simulation tool, the prices are here simulated 500 times for each time step. Disadvantages of this will be discussed when revising the Investment model created in this thesis.



## 9 Scenario modelling of pellets

Observations of historical data sets show that the price of pellets is much more stable than the price for electricity, gas or oil discussed above. The fact that there are no central, regional or local market places for bio fuel together with scarce market data makes the price difficult to predict, with a small degree of uncertainty, in the immediate and far future. Therefore creating a stochastic process for modelling pellets is not viable. Therefore three different scenarios were assumed for the future. In addition, a linear price process for small scale application (bag delivery) of pellet and large scale application (bulk delivery) of pellets was constructed for each scenario. The three scenarios are called **Pellets-High price**, **Pellets-Middle price** and **Pellets-Low price**. The assumptions made regarding the three scenarios were based on analysis of the pellet chain cost structure with an emphasis on key figures regarding cost of raw material, transportation and production. The chapter will start with a small discussion of the pellet chain cost structure before describing the three scenarios. Additional information regarding the value chain and the different price drivers for pellet together with calculations for how the linear price functions were derived can be found in Appendix 4.

### 9.1 Cost structure of the value chain

To be able to predict future prices, understanding the cost structure of the value chain for pellets, and future changes in it, can be valuable. Various raw materials and different end-uses of pellets products require different pre-treatment in the pelletizing process. The raw material for pellet can either be residues from wood based industry or wood from the forest. Depending on the quality of the raw material, it is ground, dried and pressed into pellets. The raw material is then either packed in to **bulks** (large scale application) or **bags** (small scale application)<sup>22</sup>. The storage time for finished pellets can be rather long due to seasonal variations in demand. Figure 16 shows the percentage distribution of the costs in the value chain for pellet.

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<sup>22</sup> Various sizes on bulks and bags exist, however this thesis consider only the two main categories.

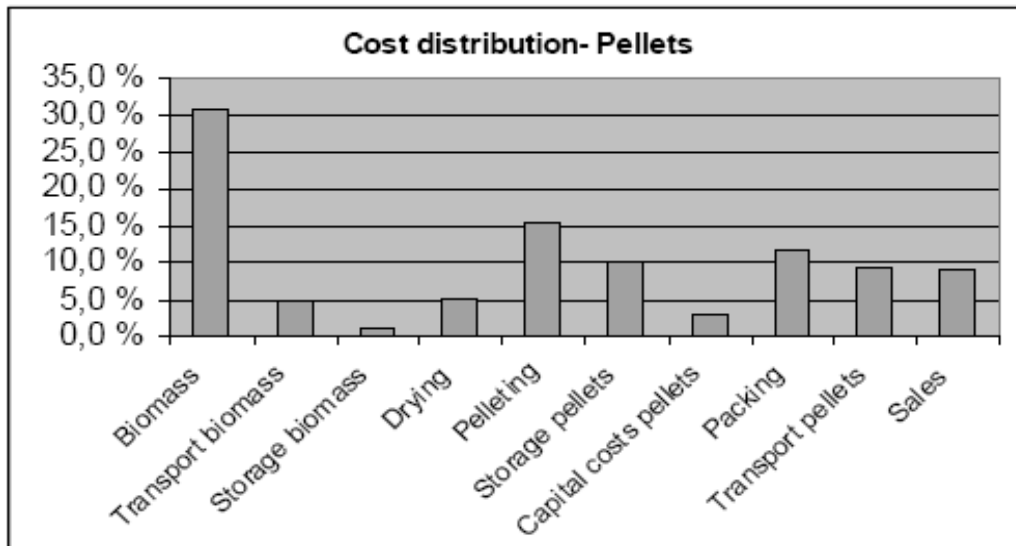


FIG 16: The distributions of costs for pellets logistic chain, biomass is the raw material in general and therefore the costs may vary somewhat depending on type of raw material used for making the pellets Energidata (2005).

### 9.1.1 Raw material and the Wood market

The Norwegian pulp wood market is very small with few players and is not transparent. Currently wood from forestry is mostly used in the form of firewood, which is not considered in this thesis<sup>23</sup>, and only a small portion, (0,1 TWh), is used as chips. For the country as a whole a potential usage in the far future can be as high as 12-16 TWh Størdal (2003), but this will exceed the highest possible demand scenario in this thesis, since the time horizon is limited to 15 years.

The degree of availability of the raw material is of high importance to the producer of pellets and a big competitor for the raw material is the chipboard industry. Further a long distance from resources to the end user will contribute to higher end user prices for the energy carrier. The Norwegian population is rather dispersed compared to other countries using bio fuel and therefore the supply structure will differ and most likely be somewhat more expensive.

A study done by Størdal (2003) regarding markets for bio fuel in Norway, shows that the resources are generally located near to where the population density is highest. The availability of pellets can not be analyzed separately from the competition for the raw material discussed in the previous paragraph. Consider the East part of the country (Østlandet) as an example. Most of the available resources go into the production of chipboards which leads to fewer resources for pellets. Also the price for raw material in the particular area can be rather expensive if the competition with the chipboard industry is high in the area. Therefore, availability of resources needs to be viewed along with the competition in the particular area when constructing the three scenarios various assumptions regarding future availability were taken into consideration.

<sup>23</sup> Most of the firewood is treated outside the bio market and availability depends severely on location, which makes a prediction of price and use unserviceable to predict.



### 9.1.2 Economy of scale

As can be seen from figure 19 the production costs for pellets, including drying, packing and storage, accounts for approximately 45% of the costs in the logistic chain. The average size of a pellets factory in Norway today is around 7,5 ktonne/year, which is rather small compared to pellets factories in Europe that have an average size of 70 ktonne/year NoBio (2003). There is a scale factor in the production of pellets, implying that the production cost per kg pellets is reduced when the quantum of production is increased. Economy of scale will be used when assuming the prices in the three scenarios. Figure 17 shows the effect of economy of scale on production of pellets for small scale delivery.

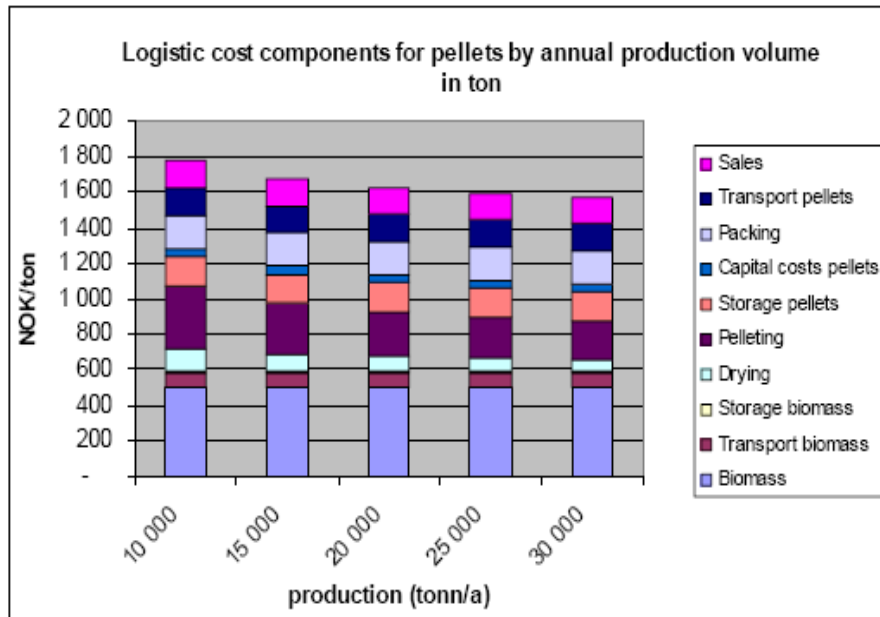


FIG 17: The effect of economy of scale on pelletizing as the production quantum increases. The costs is regarding small scale application of pellets Energidata, Transportøkonomisk institutt and KEMA consulting (2005).

As can be seen from the figure the production costs, including transport, for small scale pellets in Norway is around 1790 NOK/tonne (373 NOK/MWh)<sup>24</sup>, lower or higher depending on the size of the plant. According to NoBio (2006) the price for small scale pellets averages 1800 NOK/tonne (375 NOK/MWh) including transport costs<sup>25</sup>. For bulk delivery, the average price is 1200 NOK/ton (250NOK/MWh), transport costs are also included. The cost curve for pelletizing and drying is rather flat after a quantum of 30 000 tonne/year. This means that in Norway, where the pellets factories are rather small there is large potential for savings to be made in production costs by increasing demand and thereby production plant size. How large the future average factory size will be depends on, among other factors, the relationship between savings in production costs and increased transportation costs with centralization of factories. The middle size of European pellets factories can meanwhile only be reached in the Norwegian regions where the population density is rather high, which means that on average the factories in the future, in any case, will be smaller in Norway than in the rest of Europe. It is assumed that if the full potential for pellets is explored in the East region in Norway the

<sup>24</sup> In the calculations a heat value of 4.8 MWh/ton for pellets was used according to Tveitdal (2006).

<sup>25</sup> Transport costs constitute 100 NOK/ton in average Energidata (2005), this is with an average transport distance of 80-100 km Størdal (2003).

transportation costs can be reduced with 20-35 NOK/MWh by 2020 Energidata et al (2005). This number will not be realistic for the country as a whole, but can be considered as an upper limit of potential reduction since this is the area in the country with the highest population density. A percentage of this number will be used in the three scenarios. For the three scenarios, it is also assumed that the future prices for delivery in small bags and delivery of pellets in bulks, will have the same comparative percentage price level of 66%<sup>26</sup> as they do today.

### **9.1.3 Future demand for pellets**

There are several factors, such as population development and increased space per resident which will affect the demand for pellets in the future. The predictions of future demand for the three scenarios will be based on

- Extended use within existing buildings
- Choice of Bio fuel in building new residential and industrial buildings

Regarding existing buildings, pellets have to outstrip the existing energy system, which can only be done if the price of pellets is cheaper in use and at least as convenient. It is also easier to change to bio fuel if the existing heating system is at its end of lifetime. In addition, the building should be suited for usage of bio fuel, which means that a storage place for pellets is required. According to SSB (2004) 59,8% of Norwegian households use electricity and stove (point) heating to serve their heating demand. This means that pellets stoves are the most likely to compete with the existing heat system, due to the fact that there has been a drastic shift in the energy system towards a replacement of water based heat transport system. In newer buildings water based heating systems has become more and more common. In 2002, 42,3 % of all new buildings in Norway were built with a water heat based heating system, which was a growth of 11,9% compared to 1997 SSB (2004). It is therefore assumed that pellets used in water based heating systems will be more common in new buildings and pellets stove within existing buildings. However, it is hard to predict how the pellets stove can penetrate or outstrip the traditional fire wood market, since much of the firewood is purchased outside the market at a very low price. Further it exists an upper limit on the price, for the energy carrier that the end user is willing to pay for choosing pellets. The reason for this is that the investment costs in pellets technology are generally higher than the technology and infrastructure needed for usage of oil and gas as an energy carrier.

## **9.2 The three scenarios**

### **Pellets-Low price**

The scenario assumes that every measure and incident that happens has a positive effect on the end user market of bio fuel, and the market development is close to a maximum regarding market potential. Political objectives arrange and stimulate to promote increased usage of bio

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<sup>26</sup>  $1200/1800=0,66$ , this is done since there was no explicit numbers, on economy of scale in production and logistic costs for bulk delivery of pellets available.

fuel. International agreements such as the Kyoto protocol are fully implemented. In addition, better logistics and improved technology increases margins for production of bio fuel. Pellets ovens and boilers are made more user friendly and today 50 % SSB (2005)<sup>27</sup> of all new houses are built with a water carrying heating system. Also, there are no restrictions on raw material. In addition, a standard market place for bio fuel is developed which helps to give a better overview for the consumers. The electricity spot price is assumed to be high, an average of 600 NOK/MWh during the next 15 years. The government achieves the goal of increased usage, 4 TWh by year 2010, of renewable energy and the main weight is on bio fuel ODIN (2003). Based on the above assumptions, the following conclusions regarding pellets price for this scenario was made;

- The Average size of a Norwegian Pellets factory is a production of 40 000 tonne/year by 2020
- Economies of scale reduce the costs for drying and pelletsizing from today's level at 510 NOK/tonne to 300 NOK/tonne, see figure 17 above.
- The transport/logistic costs, due to better logistics, will be reduced to 70% of the max potential reduction for an area which has a large population density, which is around 25 NOK/MWh<sup>28</sup>.
- With no future restrictions on raw material the price will be the same as today
- The price for bag delivery of pellets will be assumed to be linearly reduced from today's average level of 375 NOK/MWh to 306<sup>29</sup> NOK/MWh in 2021.
- In total the price for bulk delivery will be assumed to be reduced (assumed linear price depression) from today's average level of 250 NOK/MWh to 202 NOK/MWh in 2021.

## Pellets-Middle price

This scenario assumes that the government uses maximum effort to stimulate the usage of bio fuel. The development of new houses with water carrying energy system is assumed to follow the same growth as today. A standard market place for bio fuel will not exist, but the market will be more surveyable and user friendly. Further, there will also be increased taxes on non renewable energy carriers which will favour pellets, and the electricity price is assumed to be around 450 NOK/MWh as an average for the next 15 years. The growth of inland usage of pellets is assumed to follow today's rate, of 60 %, which was the growth from 2003-2004 NoBio (2006). Due to competition with the wood market the restriction on raw material will cause prices to be kept at a higher level than today's prices for raw material. As with the Pellets-low price scenario, the Kyoto agreement is implemented. Based on the above assumptions, the prices for pellets in this scenario are assumed as follows:

- The average size of a Norwegian plant will be 20 000 tonne/year.
- The economies of scale reduce the costs of drying and peletizing from today's level at 510 NOK/MWh to 330 NOK/MWh by year 2020, see figure 17.
- The logistic costs will be reduced by 10 NOK/MWh (33% of maximum potential for reduction) by year 2020.
- Restrictions on future need for increased raw material keep the prices for raw material on average 20 NOK/tonne higher than the prices today.

<sup>27</sup> 50% is a continued growth of the increase from 2003-2004

<sup>28</sup> 70%\*30 NOK/Mwh, see section on economy of scale and transportation costs.

<sup>29</sup> The calculations can be viewed in appendix 4

- In total the price for bag delivery will be assumed to be reduced (linearly) from today's average level at 375 NOK/MWh to 331 NOK/MWh in 2021.
- In total the price for bulk delivery will be assumed to be reduced (linearly) from today's average level at 250 NOK/MWh to 218 NOK/MWh in 2021.

## Pellets-High price

In this scenario, the electricity spot price is assumed to stay in the range of 250 NOK/MWh and electricity continues to be the leading energy carrier in Norway. As an alternative energy source, pellets loses market share to other energy carriers and technologies such as gas and heat pumps. The number of new houses and industrial buildings built with water based heating systems are decreasing and the government does not give enough means to stimulate the use of pellets and other bio fuels. Further, it is assumed that there will be low taxes for energy carriers letting out green house gasses. Lastly, the wood market is heavily restricting the raw material for production of pellets. With the above assumptions, the pellets prices are modelled as follows:

- The average size of a Norwegian pellets plant will not increase and will stay at today's level of 7500 tonne/year.
- Logistic costs will stay at the same level as today.
- The price of pellets delivered in bags will be the same as the prices today, which is 375 NOK/MWh.
- The price of pellets delivered in bulk will be the same as the prices today, which is 250 NOK/MWh.

The three scenarios for the two scales of application are summarized in the below table. The calculations of the specific prices can be found in Appendix 4.

Table 6; The three prices functions for pellets delivered in bulk and bag, the prices are in NOK/MWh.

<b>t : (number of years from 2006, max = 15)</b>	<b>Large scale application</b>	<b>Small scale application</b>
<b>Pellet-Low price</b>	250-3t	375-4,6t
<b>Pellet-Middle price</b>	250-2t	375-2,93t
<b>Pellet-High price</b>	250	375

## 9.4 Discussion of the prices in three scenarios

According to Energidata et al (2005) the average price in Europe (for annual delivery of 3-5 ton) *small scale* application is 150-170 euro/tonne (244-277 NOK/tonne)<sup>30</sup>, thus the price varies a great deal among the countries. Except from Norway, Sweden has the highest price with 210 euro/tonne (342 NOK/MWh). The lowest price for pellets is paid in the Czech Republic and is 110 euro/tonne (142 NOK/MWh). The prices in both Pellets-Middle price and Pellets-Low price scenario (small scale application) lie between the two above values within 15 years. However, the prices are closer to prices paid for pellets in Sweden than the Czech Republic.

<sup>30</sup> 1euro=7,83 NOK Oanda (2006). Appendix 4 shows how to convert from tonne to MWh.

According to Størdal (2003), the price for *large scale* applications averages 160-200 NOK/MWh. This is not unrealistic due to the fact that the Norwegian market will never be as large as the comparative countries. As was demonstrated in the above sections, the raw material and pelletizing (together with drying) makes up a large fraction of the costs in the logistic chain of pellets. Hence, reasons why the pellets prices in Norway deviate from the average pellets prices in Europe can be summarized as follows;

- There is larger competition for the raw material that is needed to make pellets, this keeps the prices for raw materials high and can limit the production of pellets.
- The population density is lower in Norway and it will therefore be harder to centralize production thus transport costs are likely to be higher in Norway than for other countries.
- The total demand is generally lower in Norway.



## 10 Correlation between the energy carriers

Correlation is here defined as the measure of dependence between two random variables represented in different price processes. The maximum possible correlation refers to the perfect (positive) dependence. Here, perfect dependence implies the ability to express one variable as a deterministic function of the other.

### 10.1 Modelling correlation between oil, gas and electricity

If there are  $n$  log normally distributed price processes these can be modelled as

$$\ln(S_{n_t}) = \ln(S_{n_0}) + (\alpha_{s_n} - 0,5\sigma_{s_n}^2)t + \sigma_{s_n} \varepsilon_n \sqrt{t} \quad (10.1)$$

Where  $\varepsilon_n \sqrt{dt} = dW_n$  is a wiener process as discussed in Appendix 2. If the  $n$  processes are uncorrelated, the prices can be simulated by drawing independent  $dW_n$ . However, the price processes can also be correlated as is the case for the four energy carriers modelled in this thesis. Since only three of the four energy carriers, namely gas, oil and electricity, could be modelled as stochastic processes, these are the ones that will be correlated as shown in this subchapter. Regarding pellets, the prices were implicitly correlated with the electricity prices in the assumed scenarios. When correlating the price processes, it was assumed that the correlations between the various  $dW_{ns}$  are  $\rho_{ij}$ . Although there are only three energy carriers correlated in this chapter there will be four correlating processes. This is due to the fact that the price process for electricity was modelled using a two-factor model and therefore has two stochastic variables. With the presence of four correlated variables, there were 6 pairwise correlations that needed consideration. Further details on how the correlations were derived can be found in Appendix 5. The correlation between variables  $i$  and  $j$  are denoted as  $\rho_{ij}$ . Further, the original uncorrelated random variables are denoted as  $\xi_{elx}$  (Short term electricity),  $\xi_{ele}$  (long term electricity),  $\xi_{gas}$  (gas) and  $\xi_{oil}$  (oil). The corresponding correlated variables are  $W(el_x)$ ,  $W(el_e)$ ,  $W(gas)$  and  $W(oil)$  with

$$E[W(i) * W(j)] = \rho_{i,j} \quad (10.2)$$

$W(i)$  was then generalized as;

$$W(i) = \sum_{j=1}^i a_{i,j} \xi_j \quad (10.3)$$

Where  $a_{ij}$  are coefficients selected to make sure the pairwise correlations are correct. To create the coefficients,  $a_{ij}$ , a recursive solution was used. With the recursive procedure  $W(1)$  was first constructed and then  $W(2)$  was found by using solution of  $W(1)$  and so on. The general formula for the  $a_{ij}$ 's are Hull(2003) ;

$$a_{i,j} = \frac{1}{a_{j,j}} \left[ \rho_{i,j} - \sum_{k=1}^{j-1} a_{j,k} a_{i,k} \right] \quad i > j \quad (10.4)$$

$$a_{i,i} = \sqrt{1 - \sum_{k=1}^{i-1} a_{i,k}^2}$$

The matrix of Equation (10.4) is also called the Cholesky decomposition of the original correlation matrix, and it is used to be able to simulate the different Wiener processes despite their dependence on each other. The Cholesky matrix is a lower triangular matrix with zero in the upper right corner. In addition the matrix has to be positive definite as shown in Appendix 5. The different  $\rho_{i,j}$  in this thesis were estimated from the change in the natural logarithm for spot price of the different energy carriers from September 2000 to January 2006. The correlation between the long term and short term electricity price, in the two factor model, was estimated from the Kalman filter in Appendix 3. As for the correlation between long term electricity and the other energy carriers, forward prices for electricity with delivery in one, two and three years, between the period 2002-2005 were used. Since several contracts were used to find the correlation between prices for heating oil/gas and long-term electricity prices, a mean correlation coefficient had to be calculated. The correlation coefficients are not additive<sup>31</sup>, hence a Fisher transformation was used. The equations and the method for Fisher transformation can be viewed in Appendix 5.

Since the calculations are based on a selected sample which is just a part of all the observations of the population, uncertainties in the numbers are present. This is illustrated in figure 18.

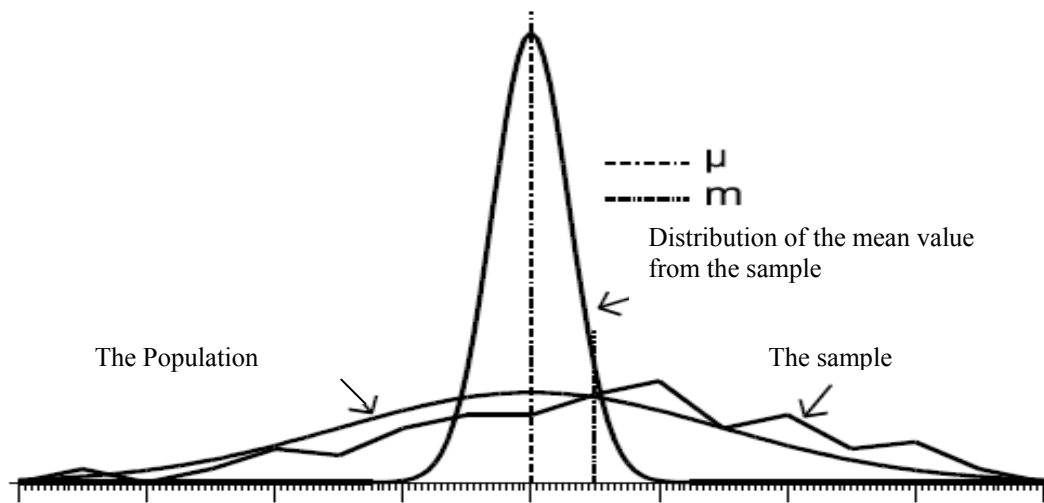


FIG 18: The distribution of the population and the sample together with the distribution of the mean value of the sample.  $m$  is the sample mean and  $\mu$  is the population mean.

Although one seeks a sample that is representative for all the possible observations one has to bear in mind that when calculating statistical data it is very important to consider that the results are not random, which also applies to the correlations estimated in this thesis. A check to ensure that the estimated correlations were statistically significant<sup>32</sup> was therefore performed using a confidence interval. The confidence interval represents the area, within which the value is most likely to fall. Since the Fisher Z value is normally distributed, it was

<sup>31</sup> The correlation coefficient is not a linear function of the size of relation between the variables that are correlated and thus can not simply be summed to find a mean that is representative as the mean value for the correlation coefficients.

<sup>32</sup> According to Hopkins (2000) a value is said to be statistically significant when a confidence interval chosen, mostly a 95% confidence interval, around the estimated value does not contain zero.



also used when constructing the 95% confidence interval for the correlation coefficients considered. If the calculated confidence interval did not contain zero the result was taken as statistically different from zero.

Table 7 shows the values calculated for the estimated correlation coefficients and the 95% confidence interval.

Table 7: The various correlation factors for the correlated energy price processes

Energy carrier	$\rho$	Confidence interval <sup>33</sup> [ $\rho_{min}, \rho_{max}$ ]
Correlation between oil price and gas price; $\rho_{oil-gas}$	0,128	[0,025, 0,228]
Correlation between oil price and short term (spot) electricity price; $\rho_{oil-elx}$	0,092	[-0,024, 0,205]
Correlation between gas and short term (spot) electricity; $\rho_{gas-elx}$	0,129	[0,013, 0,242]
Correlation between gas and long term (forward) electricity price; $\rho_{gas-el_e}$	0,075	[0,012, 0,138]
Correlation between oil and long term(forward) electricity price; $\rho_{oil-el_e}$	0,140	[0,060, 0,219]

In addition to the correlations shown in table 7, the correlation between the long term and short term electricity price  $\rho_{elx-el_e}$  was estimated to be 0,0073 by using the Kalman filter<sup>34</sup>. As can be seen from table 7, the correlation between the oil price and electricity spot price is the only correlation coefficient that is, in accordance with the definitions in this thesis, not statistically different from zero. Therefore it cannot statistically be said that there is a correlation between the heating oil and electricity prices used in this thesis. Further, an investigation of the correlation coefficient being zero was therefore done by performing a two tailed hypothesis test. As a null hypothesis, the correlation coefficient was set to zero and the alternative hypothesis was that the correlation coefficient is different from zero. The hypothesis test can be found in Appendix 6. Different confidence intervals were used to investigate the strength of the zero hypotheses. The analysis showed that with a 95 % confidence interval, or a 5 % level of significance it was neither possible to reject the null hypothesis, nor viable to accept the null hypothesis which sets the correlation coefficient to zero. By being less fastidious and setting the confidence interval at 90% and performing the same hypothesis test the null hypothesis was rejected. This means that the correlation will be different from zero with a probability of 90 %. How small the level of significance is set depends on how certain one wants the outcome to be. A level of significance set at 10% might seem high in some cases but in this case there are also several other sources of uncertainty in the Energy Investment model.

Using the Equations (10.2) to (10.4) the correlations between the energy carriers can be described as follows;

$$\begin{aligned}
 dW_{el_x} &= a_{11} d\xi_{el_x} \\
 dW_{el_e} &= a_{21} d\xi_{el_x} + a_{22} d\xi_{el_e} \\
 dW_{oil} &= a_{31} d\xi_{el_x} + a_{32} d\xi_{el_e} + a_{33} d\xi_{oil} \\
 dW_{gas} &= a_{41} d\xi_{el_x} + a_{42} d\xi_{el_e} + a_{43} d\xi_{oil} + a_{44} d\xi_{gas}
 \end{aligned} \tag{10.5}$$

<sup>33</sup> The sample size varies among the energy carriers due to the amount of available and adequate data for each type of energy carrier. The larger the sample size is the smaller the standard deviation and hence the 95% confidence interval is narrower. For Equations see Appendix 7.

<sup>34</sup> Due to the large quantity of data in the Kalman filter the correlation was set statistically significant.

Where the  $a_{i,j}$  are calculated as

$$\begin{aligned}
a_{11} &= 1 \\
a_{21} &= \rho_{el_x-el_e} \\
a_{22} &= \sqrt{1-a_{21}^2} \\
a_{31} &= \rho_{oil-el_x} \\
a_{32} &= \frac{1}{a_{22}} [\rho_{oil-el_e} - a_{21}a_{31}] \\
a_{33} &= \sqrt{1-(a_{31}^2 + a_{32}^2)} \\
a_{41} &= \rho_{gas-el_x} \\
a_{42} &= \frac{1}{a_{22}} [\rho_{gas-el_e} - a_{21}a_{41}] \\
a_{43} &= \frac{1}{a_{33}} [\rho_{gas-oil} - a_{31}a_{41} - a_{32}a_{42}] \\
a_{44} &= \sqrt{1-a_{41}^2 - a_{42}^2 - a_{43}^2}
\end{aligned} \tag{10.6}$$

The values for  $\rho_{i,j}$  are found in table 7.

## 10.2 Conformity between the correlation coefficients and the price models

At this point there might be confusion regarding modelling the electricity prices with the Long term-Short term two-factor model and at the same time using the correlations described above. Using the two factor model the correlation between the short term deviations and the long term equilibrium is;

$$dW_{el_e} dW_{el_x} = \rho_{el_x-el_e}^* dt \Rightarrow dW_{el_e} = \frac{\rho_{el_x-el_e}^* dt}{dW_{el_x}} \tag{10.7}$$

Further, the second line in the Equation (10,5) shows the same  $dW_{el_e}$  as;

$$dW_{el_e} = \rho_{el_x-el_e} d\xi_{el_x} + \sqrt{1-\rho_{el_x-el_e}^2} d\xi_{el_e} \tag{10.8}$$

The question is then whether the two correlations coefficients are equal (if  $\rho_{el_x-el_e}^* = \rho_{el_x-el_e}$ ). The answer is yes, and the viability is shown in Appendix 9.

## 10.3 Discussion of the correlation coefficients

As with many other qualities of energy commodities, the data available may sometimes be limited and hence narrow the analysis and the ability to prove certain effects. Using the correlations estimated in this thesis, one must bear in mind that the applicability of historically derived correlations to future conditions can sometimes be quite limited. In

addition, some argue that correlations are not an appropriate measure of dependence for distributions with fat tails, which is true to a certain extent. For further arguments see Nelsen (1999). The correlations estimated in this thesis are constant. Often correlations vary with time, thus using a constant will only be an approximation.

### 10.3.1 Correlations in practise

In many ways we can say that the four energy carriers analyzed in this thesis are substitutes, but in a weak form. This is due to the fact they are all used for heating in Norway. The importance of emphasizing *weak* lies within the fact that switching from one energy carrier to another can be a major task if the user's energy system is not flexible. In Norway, electricity is the most used energy carrier and serves 79 % of the national heating demand SSB (2004). This is probably because electricity is the most "convenient" energy carrier to use. Also the fact that electricity is used for lightning makes it necessary to establish infrastructure for the energy carrier. This fact may amplify the hassle to set up additional infrastructure for another energy carrier for heating purposes in the same building. The above reasons indicate that electricity in many ways is one of the main price drivers<sup>35</sup> for alternative energy carriers used for heating purposes. This fact was used when modelling the correlations and therefore all of the energy carriers were correlated with the changes in the electricity prices.

There are several examples of how alternative energies are priced with reference to the electricity prices. Take prices of natural gas from Gasnor as an example. When Gasnor set their margin, they consider, among others, the electricity prices. If the electricity prices increase the natural gas prices often follow. However to attract new users they are always set below the prices for electricity. If the customer owns a flexible energy system and can switch between energy carriers the customer often gets a better price.

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<sup>35</sup> Another important price driver is the world market.



## 11 Time resolution and modelling the baseline in the Energy Investment model

It is possible to combine several energy carriers in the Energy Investment model. The baseline therefore has to include the distribution between the peak load and base load. Furthermore, the calculations in the Energy Investment model are based on a monthly time resolution. The reason for choosing the monthly resolution is both convenience for the user and time consumption for calculations in Excel. Using a smaller time resolution in the Energy Investment model might make it more difficult for the user to provide inputs for an accurate baseline. This is due to the fact that it would demand more measurements of previous energy use. In addition, Excel is not powerful enough to do several thousand simulations. Hence the computational time may increase considerably. However, using a time resolution of one month in the model requires some adjustments. Figure 19 shows the deviations caused by using a monthly time resolution instead of an hourly time resolution.

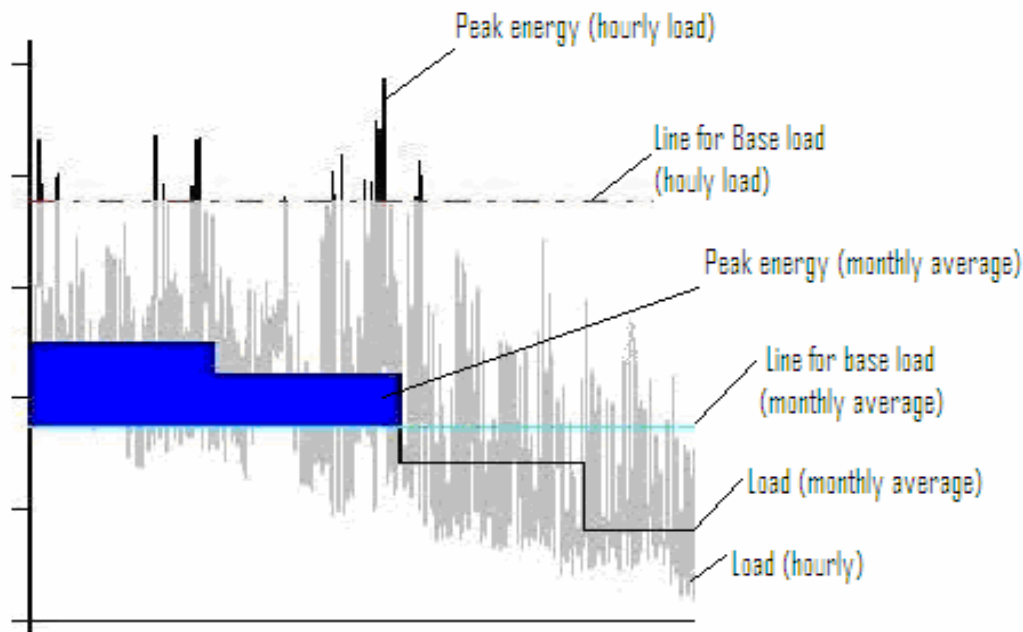


FIG 19: The figure shows the deviations that need to be adjusted by using month as the time step

As the above figure shows there is a mismatch between the two areas that represent the peak energy with hourly load (black area) and the blue area representing the peak load energy with monthly average. The reason for this is that when the model calculates the line for the base load using average monthly consumption and the demand exceeds the base load, the peak will be set to cover this demand through the whole month. In practice only the black area will be covered by the peak load energy carrier. By adding weight factors in to the Energy Investment model these deviations from practice are reduced. When using the weight factors the size of the blue area is scaled down towards the size of the black area. In the model the user specifies a weight factor for each month where the peak load is used. The weight factor represents the total time fraction of a month when the demand is assumed to be covered by the peak load. If the peak load is expected to be used in January and the weight factor for January is 1/3 this

implies that the total time use of the peak energy carrier in January is 10 days instead of 30 and the blue area in January is reduced to 1/3 of its original size.

When the distribution between the base load and peak load has been specified, the price for using the peak load is collected from the prices for the peak load energy carrier while the energy demand served base load is covered by the base load energy carrier. If the total load is below the limit for the base load, the whole load will be served by the base load energy carrier. When choosing multiple energy carriers in the model, there is no need to specify which energy carrier serves the peak load and which energy carrier serves the base load. This is already decided from the cost structures for the different energy carriers in the Energy Investment Model. How the model calculates the distribution between the cost for the base load and peak load through a year can be summarized with the following Equations:

$$\text{MAX\_BL} = \text{PERC\_BL} * \max\{\text{TL}_m\} \quad (11.1)$$

$$\text{PL}_m = \text{TL}_m - \text{MAX\_BL} \quad (11.2)$$

$$C_m = \left\{ \begin{array}{ll} \text{MAX\_BL} * \text{PRICE\_BL}_m + \text{WF}_m (\text{PL}_m * \text{PRICE\_PL}_m) + \\ (1 - \text{WF}_m) * (\text{PRICE\_BL}_m * \text{PL}_m) & \text{for } \text{TL}_m \geq \text{BL} \\ \text{TL}_m * \text{PRICE\_BL}_m & \text{for } \text{TL}_m \leq \text{BL} \end{array} \right\} \quad (11.3)$$

$m \in [1,12]$

$m$  – The number of month in a year, (Jan=1...Des=12)

$\text{PERC\_BL}$  – Maximum power for the base load [%]

$\text{TL}_m$  – Total load in month  $m$  [kWh]

$\text{PRICE\_PL}_m$  – Price in month  $m$  for the energy carrier serving the peak load [NOK/kWh]

$\text{PRICE\_BL}_m$  – Prices in month  $m$  for the energy carrier serving the base load [NOK/kWh]

$\text{WF}_m$  – Weight factor for month  $m$  in fractions of the month,

$\text{MAX\_BL}$  – Maximum power covered by the base load [kWh]

$\text{PL}_m$  – Peak load in month  $m$  [kWh]

$C_m$  – Cost for energy consumption in month  $m$  [NOK]

Equation 11.1 shows how the Energy Investment model calculates the line for the base load energy carrier. The model finds the month (searching the input values for the baseline) with the highest energy consumption and calculates the max power for the base load according to the distribution between the base load and peak load specified by the user. Further, Equation 11.2 shows that the peak load in month  $m$  is the total load subtracted the load covered by the base load.

Equation 11.3 shows that if the total load in month  $m$  is above the base load then the model combines the right load with the right prices. Hence the base load demand is covered by the base load energy carrier and the peak load demand is covered by the peak load energy carrier. Further, the Equation shows how the weight factor is added in the model. Since the weight factor represents the fraction of a month where the peak load is used it is multiplied with the cost of using the peak load energy carrier. The rest of the time  $(1-WF_m)$  the peak load is served by using the base load energy carrier.

However, if the total load in month  $m$  is below the maximum power covered by the base load, the peak load is not used in that month. The cost for energy consumption will then simply be the energy consumption in the particular month multiplied with the price for the base load energy carrier. How to provide the input parameters in to the Energy Investment model will be shown in chapter 14 when discussing the use of the model.

The weight factor is only relevant if the energy system contains multiple energy carriers. If an energy system with only one energy carrier is chosen, the costs for energy consumption at time  $m$ , will simply be calculated as

$$C_m = EP_m * TL_m \quad (13.6)$$

Where  $EP_m$  represents the price (NOK/kWh) for the single energy carrier chosen in the heating system





## 12 Sensitivity in Energy Prices

This chapter considers *Value at risk* as a risk measure regarding the prices for the energy carriers modelled in the Energy Investment model. In later chapters, when using the Energy Investment model on real cases, sensitivity analysis will be conducted on how the different values of drift and mean reversion level affects the profitability for an energy investor.

### 12.1 Value at risk (VaR)

Value at risk has turned out to be one of the most popular methodologies to model and communicate the down-side risk of an investment project. In spite of its popularity, some drawbacks of the method will be discussed, and conditional Value at Risk (CVaR) is introduced as a supplement to the traditional VaR analysis. As discussed in previous chapters energy prices have a big influence on the profitability for an energy investor which will also be revealed when analysing the real cases in chapter 15. The risk in energy price is probably the easiest and most accurate risk to measure and incorporate in the Energy Investment model and therefore a value at risk is done for the variations in energy prices. Basic statistics and the moments of a distribution will not be elaborated in this chapter but can rather be found in Appendix 7

### 12.2 Calculating VaR

VaR can be defined as follows; *VAR summarizes the expected maximum loss over a target horizon within a given confidence interval* Jorion (2000). The purpose of incorporating VaR in to the model is to communicate the uncertainty and down-side risks due to energy prices following the investment for an Energy investor.

According to Jorion (2000) the Value at risk can be calculated as ;

$$\text{VAR}_\alpha(W) = E(W) - Q_\alpha(W) \quad (12.1)$$

Where

$$Q_\alpha(W) = \inf\{U: F(u) > \alpha\} \quad (12.2)$$

Equations 12.1 and 12.2 shows that the VaR is the difference between the expected value of the asset and the value of the asset at the  $\alpha$  % quantile. When calculating VaR, two main methods can be used. The first method considers the actual empirical distribution. The second method uses a parametric approximation, such as the normal distribution, and then VaR is derived through use of the standard deviation. In this thesis the first method will be used. Discussion on the second method can be found in Appendix 8

#### 12.3.1 VAR for general distributions

In this method the initial investment is defined as  $W_0$ , and  $R$  as its rate of return. By the end of a contracting period the value of the energy investors investment has grown to  $W = W_0(1 + R)$ . The expected return and volatility of  $R$  are  $\mu$  and  $\sigma$ . Hence, the purpose of VaR is to define the minimum value  $W^*$  or the cut-off region  $R^*$  and the lowest value of the investment at the end of the contract period is then set to be  $W^* = W_0(1 + R^*)$  at a given confidence level  $c$ . Calculation of VaR can be done either as *relative VaR*, which in the case of the Energy investor means loss in NOK relative to the mean or expected value of the NPV. This can be written as:

$$\text{VaR}(\text{mean}) = E(W) - W^* = W_0(R^* - \mu) \quad (12.3)$$

The VaR can also be calculated on an absolute basis, which represents the loss in NOK relative to zero or without reference to the expected value:

$$\text{VaR}(\text{zero}) = W_0 - W^* = -W_0R^* \quad (12.4)$$

Since the investment problem in this thesis represents a time horizon that varies from 1-15 years and a possible mean return can be quite high, the need for viewing risk in terms of a deviation from the mean is more appropriate than absolute VaR. Hence relative VaR will be used in this thesis.

VaR can generally be derived from the probability function of the future portfolio value  $f(w)$ . As mention above,  $W^*$  is called the quantile of the distribution and represents the worst possible realization or minimum value of the NPV for the energy investor. The probability of exceeding this value is  $c$  which is given by:

$$c = \int_{W^*}^{\infty} f(w)dw \quad (12.5)$$

As mentioned above this way of computing the VaR is valid for any distribution, discrete or continuous, fat or thin –tailed.

### **12.3 Quantitative factors in VaR calculation**

Two quantitative factors  $c$ , which gives  $\alpha$ , and  $\Delta t$  has to be defined in order to calculate the VaR. In general VaR will increase with either a longer time horizon  $\Delta t$  or a greater confidence level  $c$ . The choice of the two factors depends on what the risk measure will be used for. If the VaR is used directly to set a capital cushion for the energy investor, a loss exceeding the VaR would wipe out the equity capital, leading to bankruptcy. As mentioned in the beginning of this chapter, the VaR in this thesis is used as support for decisions based on uncertainty in the price of the energy carrier. The risk aversion and the cost of exceeding VaR for the energy investor should therefore both be reflected in the confidence level chosen. Higher risk aversion or greater costs implies that a greater amount of capital should cover possible losses, thus leading to higher confidence level. The time horizon should be chosen such that it corresponds with the time needed to undertake corrective actions when losses start to appear. In this thesis the quantile is set by the Energy investor to fit each specific case. If the quatile is not given, a default value of 0,95 (95%) is set in the model.

## 12.4 Discussion of VAR as a measurement of risk for the energy investor

The notion of risk itself can be hard to appreciate without a clear idea of what is meant by measuring risk. Therefore Artzner, Delbaen, Eber and Heath (1997, 1999) postulated a set of risk-measure axioms – the axioms of coherency, to clarify which criteria a good measure of risk should satisfy. Assume that risk measure is a function of the distribution of portfolio value  $W$  summarized into one single number  $\rho(W)$ , the four following axioms should be applicable;

- **Monotonicity:** If  $W_1 \leq W_2$  then  $\rho(W_1) \geq \rho(W_2)$ ;  
If one portfolio has systematically lower returns than another in all possible cases, its risk must be greater.
- **Translation in Variance:**  $\rho(W + k) = \rho(W) + k$   
If an amount of cash  $k$  is added to a portfolio, this should reduce the risk of a portfolio by  $k$ .
- **Homogeneity:**  $\rho(bW) = b\rho(W)$   
When increasing a portfolio's size by  $b$ , the risk of the portfolio should be scaled by the same amount of cash added.
- **Subadditivity:**  $\rho(W_1 + W_2) \leq \rho(W_1) + \rho(W_2)$   
Combining portfolios should not increase the risk.

A risk measure that satisfies all the above conditions is called coherent. Further Artzner et al (1997,1999) showed that VaR satisfies the first three conditions, but fails to satisfy the condition of sub additivity, and thus is not coherent. To understand what this means for the energy investors investment conclusion, it is vital to understand the nature of the investment decision. The fact that the condition of subadditivity is not satisfied conflicts with the energy investor's possibility of investing in a heating system containing multiple energy carriers and at the same time using VaR as a risk measure. If the energy investor is considering an energy system composed of both a peak load and an off-peak load the risk can increase. In other words by combining two portfolios of different energy carriers, the Energy Investment model might give a higher measure of risk<sup>36</sup>. One way of overcoming this barrier is by introducing Conditional value at risk (CVaR) into the Energy Investment model.

Measuring VaR is a sort of “best of worst cases” scenario, which means that for the energy investor it shows the highest value of loss from the expected value, within the confidence interval chosen. There is thus no information about what happens outside the chosen confidence interval. Considering the distributions in figure 20, they all have the same VaR, at the 5% quantile, but the expected loss exceeding VaR is bigger for the stipulated line than for the solid line in the first graph.

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<sup>36</sup> In addition Wu and Xiao (2002) analyzed the performance of VaR for different distributions and showed that VaR as a risk measure may fall short when the distributions are very uncertain and for example exhibit spikes and jumps.

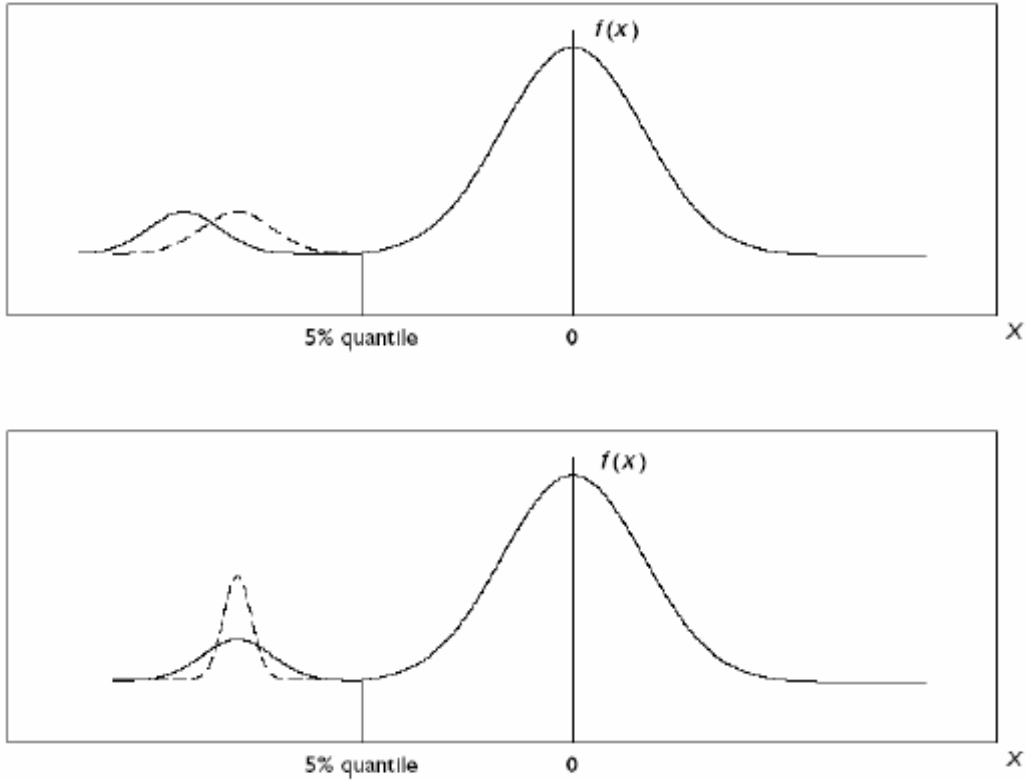


FIG 20 Various distributions that have the same Value at risk measure Wu and Xiao (2002)<sup>37</sup>.

In the lower graph the stipulated line has higher variance for the losses exceeding VaR than for the solid line. The four graphs show that although VaR is the same, the nature of the losses can be quite different. By introducing Conditional value at risk (CVaR) it is possible to capture these differences among distributions exceeding the VaR. CVaR measures the expected loss (EL) and the standard deviation of the loss (SDLL), if the loss exceeds the Value at risk. By using CVaR one can therefore identify the extra risk for a distribution with fat tails, which is very useful when it comes to distributions of energy prices. The conditional mean of losses larger than VaR can be calculated as Wu and Xiao (2002) ;

$$CVAR = -E[r_t | r_t \leq -VAR_t(\tau); I_{t-1}] \quad (12.6)$$

Where  $\tau$  is the quantile of VAR and  $I_{t-1}$  is the information one has at the time t-1. The standard deviation of losses larger than VAR, SDLL, can be calculated in the usual way as

$$SDLL = \sqrt{r_t - (E\{[r_t | r_t \leq -VAR_t(\tau); I_{t-1}]^2 | r_t \leq -VAR_t(\tau); I_{t-1}\})} \quad (11.7)$$

CVaR satisfies the properties of being a coherent risk measure. CVaR can therefore be calculated for large portfolios without the need for expert opinion and subjective judgement of correlations between the multiple assets. In other words it is viable as a risk measure also when the energy investor considers an energy system containing multiple energy carriers. Although it might seem like CVaR gives the right measure of risk, one should remember that the risk is measured from the distribution in the left tail which again is based on very few observations and therefore can be subject to large errors in the distribution at the tail. Hence

<sup>37</sup> The solid and the stipulated line in the highest graph are such that the expected value for the whole distribution remains the same. All though this is difficult to see from the figure, the fact is assumed in this thesis.

the calculations of CVaR and SDLL may be somewhat uncertain. In the Energy Investment model the VaR will be calculated, since the model also includes flexible energy systems with combining two or more energy carriers, CVaR will be calculated as well. As the final decision-maker, it is the responsibility of the user of the model to draw conclusions based on the information about VaR, CVaR and the SDLL provided by the model.



## 13 Environmental consideration

Up to this point, the perspective in the thesis has been on corporate profitability. If the government regulations were to change in the future, social costs and benefits would also affect the investment decision for an energy investor. In the latter years we have seen an increased focus towards how each individual building perform according to energy use and environmental disadvantages. One example is the suggestion for incorporating building energy certificate in Norwegian buildings. With the increased focus on building performance, a change in laws towards a taxation system based on what type of energy system and carrier that is used in the building and how this energy system affects the environment. The increased focus on environmental and social disadvantages due to energy use might therefore affect the energy investor through increased taxes and thereby lower income.

The definition of “environmental effects” is vague with many different interpretations. The meaning of environment effects in this thesis does not include the aesthetic or noise aspect, but rather reflects pollution on the natural environment.

### **13.1 How to model environmental effects**

How a building affects the environment can be measured in many ways. Some take the total heat demand and transmission losses into consideration. Others also include how, by which energy carrier and technology, the heat demand is served. Until now there have only been national regulations regarding the size of heat demand in a building. Because the government in Norway endeavours more use of renewable energies as well as increased security for energy supply, a new EU directive suggested by the European Parliament (2002) will be up for discussion in January 2007. The directive considers the energy performance of buildings together with seeking a joint method to measure this energy use. The directive also suggests new and enforced national demands for energy use in new and renovated buildings. In addition, a new system for energy certificates is presented. The certificate shows the energy performance as well as how environmentally sound a building is together with how to improve the energy performance for the building. The energy certificate must be visible in all public buildings.

#### **13.1.1 System boundary**

An important question when analysing the environmental effects for the different energy carriers is where to put the system boundary. Even more important is the assurance that the system boundary is set equally (at the same place) for all the energy carriers. There exist several environmental studies where the system boundaries are set differently among the energy carriers analysed, which can be rather unfair between the energy carriers. For example, if the system boundary is not set around the users building but rather accounts for the whole value chain of the energy carriers analysed, there would be some inaccuracy if bio fuel is set to be CO<sub>2</sub> neutral. The reason for this is that the bio fuel has to be transported to the client, normally done by truck, which implies CO<sub>2</sub> emissions. In some environmental studies, emissions from electricity are also often misinterpreted for certain reasons. If the system boundary is set around the users building it is of no importance in the calculations how the

electricity is produced. With this perspective it is irrelevant whether the marginal increase<sup>38</sup> in electricity is produced from gas-fired power plants or from windmills. Contrarily, if the boundary is not set around the building, but rather takes the whole value chain into consideration the above questions for electricity will be relevant. If this perspective is to be used, it is important to also do this for the comparative energy carriers and therefore include CO<sub>2</sub> emissions from transportation of energy carriers such as pellets, gas and oil. Another interesting thought is that if the boundary is set around the whole value chain of an energy carrier, some of the environmental effects and disadvantages can be charged for twice. The reason for this is that the price that a customer has to pay for an energy carrier already includes environmental taxes that in theory is assumed to already reflect all of the environmental effects.

### **13.1.2 The boundary set in this thesis**

Although it is very interesting and relevant to set the boundary around the total value chains of the energy carriers, this is of more relevance when a socio-economic analysis is performed. In this thesis, the emphasis is on business profitability and risk for an energy investor, and therefore it is of more importance to investigate the exact effects for a potential client rather than for the society as a whole. Another perspective is to consider a future system of environmental taxes whereby the owners have to pay taxes on the emission from their own buildings. This perspective might not be as unrealistic due to the increased focus on how buildings affect the natural environment. With such alterations in the government rules regarding environmental tax payment, a system boundary around the building is of high importance and of relevance in this thesis. Due to the above aspects, the boundary for environmental analysis will therefore, in this thesis, be set around the client's building.

Setting the boundary around the client's building, the prices that are paid for the electricity, oil, gas and pellets at delivery includes all the environmental disadvantages that have occurred in the value chain up to the point of delivery. The method used for the study of environmental effect in this thesis will be to assign each energy carrier a value (or weight them) according to a set of environmental parameters. The method is called environmental energy supply.

### **13.2 Environmental energy supply**

The environmental energy supply takes both the buildings need for energy supply and how this supply is served into consideration. In the model the energy demand is multiplied by different environmental parameters. There are currently some disagreements about which environmental parameters that should be used. Two methods have been considered in the thesis, namely CO<sub>2</sub> *emission* and the *total environmental costs* for NO<sub>x</sub>, SO<sub>2</sub>, dust and CO<sub>2</sub>.

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<sup>38</sup> With new buildings, or renovated buildings that switches from an old energy(oil/Gas) carrier to electricity(heat pump or electricity-fired boiler), the importance is where the **marginal** increase in electricity in electricity come from. This is because Norway already consumes more than what is produced from Hydro power, and any new consumption has to be served by increase in production (Windmills, Gas-fired power plants) or import.



### 13.2.1 CO<sub>2</sub> emission as an environmental parameter

As mentioned above one of the environmental indicators used can be the amount of CO<sub>2</sub> emission from a buildings energy system. If this suggestion is followed, the basis for the calculations will be the amount of CO<sub>2</sub> that is developed when the energy carrier is burned to create/transform into 1 kWh of energy use. The total energy supply for the building will then be multiplied by a number which represents the energy carrier's emission of CO<sub>2</sub>, according to the Equation below;

$$E\_CO2_i = ES_i * W\_CO2_i \quad (13.1)$$

i-Type of energy carrier (oil, gas, electricity and pellets)

E\_CO2<sub>i</sub> – Emission of CO<sub>2</sub> due to use of energy carrier i in a building [g]

ES<sub>i</sub> – Energy supply for the building when using energy carrier i [kWh]

W\_CO2<sub>i</sub> – Weight factor for energy carrier i [g/kWh]

The various energy carriers discussed in this thesis release CO<sub>2</sub> according to the table below.

Table 8: CO<sub>2</sub> emission from the various energy carriers in the thesis COWI (2005). Heat efficiency of the building is not included

Energy Carrier	CO <sub>2</sub> g/kWh
Heating oil	273
Gas	202
Pellets	0
Electricity	0

The heat efficiency for the energy systems chosen are not accounted for in the above numbers. This is due to the fact that the heat efficiency varies a great deal among the technologies and will rather be accounted for when providing the baseline in the Energy Investment model for each particular case. Further combustion of pellets is considered as CO<sub>2</sub> neutral since the growth in biomass is taken to be the equivalent to the amount used, and bio fuel captures the CO<sub>2</sub> in the atmosphere. Electricity will also have zero CO<sub>2</sub> emission due to the placement of the system boundary. The value for heating oil and gas in table 8 is dependent on the quality of the field which the oil is taken from, but can be regarded as an average value.

There are several environmental aspects not covered by just viewing the CO<sub>2</sub> emission among the energy carriers. Take bio fuel for example; this energy carrier causes other environmental damage besides CO<sub>2</sub> emission, such as emission of dust and NO<sub>x</sub>. By basing conclusions on a single environmental factor (CO<sub>2</sub> emissions), one might not arrive at the correct overall environmental solution. Therefore an alternative method based on total costs of environmental damage is suggested below.

### 13.2.2 Costs as an environmental parameter

In order to capture all the environmental aspects, it can be more appropriate to use costs related to environmental damage, instead of just the CO<sub>2</sub> emission. In this method various

emissions are given a cost. The emissions, for which the costs will be measured are (in addition to CO<sub>2</sub>) dust, NO<sub>x</sub> and SO<sub>2</sub>. By calculating the total quantity of emission for each energy carrier the total environmental costs for using the energy carrier can be found with Equation 12.2.

$$EC_i = ES * W\_COST_i \quad (13.2)$$

EC<sub>i</sub>-Environmental costs for using energy carrier *i* in a building [NOK]

W\_COST<sub>i</sub>- Cost of emissions for each energy carrier [NOK/kWh]

When placing the boundary around the clients building, the four energy carriers considered in this thesis have the following emissions.

Table 9 The emissions of different environmental damaging substances for the Different energy carriers considered in the thesis. The emissions do not account for the heat efficiency of the technology that is used<sup>39</sup>.

	Bio fuel	Gas	Heating Oil	Electricity
Dust[mg/kWh]	9	0	6	0
NO <sub>x</sub> [mg/kWh]	270	80	240	0
SO <sub>2</sub> [mg/kWh]	3	14	85	0
CO <sub>2</sub> [g/kWh]	0	202	273	0

The various costs for emission of the above substances are shown in table 10. The costs are collected from SSB (2004), and reflect the social costs due to using the different energy carriers.

Table 10 Costs for the various environmental parameters; CO<sub>2</sub>,NO<sub>x</sub>,dust and SO<sub>2</sub>.

Substance	Costs [NOK/kg]
Dust	590
NO <sub>x</sub>	18
SO <sub>2</sub>	14
CO <sub>2</sub>	0,08

The cost for dust varies by location in Norway, but the costs here are the average costs for the whole country. When the environmental costs for the different substances as well as the amount of emissions for each energy carrier are known, it is relatively easy to calculate the environmental costs for each energy carrier in the thesis. Table 11 shows the results

Table 11 Various costs related to the energy carriers modelled in the thesis

	Bio	Gas	Heating Oil	Electricity
Costs [NOK/KWh]	0,010	0,018	0,031	0

For heating systems that contain multiple energy carriers, the costs will be weighted according to use of the different energy carriers, which is based on the distribution between the peak load and base load.

<sup>39</sup> Wigenstad, Dokka, Pettersen and Myhre (2005)

### ***13.3 Discussion of the chosen method***

The method for measuring environmental effects applied in the Energy Investment Model is based on the last method with costs as an environmental parameter. The reason for choosing the second method is quite obvious. The greater the number of environmental parameters included, the more accurate is the comparison of the environmental effects for the different energy carriers. This is because each energy carrier lets out different environmental damaging substances. An environmental graph that shows the environmental costs due to the use of the various energy carriers are provided in the Energy Investment model. The environmental graph can be used to compare the environmental costs for the various investment alternatives within a project.



## **14 The Energy Investment model**

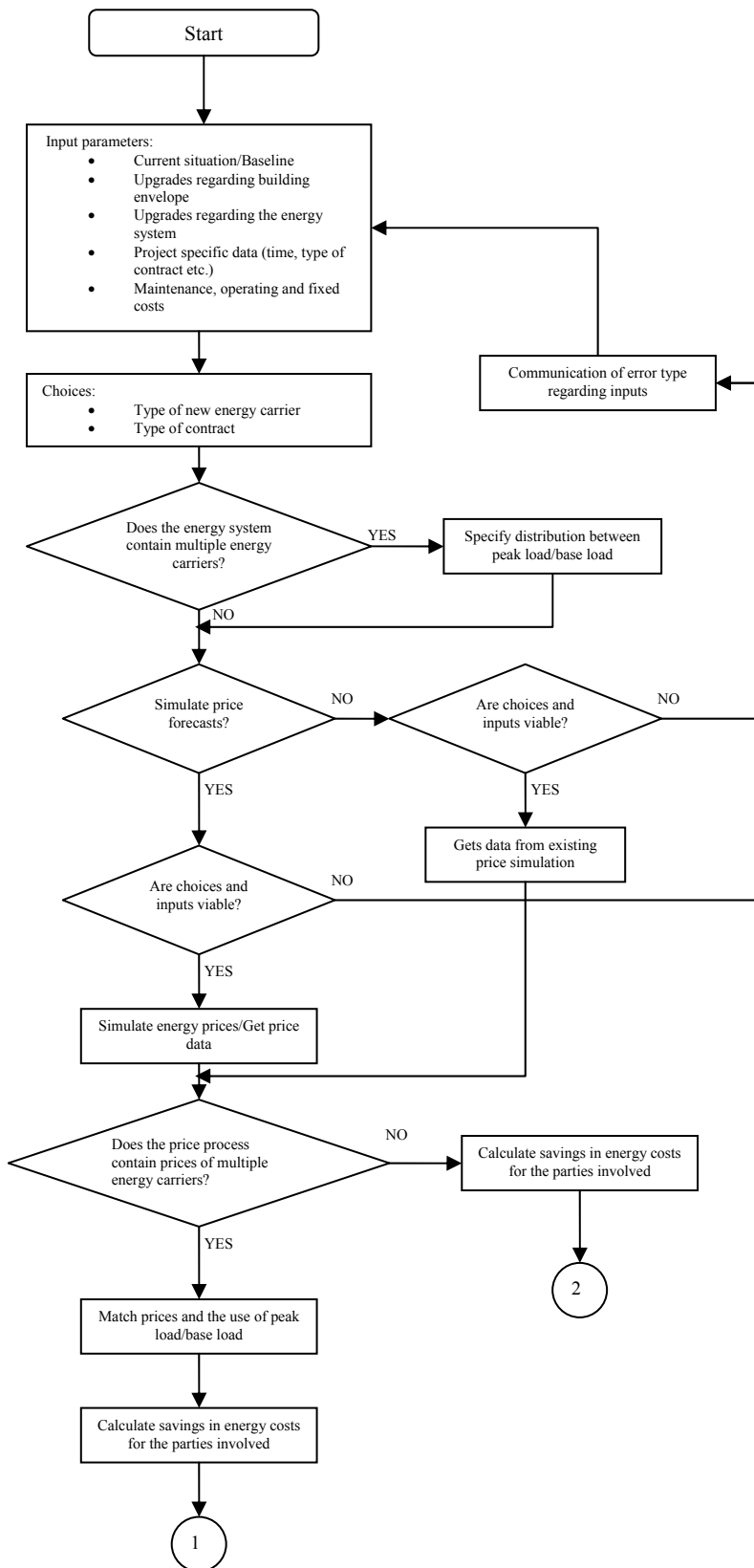
The Energy Investment model is a decision support tool, based on net present value analyses, made for an energy investor viewing various types of contracts for an investment. The model takes into account the uncertainties in important parameters such as prices of electricity, gas, heating oil and pellets, together with incorporating correlation between the energy prices. The uncertainties are communicated using a Value at risk analysis. Furthermore, the model also considers environmental costs and benefits. The model consists of macros, which can be viewed in appendix 13, programmed in VBA. A CD containing the program is added at the end of the thesis. Further, the Energy Investment model can help to make decisions regarding:

- How to structure an Energy Performance Contract
- What types of investments that are most profitable
- How the income, investment and expenses should be allocated among the involved parties.
- The environmental costs of an energy investment
- How the risk in prices of the chosen energy carrier(s) affects the net present value for the energy investor

This chapter will explain how the model is constructed, and how it works. The next chapter will give examples of the model being used when analyzing real cases in Norway.

### ***14.1 Understanding the Energy Investment model***

The Energy Investment model is based on both input parameters estimated from various energy price analyses, and input parameters provided by the user, to match each case analyzed. By letting the user provide some parameters the model is highly generalized which allows it to fit a number of cases. There are three different contract types to choose from in the model. The three contract types are Energy service contract, Shared savings and Guaranteed savings. The conditions for the three contract types are default in the model. The model will therefore do a check on input parameters provided by the user and communicate any mismatch between these and the choices made regarding type of contract. To understand how the model works a flow diagram has been constructed. The flow diagram is illustrated in figure 21 and shows the main tasks and steps made in the Energy Investment model.



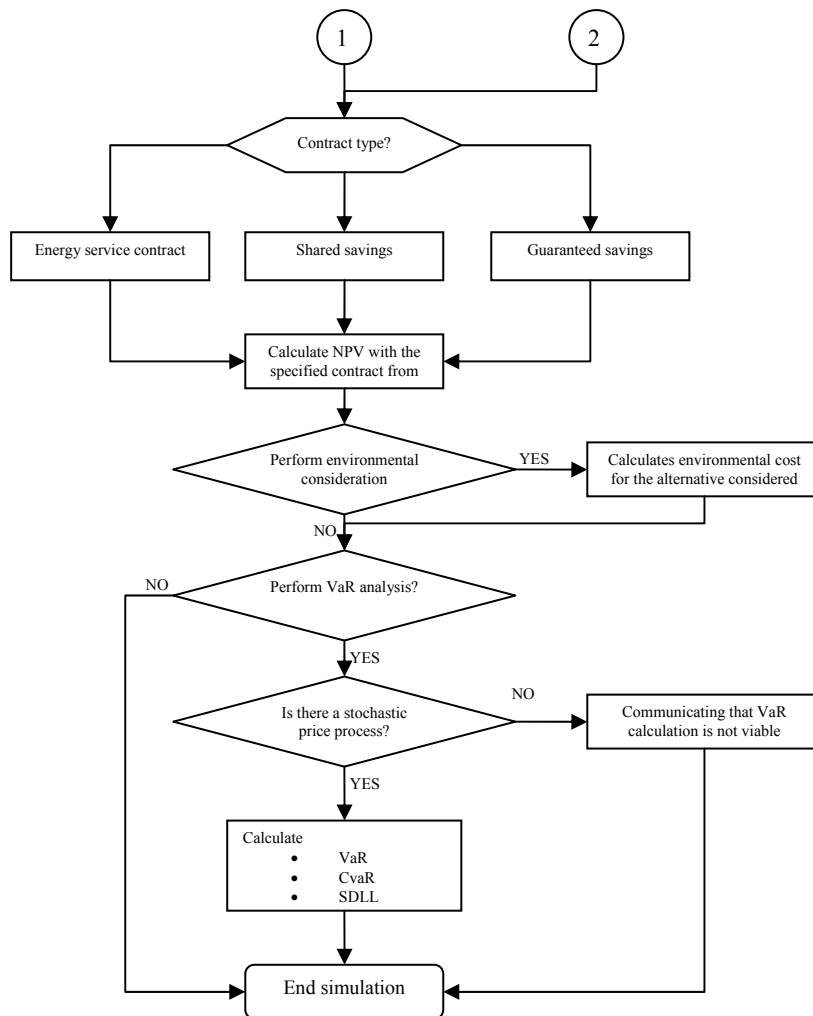


FIG 21: Flow diagram for how the Energy Investment Model works

As can be seen from the flow diagram, using the model starts with specifying input parameters. After specifying the input parameters the user must choose which type of contract and energy carrier to use in the analysis. If the new energy system contains several energy carriers, a specification of the distribution between the peak load and base load is needed. The next step for the user is to decide between doing a simulation of energy prices or keeping old price forecasts. The old forecasts will be the ones simulated the last time the Energy Investment model was used to simulate prices. If the energy carrier or start date for the project is equal between to simulations, there is no need for new price forecasts. The purpose of giving the user this choice is to reduce the processing time for calculations in the model. It takes longer time to run the model when the model has to create price forecasts. Further all the cell values are checked before running any simulations. This is to ensure that the input variables are in alignment with the choices made in the model. When there is a mismatch between cell values and choices, the model communicates which cells that might contain the error. When having an energy system with multiple energy carriers, the model will match the peak load and base load with their right prices at the right time. The first results calculated in the model are the cash flows due to savings in energy costs for the different parties involved. Next the model calculates the net present values for the parties involved. If the user wishes an environmental consideration, these costs are calculated by the model and shown graphically. The model also contains a VaR analysis together with showing both CVaR and SDLL, but can only be used for the prices that contain stochastic variables. This means that if only pellet

is chosen the VaR calculation will not be viable. The next subchapters elaborate the main steps using the model.

### 14.2 Input parameters

The input parameters provided by the user describe the current situation for the building and energy system, as well as project information such as contract type and length. The cells which require input parameters have a green colour. The cells that are set in advance, and can not to be edited are blue. Further, a yellow cell indicates that the user has to decide between alternatives in a drop down menu.

#### 14.2.1 Current situation of the building

The current situation of the building is provided enabling the model to derive a baseline for comparisons to future savings in energy costs. Since the time-frame for the energy prices in the model is months, the user is asked to provide information about average energy consumption each month before any investments are made. It is also possible to incorporate future growth in energy demand. The future growth can arise from increased comfort or increase in production in the clients building. The future growth is incorporated by adding the predicted (yearly) percentage increase in energy demand as an input in “expected growth in energy consumption”. A figure of the worksheet, “Current situation”, for the above inputs is shown in the figure below.

Month	Energy expenses	Energy consumption (Kwh)
Jan	1 209 859,38	1728370,545
Feb	1 131 230,42	1616043,455
Mar	893 043,23	1313298,864
Apr	646 677,99	1077796,655
May	627 355,18	985161,8182
June	625 204,57	893149,3818
July	603 391,90	861968,4273
Aug	538 296,57	868220,2727
Sept	711 695,22	1016707,455
Okt	866 396,46	1332917,636
Nov	1 092 984,53	1539414,836
Des	1 104 464,26	1577806,082
<b>Yearly energy expenses</b>	<b>5 025 299,86</b>	<b>7 395 437,71</b>

Current energy carrier: Oil

Expected yearly growth in energyconsumption (%): 0

FIG 22: Sheet “Current situation”

When a baseline is constructed, it is of importance that it reflects the energy supply and not the energy demand. This will be satisfied if former energy bills are used. If a new building is considered and only heat demand is known, the energy supply can be calculated using the efficiency rate for the energy system under consideration. How to calculate the energy supply can be found in appendix 12. If there are no former energy bills or data on heat demand from previous years the reader can follow the steps in chapter 15.2.3 .The chapter shows how to construct a baseline for approximation, when one is not available.



## 14.2.2 Upgrades

In the Energy Investment model, the upgrades are divided in two main categories; the first category represents the upgrades due to the building envelope. These upgrades can be isolation of walls, roofs, ground floors together with investment in glasses with low U-values<sup>40</sup>. The costs can be provided either as a total cost or as separate material and labour costs. Figure 23 shows the sheet for the inputs regarding the building envelope.

	A	B	C	D	E	F		
1								
2								
3	Building upgrades							
4								
5	<b>Type of Upgrading or investment</b>	<b>Cost of material / or technology</b>	<b>Setup and installation costs</b>	<b>Total Cost [NOK]</b>	The costs for setup / installation and material can be provided as one total cost. If this is the case then only one of the green columns (B or C) should be used			
6	<b>Svartlamoen Residential (960m<sup>2</sup>)</b>	0,00	0,00	0,00				
7	Isolation of Wall, 40mm ekstra, mineral wool, $\lambda$ is 0,037W/mK	300 000,00	0,00	300 000,00				
8	Isolation of Roof, 100mm, mineral wool, $\lambda$ is 0,037W/mK	600 000,00	0,00	600 000,00				
9	Window, changing to standard 11 window	800 000,00	0,00	800 000,00				
10	Ventilation, changing to balanced VVX 60%	300 000,00	0,00	300 000,00				
11		0,00	0,00	0,00				
12		0,00	0,00	0,00				
13		0,00	0,00	0,00				
14		0,00	0,00	0,00				
15		0,00	0,00	0,00				
16		0,00	0,00	0,00				
17		0,00	0,00	0,00				
18		0,00	0,00	0,00				
19		0,00	0,00	0,00				
20		0,00	0,00	0,00				
21		0,00	0,00	0,00				
22		0,00	0,00	0,00				
23		0,00	0,00	0,00				
24		0,00	0,00	0,00				
25		0,00	0,00	0,00				
26		0,00	0,00	0,00				
27		0,00	0,00	0,00				
28		0,00	0,00	0,00				
29		0,00	0,00	0,00				
30		0,00	0,00	0,00				
31		0,00	0,00	0,00				
32		0,00	0,00	0,00				
33	<b>Sum Costs</b>	<b>2 000 000,00</b>	<b>0,00</b>	<b>2 000 000,00</b>				
34								

FIG 23: Sheet "Upgrading Building".

The second main category is investments regarding improvements of the heating system. The sheet where the input parameters are requested is called "Upgrading Energy system". The various costs for the investments can either be provided as total costs or separately as technology and labour costs. Further, the user communicates the energy carrier chosen by selecting one of the options provided in the yellow drop down menu in figure 25. The various energy carriers to choose from and how they are combined (which is used as peak load energy carrier and which is used as the base load energy carrier) in the model are shown in figure 24.

<sup>40</sup> According to Hanssen, Thue, Skarstein, Gjerstad and Novacovic (1996) U is a measure of air-to-air heat transmission (loss or gain) due to thermal conductance and the difference in indoor and outdoor temperatures. As the U-value decreases, so does the amount of heat that is transferred through the material.

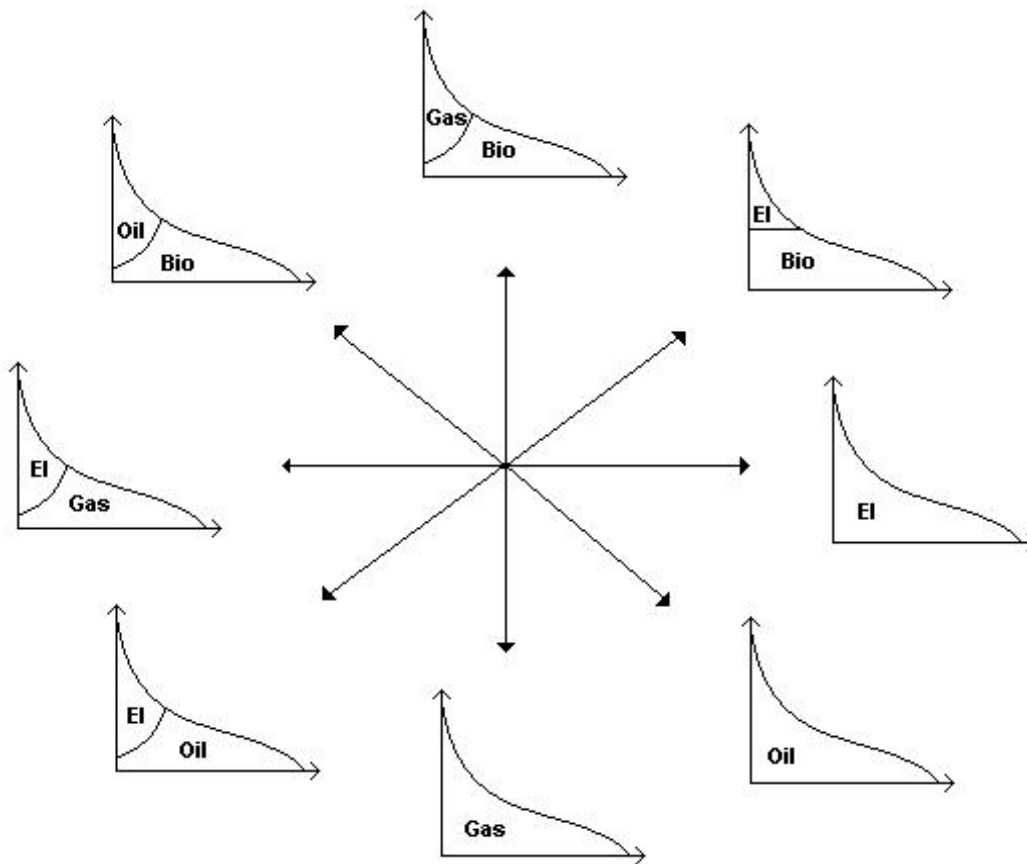


Figure 24: The various choices of energy carrier in the Energy Investment model

As can be seen, the options contain both energy systems with a single energy carrier and options with multiple energy carriers. However, if a system with multiple energy carriers is chosen, there is a need to specify the distribution between peak load and base load for the particular building analyzed<sup>41</sup>. In the Energy Investment model this is done by specifying which months the peak load is used together with the peak load/base load percentage distribution. The Energy Investment model will automatically find the month with the highest consumption and calculate the base load as a percentage of that consumption. For each month, if the total load exceeds the base load, the peak load is calculated to serve the deviation from the base load in the particular month. If none of the options on energy carrier(s) fits the new energy system, the user can choose “other” from the drop down menu. When doing this the user has to explicitly specify the average price of the “other” energy carrier during the contract period. This price information is added in the right top corner as can be seen from figure 32. The prices that are compared to each other for the different heating alternatives must be the total prices that the client has to pay for an energy carrier. The default prices for heating oil and gas are prices paid by the client, including all possible taxes. Regarding electricity the default prices only reflect the spot prices. To achieve the right comparison between the energy prices and since the grid charge varies by location in Norway a cell “Grid charge and tax” that requires the grid charge + taxes for electricity has been provided in the model. Further when the energy carrier chosen is pellets the user needs to specify whether the application is large scale (Bulk) or small scale (Bag). This is due to the fact that the price for the energy carrier is highly dependent on the form of delivery. In addition, the user also needs to specify which price scenario **Pellets–High price, Pellets–Middle price or Pellets–Low price** to use in the project analysis.

<sup>41</sup> Further information on peak load and base load can be found in chapter 3.2.1

	A	B	C	D
1				
2				
3	Upgrades regarding the energysystem			
4				
5	Type of energy carrier (new) :	Gass		
6	Grid charge and tax (NOK/Kwh, if electricity is chosen	0,23		
7				
8	Type of upgrading or investment	cost of equipment td	Installation costs	
9	Pipes and radiator	1550 000,00		1550 000,00
10	VVB	300 000,00		300 000,00
11		0,00		0,00
12		0,00		0,00
13		0,00		0,00
14		0,00		0,00
15		0,00		0,00
16		0,00		0,00
17		0,00		0,00
18		0,00		0,00
19		0,00		0,00
20		0,00		0,00
21		0,00		0,00
22		0,00		0,00
23		0,00		0,00
24	Sum costs	1850 000,00	0,00	1850 000,00
25				
26				
27	Expected savings in energycosts after investment (%)	20,2		
28				
29				
30				
31				
32				
33				

Figure 25: Sheet “Upgrading energy system.” (left side of the window)

	D	E	F	G
1				
2		If Other energy carrier is chosen, spesify price (NOK/Kwh)		
3				0,33
4		If pellet is chosen, spesify delivery and price path		
5		Delivery	Bulk	
6		Price path	Middle	
7				
8				
9	1550 000,00	If a combination of several energy carriers is chosen, spesify number of month with peak load , ezs jan=1, feb=2, maximum six months		
10	300 000,00			Weight Factor for the peak months
11	0,00	Peak month one	1	0,4
12	0,00	Peak month two	2	0,5
13	0,00	Peak month three	11	0,3
14	0,00	Peak month four	12	0,2
15	0,00			
16	0,00	Distribution between the base load and peak-load		
17	0,00	Base load [%]	70	
18	0,00	Peak load [%]	30	
19	0,00			
20	0,00			
21	0,00			
22	0,00			
23	0,00			
24	1850 000,00			
25				
26				
27				
28				
29				
30				
31				
32				
33				

Fig 26: Sheet”Upgrading energy system” right part of the window.

In the sheet for “Upgrading energy system”, specification of the level of energy savings is also requested. This is the total reduction in energy demand due to upgrading of both the building envelope and the energy system. The deviation between the heat demand and consumed energy vary with the technology’s efficiency. This has to be accounted for when

providing the percentage of energy reduction in the model. Examples of how to incorporate technologies with different energy efficiencies is shown in the chapter 15.

### 14.2.3 Administration, operating and maintenance costs

Administration costs occur from the fact that analyzing a project takes time. The energy investor must have some sort of economic compensation for the time and effort put down in an Energy Performance Contract. In addition, operating an energy system generates costs for the energy investor which also needs to be included in the net present value. However, if a client has significant experience with the energy system installed, he may choose to operate the system himself, but as discussed in chapter 4, this may generate additional risk for the energy investor. The effort spent on operating the energy system during the contract period is highly dependent on the type of technology and energy carrier chosen for the heating system. As an example, a heat pump demands a higher degree of inspection than electric radiators or even oil, bio or gas fired boilers. In addition, the different technologies have different economic and operating lifetimes and thus the number and degree of replacements during a project lifetime may vary. The costs are provided as annuities in the Energy Investment model. The user does not have to calculate these annuities but instead simply adding the different costs at the right time (year) in the sheet called “Operating costs” The window for this sheet is shown below. The blue cell which can not be edited will show the yearly operating, maintenance and fixed costs for the heating system chosen.

Year	Operating costs (OC)	Maintenance costs (MC)	Fixed/Administration costs (FC)
1	200 000,00	65 100,00	300 000,00
2	100 000,00	65 100,00	200 000,00
3	100 000,00	65 100,00	200 000,00
4	100 000,00	65 100,00	200 000,00
5	100 000,00	65 100,00	200 000,00
6	100 000,00	65 100,00	200 000,00
7	0,00		0,00
8	0,00		0,00
9	0,00		0,00
10	0,00		0,00
11	0,00		0,00
12	0,00		0,00
13	0,00		0,00
14	0,00		0,00
15	0,00		0,00
<b>Total</b>	<b>675 077,27</b>	<b>381 864,68</b>	<b>1 261 658,96</b>
<b>Yearly cost</b>	<b>112 512,88</b>	<b>63 644,11</b>	<b>210 276,49</b>

This sheet calculated the yearly operating, maintenance and Administration costs. The calculation, rent and contracting period will automatically be collected from the sheet called Upgrading Energy system once the information is provided

FIG 27: Sheet “Operating Costs” regarding operating, maintenance and fixed/administration costs in the Energy Investment Model

### 14.3 Use of solar heat and heat pumps

With the way the Energy Investment model is constructed, it is also possible to analyse the cost and benefit of installing solar heat technology or heat pumps. This is simply done by adding the extra investment costs together with the increased energy savings due to the installation. The simple idea in the Energy Investment model is that when a heat pump is

installed, electricity is still the energy carrier but the heat consumption will be much smaller than with regular electric radiators. This is then accounted for in the input of the percentage of energy reduction after investments are made. Therefore there is no need to explicitly specify the use of technology, only the investment costs. The same applies for solar energy. If the user wishes to analyse a project containing an energy system using solar heat, the user simply adds the costs for the technology and increases the percentage of energy reduction due to the “free” heat from the sun. The benefits are also included with positive effects in the environment diagram discussed in chapter 13.

### 14.4 Project specific data

To communicate which prices the Energy Investment Model should use in the calculations, the project start date needs to be specified. The price processes incorporated in the model were simulated with start in Jan. 06. Because the Energy Investment model is constructed to match dates, it will automatically get the data from the price simulation that suit the project start date and duration.

There might also be external financial support from the government if the project is environmentally sound. In such cases the amount of monetary support can be provided as an input and will be considered in the calculations. The user also has to choose whether an environmental consideration should be done. If an environmental consideration is endeavoured the user has to choose “Yes” in the yellow drop down menu. Finally, if the user wishes to do a value at risk analysis of a project, the confidence interval needs to be provided. The input sheet for the project specific, ”Project data”, is shown in figure 28 below.

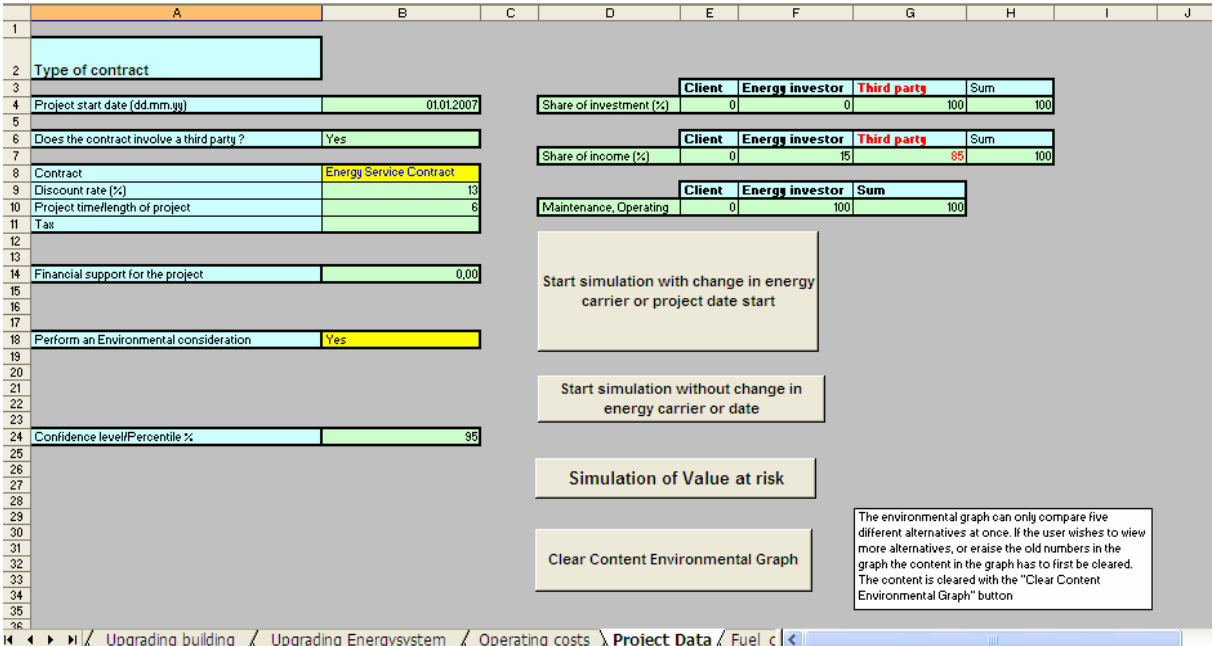


FIG 28: sheet “Project data” in the Energy Investment model.

The discount rate is needed for calculations of net present values. All though the discount rate is input provided by the user to suit each specific project analysed, it is appropriate to present a small discussion on what this rate reflects. For private investors such as an energy investor, the rate should reflect the opportunity cost of capital. Further the total risk an energy investor faces are made up of both systematic (non-specific) risk and unsystematic (or specific) risk. Systematic risk, discussed in this thesis, is that part of the total risk which is

associated with movements in the underlying market as a whole. The systematic risk can for example be movements in the energy prices. The unsystematic risk is that part of the total risk which is specific to each individual energy investor. An energy investor is able to reduce unsystematic risk through holding a diversified portfolio of shares, which means conducting Energy Performance Contracts with several different companies. The return on equity for an energy investor can be found by using the Equation below;

$$r_e = r_f + \beta_e(r_m - r_f) \quad (14.1)$$

In the Equation above,  $r_f$  represents the risk free rate and  $r_m$  the market risk. The market risk can be found by looking at historical prices for the Norwegian stock exchange (Oslo Børs). Further  $r_f$  is found by either looking at historical prices or using Norwegian Government bonds. The average deviate between the return on market  $r_m$  and short term government bonds has according to NVE (2004) been 5, 5% from year 1980 to 2003. Using this number together with today's risk free rate the market risk today would be around 8-8,5%.  $\beta_e$  measures the energy investors volatility of return on the investment relative to the market and is calculated using historical data of market movements in relation to movements in the energy business. The value of  $\beta_e$  can be hard to predict due to the fact that energy companies vary a great deal in both size and capital structure. Equation 14.1 can also be used for finding  $r_d$ . When doing this,  $\beta_d$  is often set to zero which implies that the return on debt is equal to the risk free rate. The perceived average of return on equity for some energy related companies during the past year is according to Hegnar (2006) calculated to be 17, 8 % .

In practise firms often use industry "standards" to set the hurdle rate. The analyses in this thesis will be conducted with several discount rates (between 10 and 15 %, which is assumed to be the usual interval for discount rates for private investors in the Energy and Construction sector<sup>42</sup> and then conducting a sensitivity analysis, to see how the change in rates affect the different investments decisions. Some energy investors might feel that a great amount of risk lies in the cost of the energy carrier. When adjusting the discount rate for uncertainties in energy prices one should be aware that the energy prices are risk neutral if forward curves were used when modelling the prices. However, if no information of forwards or futures were used when modelling/calibrating prices they will not be risk neutral and should be accounted for in the hurdle rate that is set. In this thesis the pellets prices are the only prices not modelled using future contracts. Thus there is uncertainty in the price predictions from the three scenarios. An interesting discussion regarding the hurdle rate may occur if the energy systems considered contain multiple energy carries and the price processes is risk neutral for one and not for the other. This can occur when using pellets as base load and electricity as peak load in the Energy Investment model. Limited research has been dedicated towards the issue regarding how to discount combined cash flows with different risks. Hence it is difficult to provide the reader with an exact answer on this theme. One possible method could be to separate the risk neutral prices from those that bear risk and discount them using different rates. Further discussion regarding this theme is beyond the scope of this thesis and is left as a suggestion for future work.

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<sup>42</sup> NVE (2004), Bakken(2005)

### **14.4.1 Contract type**

Lastly, input parameters regarding the type of contract the user wishes to undertake when analyzing a project is needed. To give the energy investor the possibility of offering the client different contracting types matching the clients requirements, the three contracting types discussed in chapter 2 have been incorporated in the model. Hence the user has to specify type of contract, number of parties involved together with the allocation of investment, maintenance and income among the parties. As discussed in chapter two, the contract can either include a third party or only be between the energy investor and the client. The Energy Investment model will assure that for each contract type chosen, the allocation among the parties is viable. For instance if the contract type chosen is an Energy service contract, the client does not benefit from the savings until after the contract period. If the inputs are such that the client benefits from the savings during the contract period, the model will give the message that the allocations among the parties are not viable together with the necessary changes. If the user changes to viable inputs, the program will run as normal.

## **14.5 Results**

When all the inputs are provided, the Energy Investment model calculates the results. Figure 28 shoes how the user can choose between four buttons or macros on this sheet. With the top button, a full project simulation is done. This is used when the energy carrier or project start date is altered between two simulations. The program will then automatically simulate the price process for the new energy carrier chosen, match the start date for the project, and use these new data sets in the calculations. If the user wishes to alter other inputs besides the energy carrier or the project start date and do new calculations, the second button can be selected. This version is quicker, since the price simulations are not performed and there is no need to match data sets. This button can be chosen if the user wishes to investigate the cash flows of the different contract types, different upgrades, with or without financial support or different allocations of income, maintenance and operating cost among the involved parties. The third button simulates the value at risk. This calculation can not be done for pellets due to the fact that the price of the energy carrier considered in a VaR must be modelled using a stochastic variable. If the user tries to do a value at risk analysis for pellets, an error message with explanation will show. The last button is used for clearing old data in the environmental graph.

### **14.5.1 Fuel Costs**

The first result sheet is the “Fuel costs”. The sheet gives information about the monthly income, due to energy savings, for the different parties during the contract period. The first column shows the time, the next three represents the income for the energy investor, client and a possible third party. In the right of the window, a graph showing the incomes is provided

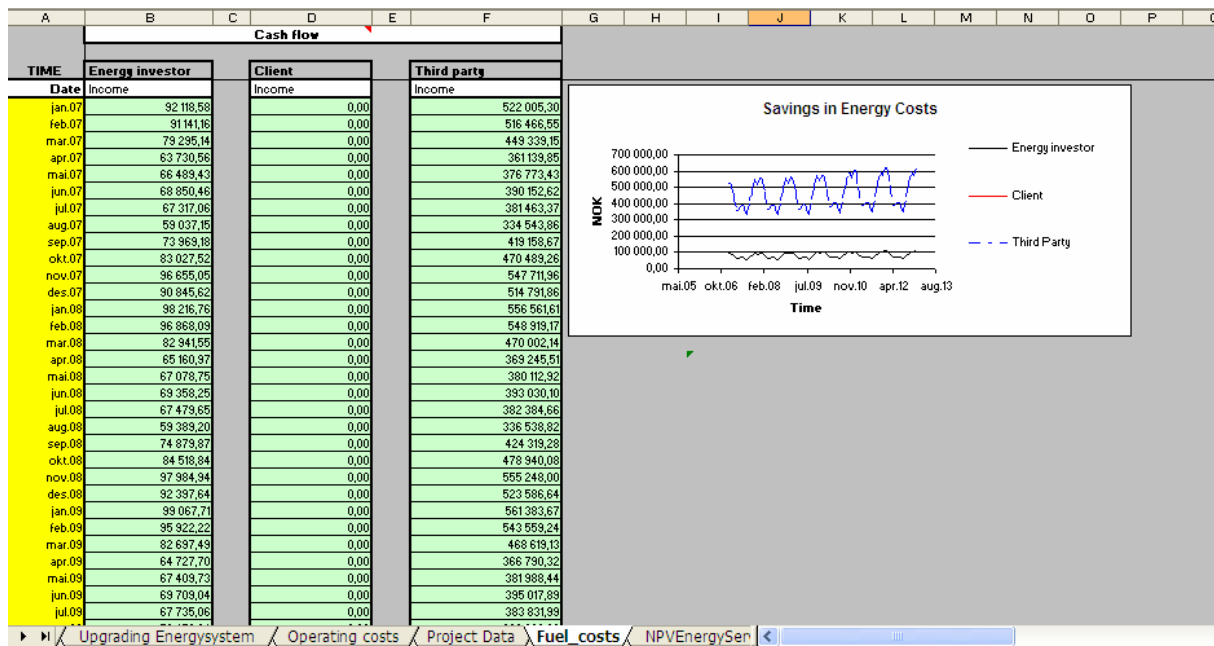


Fig 29 Sheet “Fuel Costs” that shows the income during the contract period for the various parties involved in an Energy Performance Contract.

### 14.5.2 Contract type and discounted cash flows

The model contains three sheets for net present values, one for each contract type. However only the one matching the chosen contract type will be shown, the others will be hidden. The reason for having different sheets is obvious. The different contracting types have different cash flow structures. The three sheets are called; “NPVEnergyServiceContract”, “NPVSharedSavings” and “NPVGuaranteedSavings”.

The first column on the sheet in Figure 30 represents the time horizon and is dependent on the project start date and duration. The columns representing income are collected from the “Fuel cost” sheet, but are calculated with a yearly time step instead of per month. Next the columns representing expenses are the total expenses for maintenance and operating costs. For the energy investor, the expenses also include administration costs. The various cash flows are in agreement with the input parameters regarding the allocation between the parties. At the bottom of the window, the net present value in each year of the contract period is shown graphically. This provides the user with the ability to see when (in which year) the investments are paid back.



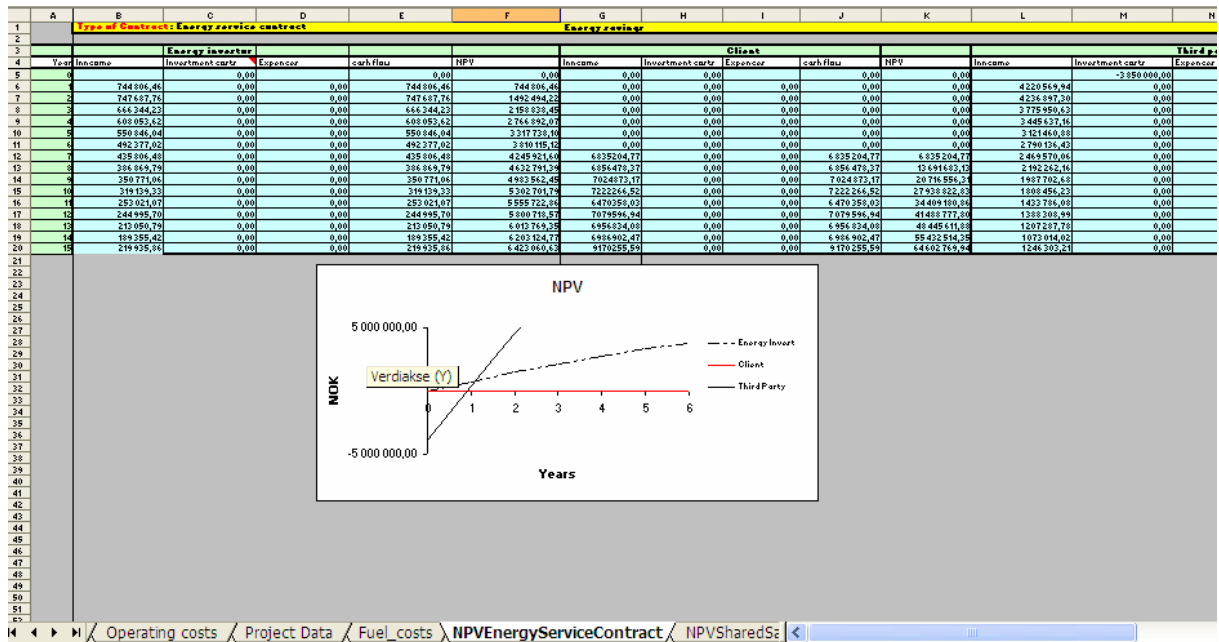


FIG 30 Sheet “NPVEnergyServiceContract”, represents the net present values for the different parties involved in the contract

### 14.5.3 Value at Risk

Given the user determined values for the confidence interval, the value at risk for the energy investor is calculated from the 500 simulated price paths. The distributions of the net present values are shown in the sheet called “Distribution of NPV” The Sheet also shows the value at risk and the conditional value at risk together with the standard deviations of the NPVs exceeding the value at risk.

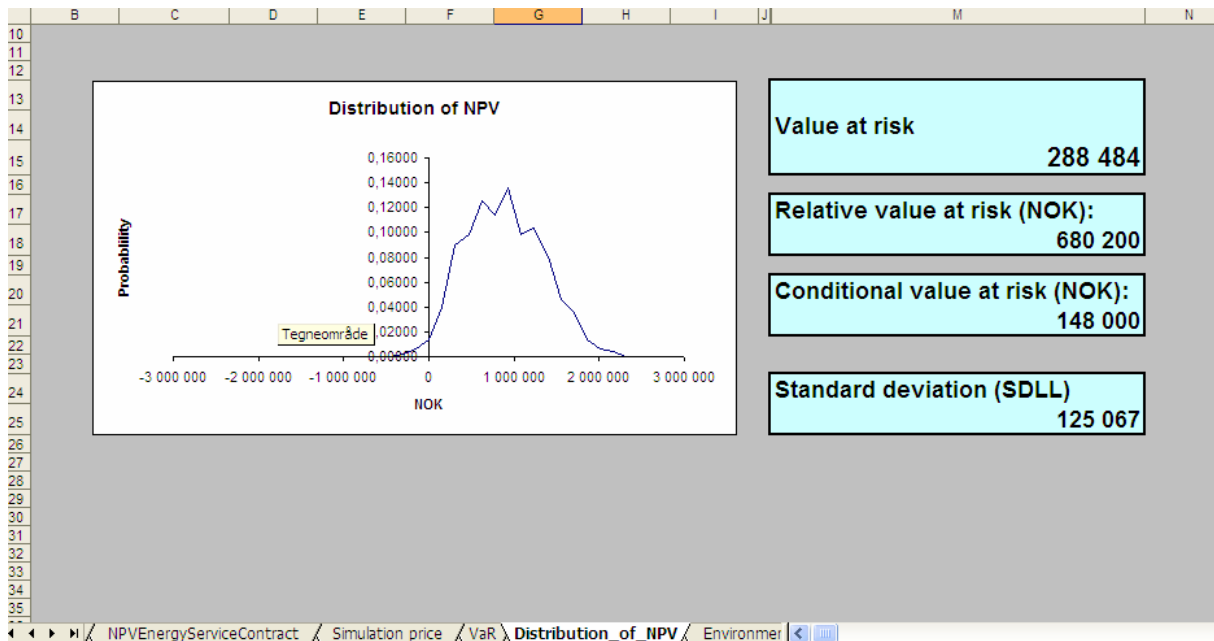


FIG 31: Sheet “ Distribution of NPV” shows the value at risk analysis in the Energy Investment model.

### 14.5.4 Environment graph

The last sheet provides the results for the environmental analysis. The sheet shows how the chosen system performs in an environmental point of view. The sheet will be most valuable if at least two or more heating alternatives for a building are compared. Without comparison between alternatives, the sheet only provides a number which can be hard to interpret. By comparing two or more alternatives the environment graph gives an indication of how environmentally sound the different choices are compared to each other. If two alternatives perform almost equally in the economic analysis or if a client wishes to have an environmentally sound energy system, the environmental analysis may help to differentiate the two alternatives.

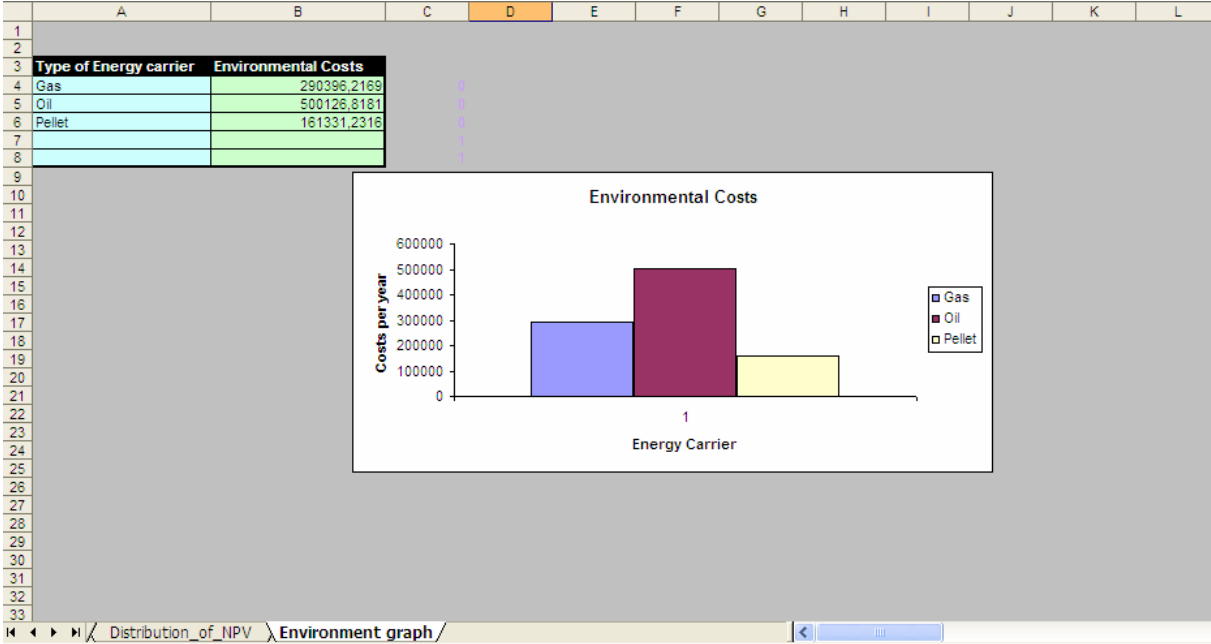


FIG 32: Sheet “Environment graph” shows the environmental cost for the energy system analysed.

## 15 Case analyses

Since the concept with Energy Performance Contracting is not yet developed in Norway there are few real cases to analyze. Still, in this chapter, the model is demonstrated on two separate cases. The considered cases are different in many ways but perhaps most interesting is their difference in size. The first case considers a major factory, Norsk Teknisk Porselensfabrikk (NTP), containing offices, laboratories, storage rooms together with a large production hall. NTP represents one of few real cases, in Norway, where Energy Performance Contracting has been used. The second case represents an area in Trondheim, called Svartlamoen, where two buildings will be rehabilitated both regarding building envelope and energy system. Presently, there is no energy investor involved at Svartlamoen and the input variables will be calculated partly on information provided by SINTEF(2006) and partly on information received from Pedersen (2005). The motivation by doing the case analysis is mainly to

1. Demonstrate how the Energy Investment model works.
2. Show how different contracting structures affect the income and uncertainties for an energy investor.
3. Perform a sensitivity analysis regarding the input parameters in the model.
4. See how the size of a buildings heat demand affects profitability for an energy investor.
5. Investigate how uncertainties in energy prices affects an energy investment

The above ranking also shows how the different motivations will be emphasized in this chapter. The main reason for doing the case analysis is hence to demonstrate the various decisions that might be supported by using the Energy Investment model. The second is to show how Energy Performance Contracts can be structured to handle the uncertainties in relation to Energy Performance contracting. Motivation number three is due to investigating and mapping how uncertainties in important parameters affects the profitability and hence the decisions regarding energy investments. Number four is the main reason for choosing to perform a case analysis on the Svartlamoen area. The case study may reveal whether the concept with Energy Performance Contracting can be used on smaller residential buildings as well large buildings, or if the investment costs and administration costs are too high compared to the financial savings attributing the reduced heat demand. The fact is that if buildings are too small for using Energy Service Contracts it might lead to selection of less “energy optimal” solutions due to lack of funding.

The first case is mainly used to satisfy motivation number one and two and three. The second case demonstrates some of the alternatives regarding choice of energy carrier(s) in the model. Further, both cases will show how variations in prices of energy carrier(s) affect an investment decision. The second case also contains how to construct a baseline, for approximation, if one does not exist along with how to incorporate the use of solar energy in to the Energy Investment model.

## 15.1 Norsk Teknisk Porselensfabrikk

Norsk Teknisk Porselensfabrikk (NTP) produces technical porcelain, mainly for electrical isolators. The factory is located in Fredrikstad and the total area for heating and ventilation is 32 550 m<sup>2</sup>. The investments<sup>43</sup> were mainly in connection with improving the heat recovery in the heating system together with installing a central control systems for ventilation of the factory. The type of investments together with the investment costs are shown in the below table:

Table 12: Investments and costs for Norsk Teknisk Porselensfabrikk

Type of investment	Cost of investment [NOK]
Central control system	1 550 000
Thermostats on air heating	300 000
Isolation of pipes and valves	2 585 000
Recycling of heat from ovens	1 285 000
Time regulator on fans	400 000
Recycling heat from ventilation	3 673 000
New air conditioning system	3 000 000
Change from oil to gas as the source for energy	3 255 000
<b>Total Cost</b>	<b>16 048 000</b>

As can be seen from table 12 the total investment costs were 16 048 000 NOK. The investments in this case were done by an external financial institution and the energy savings are guaranteed by COWI being the energy investor. The savings are measured against a baseline, containing previous energy bills and heat consumption for the factory. The baseline includes energy use in the production as well as heating and cooling of the building. Figure 33 shows the baseline for Norsk Teknisk Porselensfabrikk.

<sup>43</sup> The case data are provided by COWI (2006).

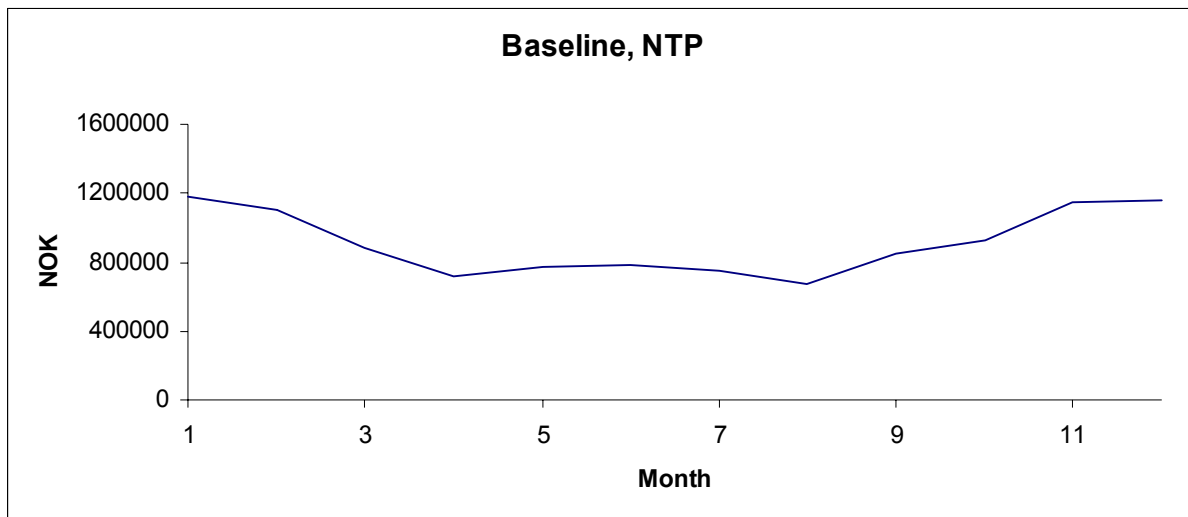


FIG 33: The baseline used in the Energy service contract at Norsk Teknisk Porselensfabrikk

The contract at NTP is structured as an Energy service contract. The third party provides funding for the whole investment and receives 85% of the energy savings during the contract period. In the contract COWI receives 15 % of the cost savings together with taking 50% of the financial risk in connection with the promised energy savings. Hence if the savings are not reached, COWI is obligated to pay 50% of the deviation to the third party. However, if the energy savings are to exceed the pre-agreed potential, COWI receives 50% of these savings and the rest benefits the client. The project operating costs are mainly paid by COWI. Although the real contract is structured as an Energy service contract it will be shown how the contract could have been structured without a third party involved or by using the contract type Shared savings.

Operation costs are mainly due to training the client in using the central control system. Since the client has experience in operating the old oil fired boiler it is agreed that the client also operates the new gas fired boiler during the project time. With the above structure of the contract the operating costs were calculated to be 200 000 NOK the first year and 50 000 NOK/year for the remaining years. Further, the administration costs for the energy investor were calculated to be 200 000 NOK the first year and 100 000 NOK/year each of the remaining years. Lastly, maintenance costs<sup>44</sup> were set to 65 100 NOK/year during the project period of 6 years. The potential for energy savings due to the investments were calculated to 3 GWh each year, which corresponds to approximately 20,2% of the baseline. Since the discount rate was not available it is in this thesis set to be 12% in alignment with chapter 14.4. When using the above calculations and assumptions as input parameters in the Energy Investment model the NPV through the contract period is shown in figure 34.

<sup>44</sup> Due to lack of data the maintenance costs in this analysis were set to be the average maintenance costs for a gas fired boiler (2 NOK/m<sup>2</sup>year) in alignment with SINTEF ( 2006)

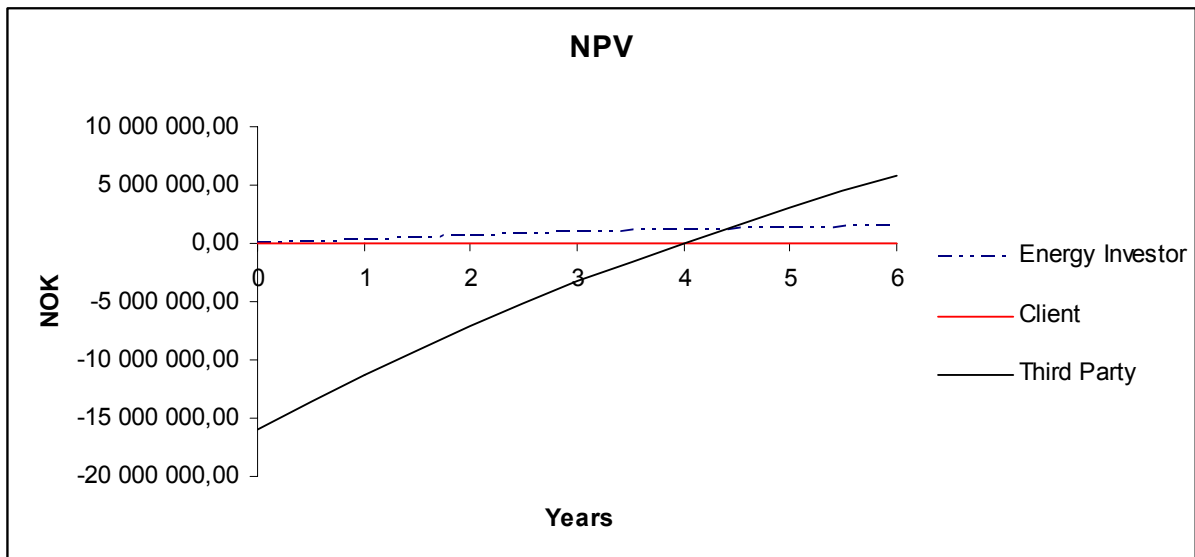


FIG 34: Net present values for the energy investor, third party and client at Norsk Teknisk Porselensfabrikk.

The net present value was calculated to be 5.776 335 NOK for the third party and 1 462 897 NOK for the energy investor. As mentioned earlier in the thesis the client will benefit from all the cost savings after the contract period of 6 years.

By doing a do a value at risk analysis, the distribution of the net present values due to Monte Carlo simulation of gas prices is illustrated in the below graph. The confidence interval was chosen to be 95%.

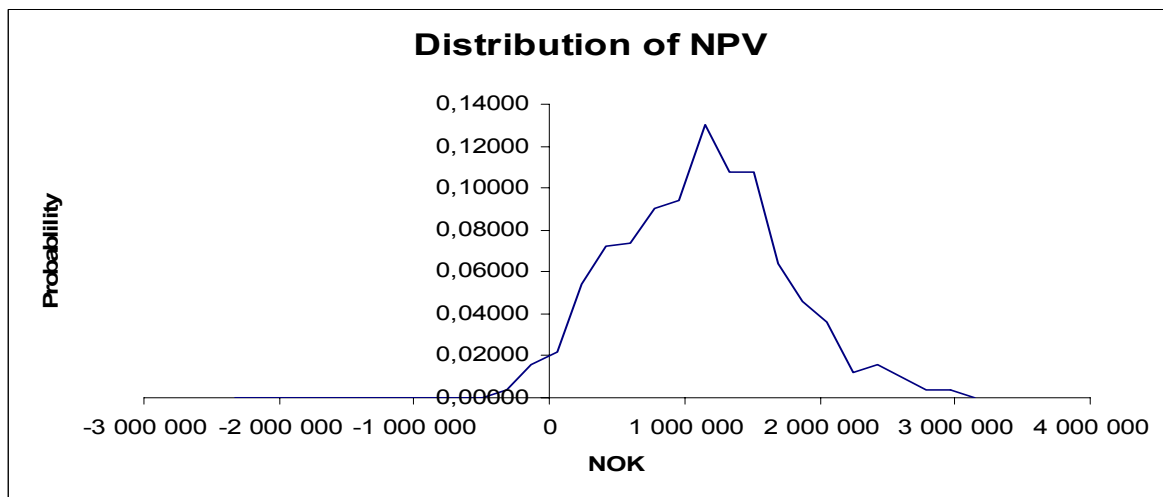


FIG 35: Distribution of net present values for the energy investor.

The Relative value at risk was calculated to be 936 631 NOK. This number illustrates the highest loss from the mean within a 95% confidence interval. The conditional value at risk was calculated to be 96 923 NOK, which represents the expected net present value if the relative value at risk exceeds 936 631 NOK. Although it has not been done in this chapter, the value at risk can be used to compare different alternatives and their uncertainty regarding the price of energy carrier.

As elaborated in previous chapters the Energy Investment model also shows how the cash flows for the parties involved in a project varies (each month) through project time. The cash

flows represent the deviation between the old energy bills and energy costs after investments are conducted. As can be seen in figure 36 the magnitude of the cash flows will often be seasonally dependent. Figure 36 shows how the cash flow for the third party and the energy investor varied through the project time. With the contract form used, the client does not benefit from the energy saving until after the project lifetime.

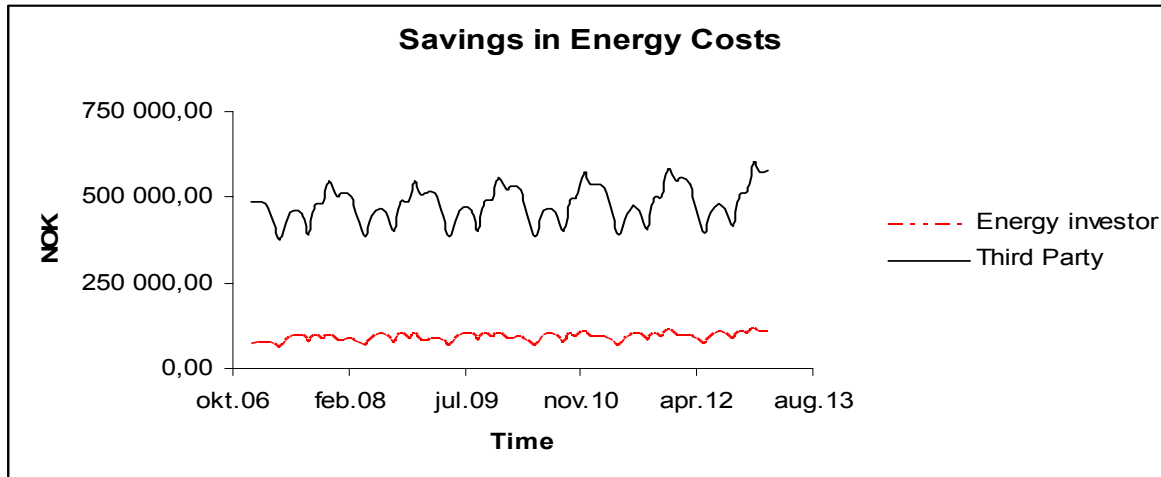


FIG 36: Calculated savings in energy costs (monthly) for COWI and the third party during the project duration

There are many contracting structures that could have been used regarding Norsk Teknisk Porselensfabrikk. One alternative is an Energy service contract without a third party involved. In this type of contract the energy investor would provide funding for the investments and hence received 100 % of the costs savings. The net present values using an Energy service contract without a third party involved, can be viewed in the left graph in Figure 37. However, since the energy investor would also pay the maintenance, operating and administration costs the project period would probably be longer than 6 years. Without a third party involved in the Energy service contract, the energy investor would avoid paying any deviations from forecasted energy savings to the third party. However, as discussed previously in the thesis, contracts may be structured so that the energy investor promises the client a certain level of energy savings and is obligated to pay any deviations to the client. The real life project at NTP was implemented during January 2004 and has been running for approximately two and a half years. During these years it has been revealed that the energy savings did not match the forecasts. Due to confidentiality, it has not been possible to obtain information regarding the size of deviations or their cause. Using a different type of contract, namely Shared savings, between the energy investor and the client, the net present value would have been allocated as shown in the right graph in figure 37. With this type of contract the client would have benefited from the cost savings also during the contract period which could have stimulated the client to lower the use of energy and thereby could have increased the energy savings during the contract period. Shared savings are especially useful if there are present risks associated with asymmetric information. In the contract illustrated in the right graph the client receives 10 % of the costs savings while paying all the maintenance and operating costs. However due to lack of information regarding the cause of deviations from forecasted energy savings at NTP, a question left unanswered is whether this structure could have reduced the deviations from forecasted values at NTP.

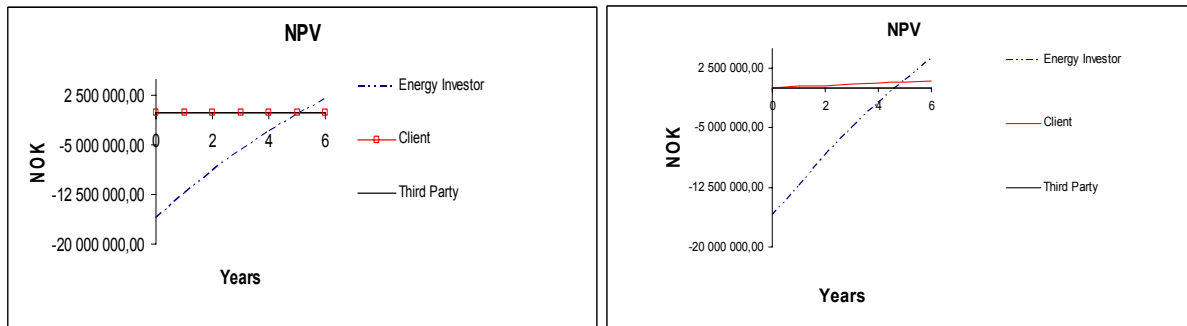


FIG 37: The left graph shows the net present values at NTP using an Energy service contract without a third party involved. The right graph shows the allocation of net present values at NTP using Shared savings.

Guaranteed savings was not taken as an alternative way to structure the contract at NTP. This is due to the client's lack of funding regarding the investment costs. The above examples are only suggestions of alternative ways the contract could have been structured at NTP, and all the input parameters are therefore the same as in the real life case. However the input parameters might change when changing the structure of a contract. One example is that the prices for technology and building improvements are often set through negotiations between the buyer and seller, and therefore might depend on the party conducting the investments. The above examples are illustrations of how the Energy Investment model can be used to analyse the possibilities and the affects of using different contracting structures in an Energy Performance Contract.

In addition the Energy Investment model can be used to assist the choice of which technology to invest in. At NTP the oil fired boiler was replaced by a gas fired boiler. As a demonstration the Energy Investment model was used to investigate the profitability of keeping the oil fired boiler instead of changing to gas as the source of energy. Figure 38 shows the expected net present value for both the energy investor and the third party when keeping the old oil fired boiler at NTP.

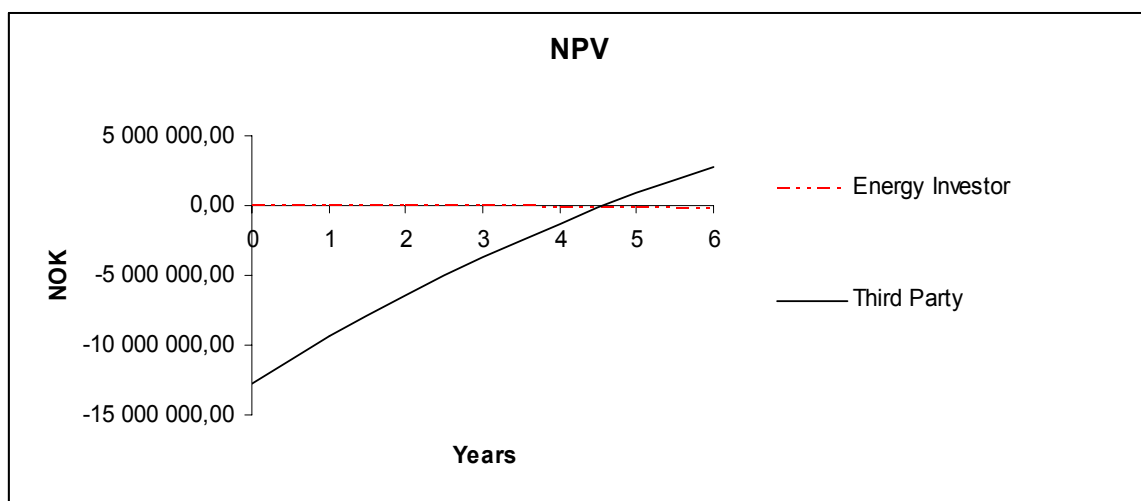


FIG 38: NPV for the energy investor and third party when keeping oil as the energy carrier at NTP

Figure 38 shows that keeping the oil fired boiler is not a profitable alternative for either the client or the energy investor. Even if the investment costs were reduced with 3 255 000 this would not account for the high level of heating oil prices. In addition keeping the oil fired boiler reduces the potential for energy savings from 20,2% to 17,5 % due to the low heat efficiency for the oil fired boiler.



As discussed previously in the thesis there might be a liberalization of the natural gas market in Norway in the future. If the market moves towards being a more centralized market, higher price fluctuations may occur. The Energy Investment model was used to test how higher price fluctuations of gas affects the decision of changing from oil to gas at Norsk Teknisk Porselensfabrikk. Figure 39 shows how the energy investor's net present value changes with the percentage change in volatility ( $\sigma$ ) for gas prices, keeping all other parameters constant.

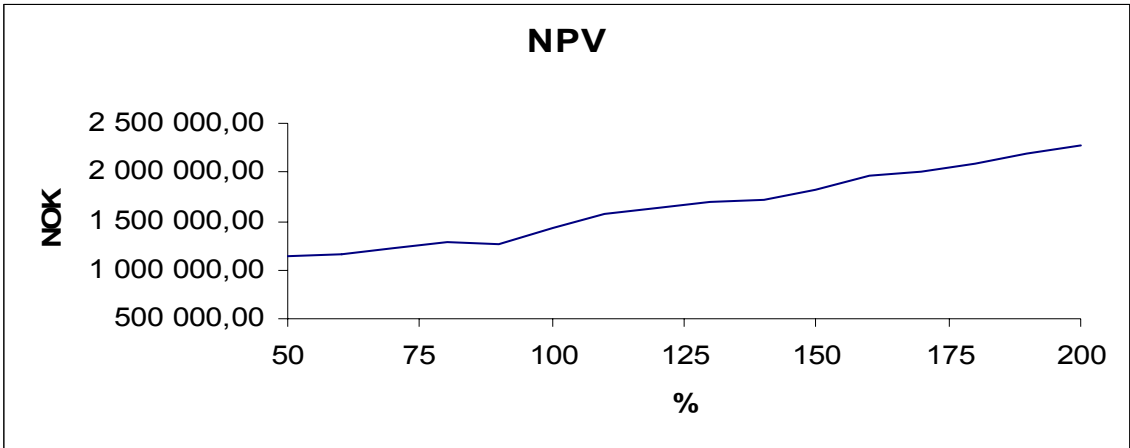


FIG 39: Change in NPV for various values of sigma in the mean reverting model for gas prices

Figure 39 shows that when increasing sigma from 50% to 150% compared to the estimated value in chapter 8.5.2 the net present value for the energy investor increases from 80% to 128% of the original value.

The fact that the net present value increases with volatility in the gas prices is not surprising. According to Schwartz (1997) the mean of logarithm of price will decrease when the volatility increases assuming all other parameters constant and using a one factor mean reverting model. Since the energy investor gets paid from the savings in energy costs it will be no surprise that the net present value increases when the mean of gas prices decrease. Further, Schwartz (1997) shows that the variance in the logarithm of the price increases when increasing the volatility keeping all other parameters constant. Hence the value at risk analysis in figure 40 shows that when the volatility increases from 50% to 150% of its original value it implies greater dispersion in the net present values. The relative value at risk increases from 878 537 NOK to 1 375 903 NOK keeping the confidence interval of 95% constant.

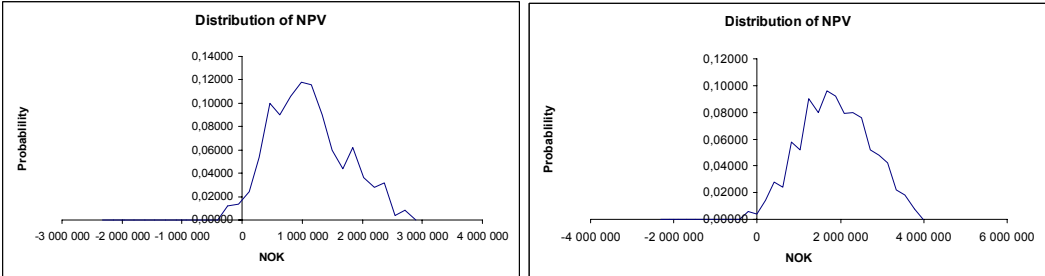


FIG 40 Shows the distribution for net present value with a volatility of 50% of the original value (to the left) and 150% of the original value (to the right)

Applying a volatility of 0 gives the, using the gas fired boiler, lowest net present value for the energy investor which is 738 593 NOK. When changing the volatility in the heating oil prices

it is revealed that it has to increase to seven times its estimated value<sup>45</sup> for the oil fired boiler to be able to compete with changing to a gas fired boiler at NTP.

### 15.1.2 Sensitivity regarding inputs

The motivation for doing this sensitivity analysis is to see how changes in the various input parameters, which bear uncertainty, affects the results in the Energy Investment model. The input parameters can be divided into parameters that directly affect the net present value, here called *direct variables*, and the parameters which have an indirect affect on the net present value, called *indirect variables*. The direct parameters are the fixed, maintenance and operating costs, the level of energy savings, discount rate and project lifetime. Further, the indirect variables are those that affect the price of the energy carrier, such as correlation among the prices of the different energy carriers together with the variance and drift and mean reverting level of the different prices. This subchapter will be concerned with the direct parameters. Figure 41 and 42 Show how the net present value is affected by varying one input parameter at the time while keeping all others constant. The different deviations from forecasted values of the input parameters are measured in % along the X'axis in both figures.

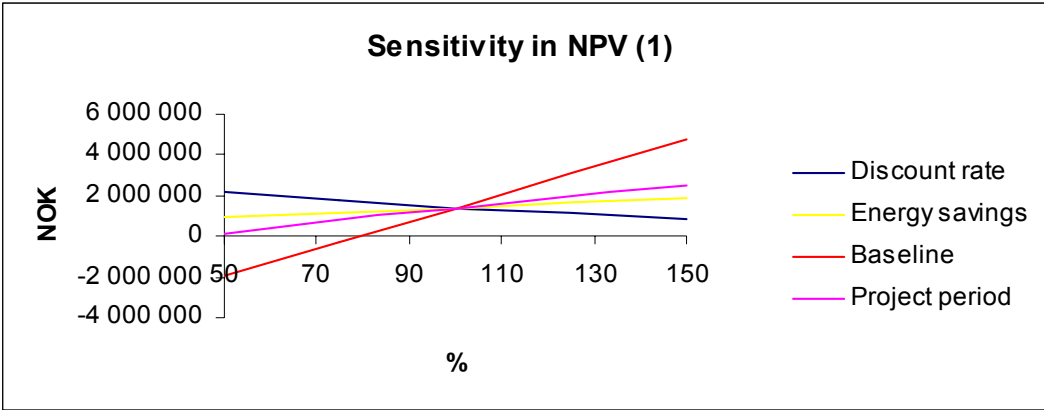


Figure 41: Sensitivity in NPV for an energy investor when varying the discount rate, level of energy savings, baseline and project period.

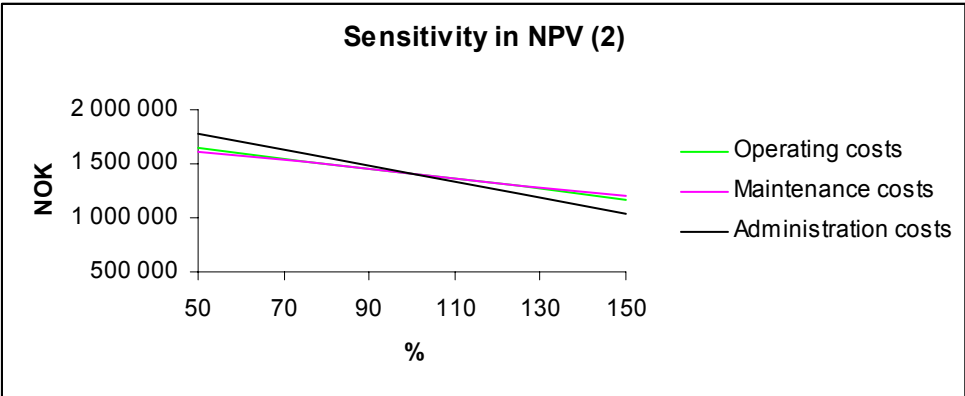


Figure 42: Sensitivity in NPV for an energy investor when varying the discount rate, level of energy savings, baseline and project period.

<sup>45</sup> It's estimated value was 4%, see chapter 8.5.2

Figure 41 and Figure 42 show that alterations in the baseline have the highest impact on net present values for an energy investor. Hence the numbers representing the baseline should be well considered before applied in the model. When the project at NTP was analysed by COWI they used old energy bills representing the baseline. However, only energy bills from the period between 2000 and 2003 were available, which might have made the baseline quite uncertain.

### 15.1.1 Discussion

To briefly summarize the above case analysis, there are two main uncertainties that might have affected the deviations at NTP. The first is regarding the contract structure. Since an Energy service contract is used, the client can not take share in any profits if the energy savings are to exceed the forecasted values, hence lack of motivation for energy savings or even asymmetric information might be present. Since the baseline was constructed by only using energy bills for two years the values might be quite uncertain. A small decrease from forecasted values in the baseline could have reduced the net present values for the energy investor.

## 15.2 Svartlamoen

Today, Svartlamoen contains a built environment of 6 400 m<sup>2</sup> distributed among 100 apartments. The built-up area represents remnants from old labour apartments built in wood and brick between 1870 and 1905. The demand for rehabilitation is huge. In addition to this, new buildings are planned which consist of 6 000 m<sup>2</sup> distributed among 120 apartments and an industrial building of size 2 900 m<sup>2</sup>. In connection with rehabilitation and construction of the new buildings there is a desire, by the building owners, that the area is presented as environmentally sound together with restrictions for the energy use in the buildings. The upper limit for energy consumption is set to be 100 kWh/m<sup>2</sup> for the new buildings and 150 kWh/m<sup>2</sup> for the rehabilitated area. This gives a weighted average of 130 kWh/m<sup>2</sup>, including lighting and other electricity usage, for energy consumption in the whole area. To meet these demands, extra investment costs are needed to build and rehabilitate the buildings in alignment with the low energy house concept.

This section uses the Energy Investment model to analyze two of the buildings in the Svartlamoen area. The case considers a **commercial building** of size 3000 m<sup>2</sup> and a **residential building** of size 960 m<sup>2</sup> with 24 apartments. Both buildings are to be rehabilitated and different heating alternatives considered. Today, heating of the two buildings are solely based on electricity. The small size of energy consumption makes this case rather interesting. The main reason for analysing this case is therefore to investigate if the heat demand is too small for using an Energy Performance Contract along with showing how to construct a baseline if one does not exist.

The investments consider upgrading the buildings compared with today's standards and regulations. In addition the case analysis will investigate the profitability investing in alternative energy systems for heating. In summary the base case is a building with isolation thickness in accordance with today's standard together with a heating system based on electric stoves. A majority of the input parameters had to be calculated and some assumptions had to be made. Hence the calculations can be found in Appendix 11. For convenience, the

sections below will be limited to representing the main input parameters together with showing how to calculate the baseline using a reference building and lastly presenting the results from the Energy Investment model

### 15.2.1 Building related investments

As discussed above, the two buildings will be upgraded compared to today's standard and in alignment with the low energy house concept. The investment costs for the two buildings are as shown in Table 13 and 14.

Table 13: **Residential building**; overview on improvements regarding the building envelope

Element of Building env.	U value before investment [W/m <sup>2</sup> K]	U value after investment [W/m <sup>2</sup> K]	Type of upgrade	Investment cost [NOK]
Facade/Wall	0,5	0,35	40 mm isolation	28 080
Roof	0,4	0,22	100 mm isolation	77 760
Glassing	1,6	1,1	Standard 1.1window	19 250
Vent. Rate (h <sup>-1</sup> )		0,6	Balanced, heat recovery, 60%	384 000
Total costs				509 090

Table 14: **Commercial building**; overview on improvements and investments regarding the building envelope

Element of Building envelope	U value before investment [W/m <sup>2</sup> K]	U value after investment [W/m <sup>2</sup> K]	Type of upgrade	Investment cost [NOK]
Facade/Wall	0,5	0,35	50 mm isolation	78 780
Roof	0,4	0,22	100 mm isolation	390 000
Glassing	1,6	1,4	1.4 window	13 800
Vent. Rate (h <sup>-1</sup> )	--	0,3-3,0	Balanced, heat recovery	900 000
Total cost				1 382 580

Costs for different improvements regarding the building envelope for the residential and commercial buildings can be found in Appendix 10. Further, calculations regarding the investments, such as the need in thickness for isolation to meet the demands set by the building owners together with some assumptions made, are as mentioned elaborated in Appendix 11. The total investments in the building envelope for the two buildings is 1 891 670 NOK.

### 15.2.2 Investments in heating systems

Several different heating alternatives were suggested to cover the heat demand at Svartlamoen. In this section four of the heating systems for the area are analysed and compared to each other. All the alternatives are water based heating systems. This is due to the fact that the building owners at Svartlamoen requests a flexible energysystem. The four considered alternatives are;

- **Electricity**  
*Investments in*
  - Electric boiler plant
  - Pipes and radiators

- Water heater (based on electricity)
- **Electricity (peak load) + Bio(base load)**  
*Investments in*
  - Biomass fired boiler (pellets) in combination with an electricity boiler
  - Pipes and radiators
  - Electric coil
- **Electricity (peak load) + Bio(base load) + Sun**  
*Investments in*
  - Heat exchanger via solar collector.
  - Biomass fired boiler in combination with electricity boiler.
  - Radiators and pipes
  - Storage battery
  - Electric coil
- **Electricity + Sun**  
*Investments in*
  - Heat exchanger via solar collector
  - Electric boiler plant
  - Radiators and pipes,
  - Storage battery
  - Electric coil

The various heating systems chosen have different heating efficiencies compared to each other<sup>46</sup>. This means that although the percentage reduction in heat demand is the same for all the alternatives, the heat consumption will vary. In addition, if solar energy is used then the energy demand will decrease due to the “free” heat from the sun. Based on this, the total energy savings, in percent, for the two buildings analyzed, will be as follows for the four heating alternatives;

Table 15: Energy savings ( in percent) using the four heating alternatives.

Type of heating system	Savings in energy consumption [%]
Electricity	25
Electricity + Bio	9
Electricity + Bio + Sun	18,5
Electricity + Sun	34,8

According to COWI(2006<sup>c</sup>) the investment costs for the four alternatives listed above are as shown in table16.

Table 16: Total investment costs for the four heating alternatives at Svartlamoen.

Type of heating system	Total investment costs [NOK]
Electricity	3 663 000
Electricity + Bio	4 059 000
Electricity + Bio + Sun	4 554 000
Electricity + Sun	4 257 000

<sup>46</sup> Further elaboration can be found in Appendix 12

Having calculated all the input parameters a baseline needs to be constructed. How this is done will be shown in the next subchapter.

### 15.2.3 Constructing a baseline for Svartlamoen

Since there were no data (old energy bills) or measurements available on how the energy demand varies through the year for the two buildings, a reference building was chosen for approximations<sup>47</sup>. The error will not be too big using this method as long as the reference building lies in the same city as the building that is analyzed. The reference building in this thesis is used for commercial activities which fits the Svartlamoen case well. The reason for this is that  $\frac{3}{4}$  of the area at Svartlamoen will be used for commercial activities. Although  $\frac{1}{4}$  of the area represents a residential area, this will not have noticeable affect on the result in the case analysis. The reason for this is that the climate (temperature) has the strongest effect on the level of heating demand throughout the year for a particular building. However there are also other variables affecting the demand, such as building category, but these variables play a bigger role in variations within a day or a week. When using the Energy Investment model it is more important to capture the seasonal variations of the energy prices and matching them with the load variations throughout the year. The load variation within a day is therefore of less importance in this context. Using the reference building and adjusting the heat demand for the size of the residential and commercial building the heat demand thought a year for the two buildings is shown in figure 43.

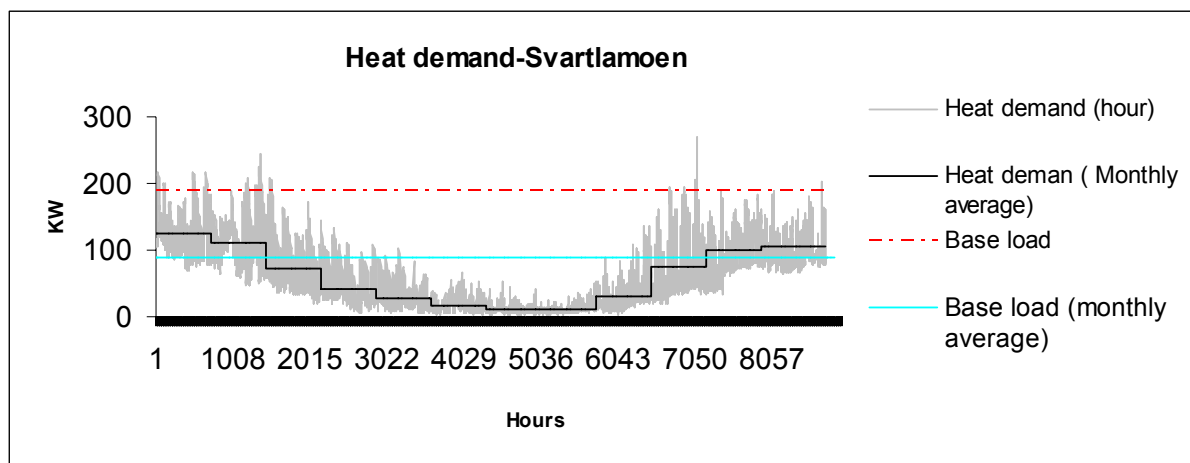


FIG 43: The variation in heat demand each hour and as monthly average trough the year. The red line represents the base load line as described in chapter 3.

Figure 43 also shows the monthly average together with a heating system based on a distribution of 70/30 between the base load and peak load<sup>48</sup>. The monthly average was constructed to fit the input requirement (of monthly time resolution) in the Energy Investment model. Electricity spot prices (monthly average), grid charge<sup>49</sup> (yearly average), and the tax costs during the years of registration of the energy consumption in the reference building was used to construct the monthly energy costs for Svartlamoen.

<sup>47</sup> Measurements of the variations in heat demand for reference building (Statens hus) was conducted every hour during three years (2002-2004).

<sup>48</sup>The distribution was calculated with Equation 3.1. Average prices from the simulation of electricity together with the average for the Pellets middle price scenario were used as prices for peak load and base load in the equation. The marginal Investment costs were collected from COWI (2005<sup>c</sup>). The combustion efficiency rate for electricity and pellets used were 1,00 and 0,85.

<sup>49</sup> The average grid charge (yearly) and tax were collected from TEV (2006)

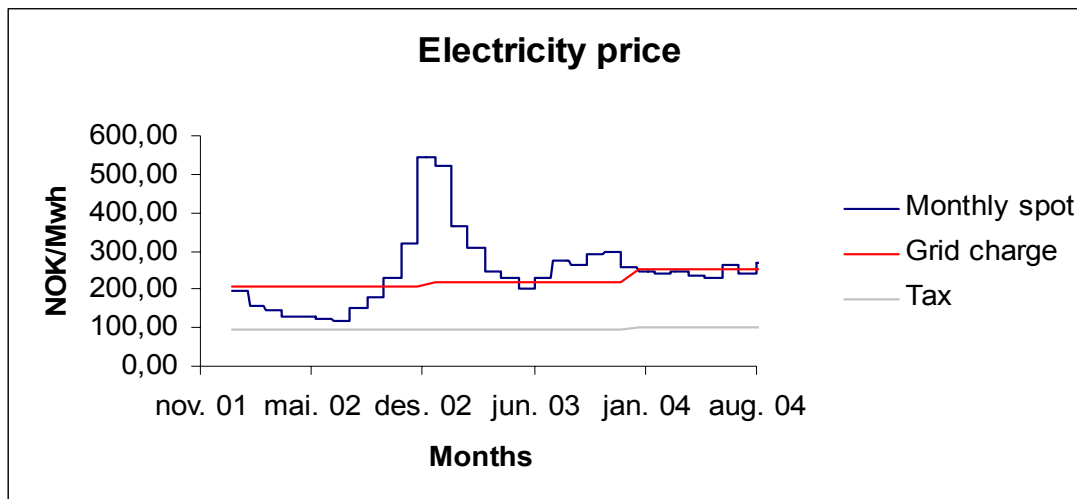


FIG 44: Average spot, grid charge and tax per month for period 2002-2004.

Combining the two figures above (total price each month and monthly energy consumption for the same period) a baseline for the energy bills at Svartlamoen was constructed and is shown in figure below.

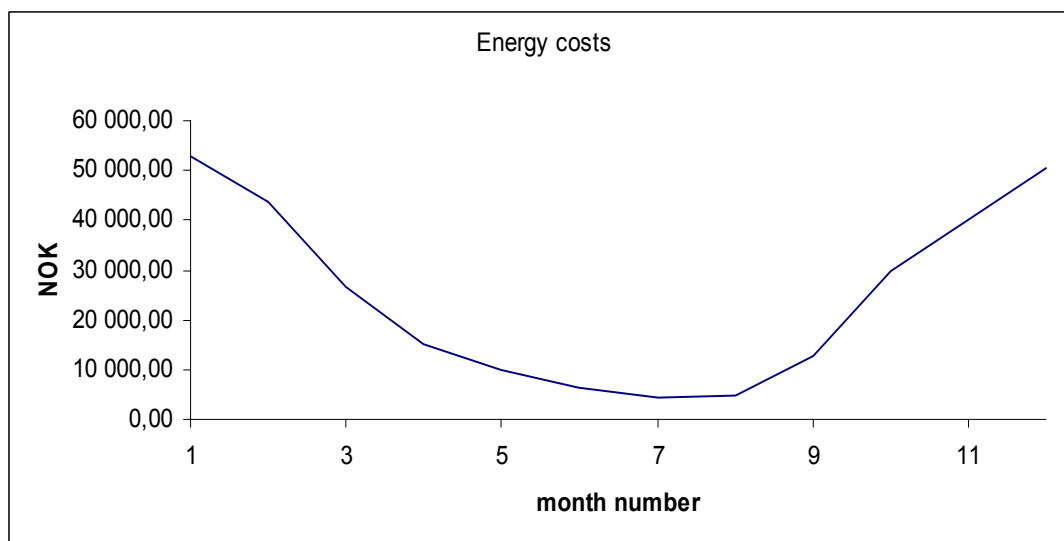


FIG 45: Monthly energy costs/Baseline for the residential and commercial building at Svartlamoen.

As can be seen from figure 45 the spot price was very high during end of year 2002 and beginning of year 2003, and this can probably lead to the baseline being (in average) somewhat higher in January and December than under “normal” conditions. This fact can lead to the energy savings being smaller than expected for those months, and represents one of the uncertainties discussed in chapter 4.

#### 15.2.4 Project specific data

The project start date is set to be the first of January 2007 and the contract period is set to be 10 years. The yearly operating and maintenance cost for the four energy systems was calculated to be:

Table 17: Yearly administration, operating and maintenance costs for Svartlamoen. The costs are obtained from SINTEF (2006<sup>o</sup>)

Heating system	Costs		
	Maintenance	Operating	Fixed
Electricity	7 920,00	3 960,00	50 000,00
Electricity + Bio	7 920,00	19 800,00	50 000,00
Electricity + Bio + Sun	7 920,00	27 720,00	50 000,00
Electricity + Sun	7 920,00	11 880,00	50 000,00

In the analysis the applied discount rate is 12%. The rate is assumed to reflect the uncertainties in the yearly operating, maintenance and fixed costs and uncertainties in the amount of yearly energy savings together with uncertainties regarding the baseline. The discount rate does not account for uncertainties in the electricity price since these are modelled using future contracts traded in the market. Regarding uncertainties in the prices for bio fuel these are assumed to be accounted for in the discount rate. This is due to the fact that the pellets prices were calculated based assumptions regarding future scenarios.

The analyses will mainly consider the use of an Energy savings contract. It is further assumed that the client pays the operating and maintenance costs during the contract period.

## 15.2.5 Results

Table 18 shows that using an Energy service contract at Svartlamoen is not profitable for the energy investor. All the alternatives give negative net present value. However they are ranked with the best alternative at the top in the table

Table 18: NPV for an energy investor conducting the different investment alternatives at Svartlamoen (Pellets - Middle price scenario)

Type of energy system	NPV for the energy investor [NOK]
Electricity	-5 782 421
Electricity + Sun	-6 375 544
Electricity (peak load) + Bio (base load)	-6 499 122
Electricity (peak load)+ Bio (base load)+ Sun	-6 858 897

The above table was calculated using the Pellets-Middle price with Bulk delivery. However using the Pellets –Low price scenario instead, the following ranking of the alternatives was observed;

Table 19: NPV for an energy investor using EPC at Svartlamoen (Pellets -Low price scenario)

Type of energy system	NPV for the energy investor [NOK]
Electricity	-5 782 421
Electricity (peak load) + Bio (base load)	-6 158 943
Electricity + Sun	-6 375 544
Electricity (peak load)+ Bio (base load)+ Sun	-6 658 897

Table 19 shows that changing from Pellets-Middle price to Pellets-Low price scenario affected the ranking of the alternatives. Using the Pellets Middle price scenario, heating with electricity and sun was more profitable than heating with electricity as the peak load and pellets as the base load. However changing to the Pellets-Low price scenario reversed the



ranking between the two. Heating with a combination of pellets and electricity had a higher net present value than using solar heat and electricity. However all the alternatives are still within the range of each other.

To check if it would be profitable to conduct the same investments not using Energy Performance Contracting the alternative with the highest net present value (Electricity) was recalculated without including the administration costs. The calculations gave a net present value of – 5 288 927 NOK. This result is not surprising due to the high level of investment costs compared with the costs savings.

One of the reasons for why all of the investments at Svartlamoen gave negative net present values can be the fact that the buildings are in alignment with the low energy house concept. This means that the heat demand is very low. Investing water based heating systems may therefore be considered as too expensive compared to the heat demand. Although heating fully with electric stoves was not desired by the building owners a test to see whether this investment could be profitable was done. The calculations showed a net present value of – 908 468 NOK. This value is considerably higher than for the water based systems. The fact that it gives a higher net present value might support that when a building has low energy demand, investing in water based heating systems are too expensive compared to the cost reductions due to having a flexible energy system and heating with renewable energy carriers such as pellets.

Lastly a scale adjustment regarding size of the baseline was done for the case considering the Svartlamoen area. For the different alternatives to be profitable an average scale adjustment of 7 had to be done. Hence this means that in order to get positive net present values for the two buildings at svartlamoen the baseline had to be seven times higher than calculated.

### **15.2.6 Concluding remarks regarding the Svartlamoen case**

The above results show that conducting an Energy Performance Contract at Svartlamoen is not profitable with the four alternatives considered. However it can not be stated that the reason for this is solely the size of heat demand. Scaling the baseline showed positive net present values, although this was when all other parameters were held constant. However this does not reflect what would happen in practice. Having a higher baseline will also imply higher costs for investment both regarding building envelope (because the size of the building would probably be larger) as well as costs for technology. However predicting how these costs would increase compared to each other is beyond the scope of this thesis. The motivation for doing the analysis was mainly to show that the Energy Investment model can be used as a support for decision regarding energy investments.



## 16 Concluding remarks

This chapter will give some concluding remarks regarding the work done in this thesis, the limits of the Energy Investment model together with suggestions for future work

### 16.1 Discussion

This thesis has introduced the different risk factors an energy investor might face when offering an Energy Performance Contract. Further a tool is developed which can assist the energy investor when analysing the profitability in a project. The tool takes in to account the risks in energy prices using stochastic price models together with a value at risk analysis. As has been discussed through the thesis, there are various risk factors affecting an energy investor profitability. However not all are quantifiable and hence possible to include in the model. In a perfect world all costs and benefits related to an energy system will be quantifiable. However, for real life cases this can be difficult.

The decision support tool is developed in Excel. The main reason for this is that it is easy to communicate and probably the most used tool in the Energy and Construction business. However Excel is limited regarding Monte Carlo simulation. To get accurate prices, several thousand simulations should be done, for example by using a more powerful tool like Matlab. The fact that excel has limited capacity regarding price simulations doing several thousand simulations can be extremely be time consuming. However the aim of the thesis is to give a suggestion to how a decision support tool can be constructed to help an energy investor analyse different projects together with communicating some of the risks that might occur when offering such contracts. Hence a decision has been made to emphasize communication before price simulations with 100% accuracy.

In this thesis monthly time resolution was used regarding the baseline together with future prices for the energy carriers. It can be a discussion whether a smaller time resolution should be used in relation with the baseline. To reduce the deviations using monthly average heat demand, a weight factor discussed in chapter 11 was introduced. However having a smaller time step for the baseline might imply difficulties due for the user providing an accurate baseline. Either way if a smaller time resolution is used Excel would again be limited regarding capacity

For convenience to the user, two separate macros can be chosen when analysing a project. One of them can be used if there are alterations in project start date or energy carrier. The second is applied when the user wishes to alter any other parameter besides the two mentioned above. The reason for this is to save time by not having to simulate prices every time one input parameter is altered.

## **16.2 Future work**

Presently, the Energy Investment model is only a suggestion for a decision support tool, and not yet commercial. Thus there are several features that can be added. The bullet points below give some suggestions as to how the tool can be improved.

- In the model three main contract types are modelled. However there exist variations within these which are not specified in the model. As an example it can be useful to be able to vary the allocation of income among the parties during the project period.
- How to construct more accurate baselines should be further considered. A possibility can be to add normative values regarding DRY- curves for the different regions in Norway. By letting the user specify location and type of building the Energy Investment model can help the user to create a baseline
- Pellets prices have been modelled using a scenario approach. By using this approach an average price for the whole country was derived. Hence this will only be an approximation. As discussed in the thesis the prices vary among the regions in Norway which should be incorporated in to the model.
- All the sensitivity analysis done in this thesis, has been done manually by changing the different input parameters in the model. However this can be rather time consuming. Since one of the objectives is to communicate risk, a future function in the program can be to allow the user to vary the different input parameters, especially regarding the baseline. An additional sheet that shows how variations in the different input parameters affect the net present value for an energy investor could be useful.
- As a concluding remark the tool should to be communicated to the industry.



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## 18 APPENDIX

### ***APPENDIX 1 - Modelling prices for technology investments***

In this Appendix two ways of how to model future technology costs will be presented. The first contains a stochastic process<sup>50</sup>. The second method does not contain a stochastic process and demands less data or information to use.

There are many indicators of technological learning, but the two variants of the model constructed in this thesis emphasizes that endogenous learning is a function of cumulative experience measured by cumulative installed capacity. The difference between the two model variants is that the learning function is in one of the variants uncertain and in the other one deterministic. Technological learning is either modelled using learning rates in % where the uncertainty is captured by a stochastic variable drawn from an assumed distribution function, or by a variable that is constant. The cost reduction function has the following form for both variants:

$$CRI_t = (2^{-\beta})^{ND_t} \quad (\text{A.1.1})$$

Where  $CRI_t$  is the cost reduction index and thus gives the ratio between technology unit costs at time  $t$  and initial cost in the basic year. Further  $ND_t$  represents the number of doublings of cumulative output that have occurred by time  $t$ , compared to the initial output.  $\beta$  represents the progress ratio of technological learning and is as discussed either a random stochastic Variable with a known distribution function, or a deterministic variable. For the variant with the stochastic  $\beta$ , it is assumed that  $\beta$  is normally distributed with a known mean and variance that is calculated from empirical data.

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<sup>50</sup> A stochastic process is a Variable that evolves over time in a way that is at least in part random

## APPENDIX 2 - Modelling energy prices

### The Wiener process

The one-factor and two-factor models used in this thesis have in common that their stochastic Variables are built up of different Wiener processes.

A wiener process, also called a Brownian motion, is a continuous +time stochastic process and has three important properties

- It is a Markov process, which implies that the past is irrelevant for the probability distribution for all future values of the process, and therefore the future values of the process depend only on its current information.
- The Wiener process has independent increments. This means that the probability function for the change in the next step in the process is independent of previous changes.
- The changes are normally distributed over any finite time interval.

A pure Wiener process will therefore have the following form

$$dW = \varepsilon\sqrt{dt} \tag{A.2.1}$$

Where  $dW$  is the Wiener-process,  $dt$  is a small increment and  $\varepsilon$  is a random drawing from a standard normal distribution with  $\Phi(0,1)$ . We therefore have;

mean of  $dW = 0$ ,

standard deviation of  $dW = \sqrt{dt}$  and

VaRiance of  $dW = dt$

Further, the wiener process serves as a building block for modelling a broad range of stochastic variables. Since the Wiener process only models the “noise” term for a price model it does not alone satisfy the requirements to be classified as a price model. Most price models also have a drift term. The most well-known is probably Geometric Brownian Motion that assumes a constant volatility,  $\sigma$ , and drift rate,  $\mu$ , for the proportional change in the asset price and is described by ;

$$dS_t = \mu S_t dt + \sigma S_t dW_t \tag{A.2.2}$$

Here  $dS_t$  represents a small increment during the time interval  $dt$ , and  $dW_t$  is a pure Wiener process. As we can see the first term in the Equation represents the drift term whilst the second term represents the “noise” from the steady drift term, or in other words the uncertainty in the price development process. It is clear from Equation (A.2.2) that the greater the price, the greater are both the expected change in the price and the randomness about it. However, studies show that energy prices are log normally distributed and rather follow a mean reverting process

Unlike pure Geometric Brownian Motion, where the price tends to move far away from the starting point, the Mean reverting model ensures that prices gravitate over time toward the mean reversion price levels. Assuming higher drift as time goes by can be misleading compared to how the real market works. As an example one can consider a jump in the

electricity price due to, for example, plant outage or transmission constraints. Most market participants would agree that it is highly probable that the prices eventually would return to their average level once the cause of jump goes away. In contrast to the geometric Brownian motion, the Mean reverting model takes this quality in to consideration and is therefore considered as a satisfying model for heating oil and gas in this thesis. The different models require different amount of price data. Due to the amount of data accessible together with fitting different market behaviours, the models therefore varied among energy carriers and electricity was modelled using a short term- long term model.

### **The model results in this thesis**

The speed of mean reversion depends on a variety of factors such as the type of commodity in consideration, the delivery provisions associated with the commodity and so on. As an example, studies show that in electricity markets one can observe sudden price spikes with very fast mean reversion to the previous price levels before the price jumps. However, for Natural Gas markets and oil markets the mean reversion rate is considerably lower, which also agrees with the results for the mean reversion rates calculated in this thesis. For oil markets the mean reversion ratio is much slower than in Natural Gas and electricity markets, and it can take months, or even years, for prices to revert to their mean, therefore the mean reversion for oil prices was rather hard to detect and was adjusted to fit the market behaviour in the future. Regarding the volatility parameters for the three energy carriers, it can be seen that electricity has the most volatile prices. Heating oil had rather low volatility which is not the case for crude oil prices. The reason for this is that the prices for the heating was not collected from a central market such as IPE, but from Norsk Petroliumsintituttt as an average from several local providers of the energy carrier.

## APPENDIX 3 - The Kalman filter

The Kalman filter is a recursive procedure based on a least square estimation for estimating unobservable state variables from data that depend on those variables. It is therefore a good tool for estimating  $X_t$  and  $\varepsilon_t$ , used in the two factor electricity price model.

### Application of the Kalman filter

The Kalman filter used in this thesis was programmed in Matlab by Rolf Magnus Alstad and Jørgen Taule Foss in their master thesis in 2004. Only small changes (such as altering the number of price columns and the risk free rate was set to 5% according to American treasury bonds) had to be done to be able to use the program for the prices analyzed in this thesis. Therefore reference to the source above is suggested if a wish for viewing the programme code is present.

When using the Kalman filter the input is a matrix that consists of the relative time of the price quotes observations followed by the prices of the contracts and time to maturity. Since the model includes seasonal variations and the first observation was in the first week of January 2000, the start time was set to  $1/52 = 0,01918$ . If there had been no seasonality the start number would have been set to zero. Figure A3 shows parts of the input matrix used.

File	Edit	Format	View	Help			
0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
0.01918	4.77159	4.85203	4.91361	4.96634	1.48219	2.48219	3.48219
0.03836	4.72639	4.85671	4.91559	4.96634	1.46301	2.46301	3.46301
0.05753	4.71276	4.85437	4.91632	4.96634	1.44384	2.44384	3.44384
0.07671	4.67982	4.84851	4.91081	4.96724	1.42466	2.42466	3.42466
0.09589	4.56124	4.84103	4.89948	4.95850	1.40548	2.40548	3.40548
0.11507	4.54063	4.83826	4.90134	4.95934	1.38630	2.38630	3.38630
0.13425	4.53991	4.85203	4.91081	4.96284	1.36712	2.36712	3.36712
0.15342	4.51360	4.84812	4.90639	4.96025	1.34795	2.34795	3.34795
0.17260	4.44379	4.84261	4.90342	4.95562	1.32877	2.32877	3.32877
0.19178	4.44082	4.85109	4.91133	4.95934	1.30959	2.30959	3.30959
0.21096	4.43082	4.85942	4.91081	4.96025	1.29041	2.29041	3.29041
0.23014	4.48582	4.87137	4.92180	4.96529	1.27123	2.27123	3.27123
0.24932	4.47164	4.86830	4.92180	4.96459	1.25205	2.25205	3.25205
0.26849	4.48300	4.87214	4.91910	4.96109	1.23288	2.23288	3.23288
0.28767	4.44124	4.85593	4.90897	4.95583	1.21370	2.21370	3.21370
0.32603	4.31174	4.84812	4.90342	4.95406	1.17534	2.17534	3.17534
0.34521	4.33729	4.86561	4.91486	4.96004	1.15616	2.15616	3.15616
0.36438	4.40830	4.87977	4.93181	4.97673	1.13699	2.13699	3.13699
0.38356	4.36628	4.87710	4.92820	4.96981	1.11781	2.11781	3.11781
0.40274	4.35989	4.88621	4.93986	4.98361	1.09863	2.09863	3.09863
0.42192	4.35350	4.88333	4.94143	4.98361	1.07945	2.07945	3.07945
0.44110	4.31749	4.87748	4.93720	4.98278	1.06027	2.06027	3.06027
0.46027	4.36310	4.88379	4.94078	4.98532	1.04110	2.04110	3.04110
0.49863	4.63453	4.87710	4.93806	4.98415	1.00274	2.00274	3.00274
0.51781	4.57471	4.86368	4.92725	4.97722	0.98356	1.98356	2.98356
0.53699	4.56695	4.88658	4.94699	4.99111	0.96438	1.96438	2.96438
0.55616	4.66345	4.88280	4.94307	4.98791	0.94521	1.94521	2.94521
0.57534	4.71850	4.88945	4.94150	4.98498	0.92603	1.92603	2.92603
0.59452	4.76002	4.89223	4.94542	4.98655	0.90685	1.90685	2.90685
0.61370	4.71402	4.87977	4.93627	4.98107	0.88767	1.88767	2.88767
0.63288	4.75789	4.87520	4.93231	4.97742	0.86849	1.86849	2.86849
0.65205	4.77491	4.88847	4.93986	4.98395	0.84932	1.84932	2.84932
0.67123	4.78122	4.88734	4.94057	4.98169	0.83014	1.83014	2.83014
0.69041	4.77068	4.88280	4.93771	4.97914	0.81096	1.81096	2.81096
0.70959	4.93720	4.88922	4.94521	4.98703	0.79178	1.79178	2.79178
0.72877	4.97155	4.92362	4.96109	4.99721	0.77260	1.77260	2.77260
0.74795	4.99043	4.92362	4.95934	4.99620	0.75342	1.75342	2.75342
0.76712	5.00395	4.92530	4.96319	4.99991	0.73425	1.73425	2.73425
0.78630	5.10595	4.93447	4.96981	5.00830	0.71507	1.71507	2.71507
0.80548	5.10291	4.93159	4.96898	5.00294	0.69589	1.69589	2.69589
0.82466	5.07517	4.89881	4.94876	4.98703	0.67671	1.67671	2.67671

Fig A31; input matrix in the Kalman filter.

The first column represents the time of the observations as a fraction of the year. The next column represents the spot price and the following columns represent the forward quotes for one, two and three years to maturity. All the prices are given as the natural logarithm of the observed prices. The following columns represent the time to maturity for the different contracts used. The time to maturity is not required for the spot prices, since a column with zeros are automatically provided by the Matlab code. The numbers in the sixth column

therefore represents the maturity of the contracts in the third column<sup>51</sup> and so on. The results for the state variables derived by the Kalman Filter are shown below.

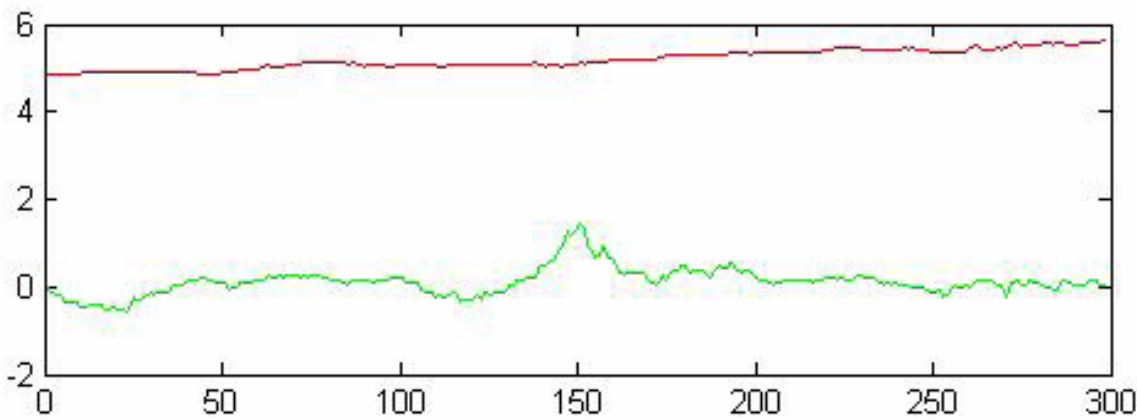


FIG A32: Shows the state variable estimated by the Kalman filter.

The green line represents X which is the short term deviations while the purple line shows the values for ε, containing the long term drift. The X-axis is in given in weeks. And as can be seen the model was calibrated on prices for a total of 300 weeks.

<sup>51</sup> The delivery date is set to be in the middle of the year, therefore the first number in the 7. column is set to be approximately 78/52

## APPENDIX 4 - Price drivers for pellets

Both circumstances in the wood market and the traditional energy market affect the future price for pellets. Further, different objectives such as environmental, energy, infrastructure and agriculture policy reflected in laws and regulations defines a critical framework for the future exploitation of bio fuel.

The raw material for Pellets can either come from Wood (Timber and bark) or Residues from wood-based industry. In this thesis both was considered, although nowadays, residues are the most common raw material .FigureA41 below shows the resources, fuels and heating systems for bio as an energy carrier. Different raw materials demand different treatment and hence have different production costs when processing to pellets. The discussion of economy of scale for production costs was also limited to production from pulpwood pine, and thus shipping in a terminal.

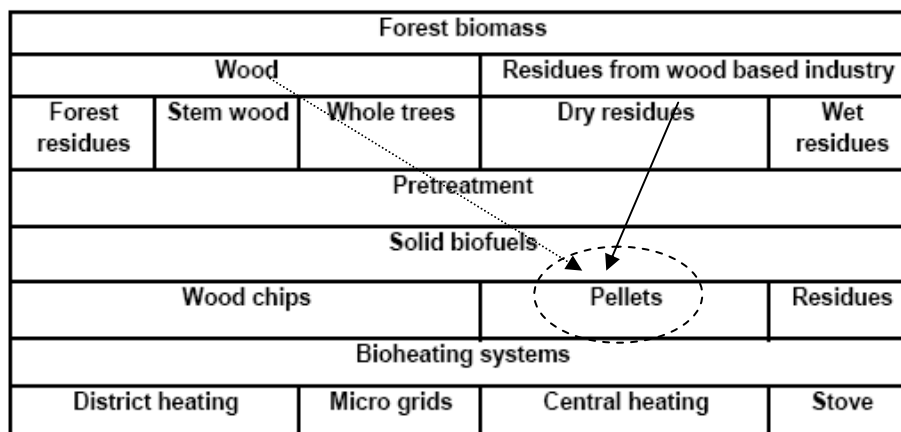


FIG A41 :Resources, fuels and heating system for Bio as an energy carrier Størdal(2003)

### Raw material and the Wood market

As can be see from the pellets chain cost structure, in figure 16 in the thesis, raw material makes up 30% of the total processing costs, therefore the price of pellets will be affected by the change in price of raw material. The supply of raw materials for the bio heat market is strongly interlinked with the pulp wood market. Structural changes within the wood segment will hence affect the availability of wood based resources at a competitive price, and therefore presumptions was made as to how the market structure will develop in the future, when the three scenarios were derived.

The figure below shows the availability of resources in the different regions of Norway. Although this is just the employment in the wood and furniture market, it indicates where the resources are most likely to be found.



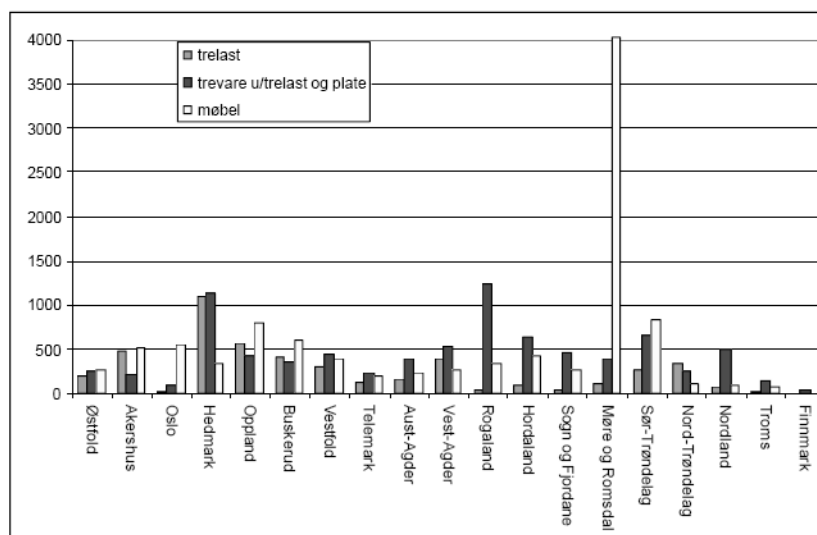


FIG A42 :Employment in the wood and furniture industry in the different regions in Norway, in number of employers

As can be seen from the figure, resources are generally located near to where the population density is highest.

### Export and import of pellets

The future of the export and import structure will depend on the prices and demand of bio fuel both internationally and in Norway in the future. Export will thus only take place if the quantum of production exceeds demand and the total price including transportation for pellets is competitive in other markets. Since transport of pellets is rather expensive compared to other energy carriers, such as gas or hydro power NoBio (2003), the Low and Middle -pellets price scenarios relies on export of those energy carriers that have a less complicated infrastructure, with decreased inland use, and instead increasing the market share of pellets nationally. Regarding the import of pellets, it will only take place if the inland demand is very high due to high transportation costs attributed to the energy carrier. Thus this is likely to happen in the Low and Middle pellets price scenarios. In the Low Pellets price scenario there are assumed to be no restrictions on raw material which would only be likely if the Norwegian chipboard industry is terminated/finished or import of raw material takes place. Although due to the low energy density of wood chips and other raw material, transportation over a distance greater than 200 km is not usual and can be rather expensive Størdal (2003). Import of finished Pellets is thus more likely than import of raw material, and hence may lower the price the end user pays for the pellets. Further, the next section shows how the Price scenarios were calculated

## Price functions for the three scenarios

The calculations for deriving the three scenarios are shown below.

(MWh/tonne)
4,8

The calculations for reduction in production costs is derived using assumptions about future production quantum and scale advantages in figure 17 represented in the thesis.

[NOK/MWh]					
Price today (2006)	Reduction in production costs	Reduction in transport costs	Increased material costs	Total reduction	Price 2021
375	44	25	0	69	306
375	38	10	4	44	331
375	0	0	0	0	375

Using the fact that the comparative price between bag delivery and bulk delivery will stay at the same level as today (66%), the prices for bulk delivery of pellet in 2021 will be as shown in the below table.

Pellet (large scale application)	Price 2021 [NOK/MWh]
Pellet-Low price	202
Pellet-Middle price	213
Pellet-High price	248

It is assumed a linear price reduction between 2006 and 2021, therefore the price processes for pellet large scale and small scale application will be as shown below.

t : (number of years from 2006, max = 15)	Large scale application	Small scale application
Pellet-Low price	250-3t	375-4,6t
Pellet-Middle price	250-2t	375-2,93t
Pellet-High price	250	375

## **APPENDIX 5 - Correlation among the price processes used in this thesis**

When modelling the correlation among the energy carriers in the thesis 6 correlation coefficients needed consideration. The reason for this is that the first of the four correlated Variables will have three pair-wise correlations with the others, the second will have two correlations, not counting its correlation with the first which is already accounted for. In general the rule for pair wise correlations that needs to be considered for n correlated Variables can be described as follows

$$n - 1 + n - 2 + \dots + 1 = \frac{1}{2}n(n - 1) \quad \text{A.5.1}$$

Since there was 4 pairwise correlations, 6 correlation coefficients were estimated.

### **The Fishers Z**

Since the correlation coefficients are not additive, they had to be transformed in to a new variable called Fisher Z value to be able to calculate an average value. The variable is approximately normally distributed, independent of the distribution of the original correlation coefficient, The Z value can further be summed for calculating a mean value. The fisher Z can be calculated as

$$Z_{i,j} = \frac{1}{2} \ln \left( \frac{1 + \rho_{i,j}}{1 - \rho_{i,j}} \right) \quad \text{A.5.2}$$

After the average for Z is calculated the correlation coefficient was simply found by rearranging formula (A.5.2) as

$$\rho_{i,j} = \frac{e^{2z_{i,j}} - 1}{e^{2z_{i,j}} + 1} \quad \text{A.5.3}$$

The Z value was also used for constructing a confidence interval when calculating the statistical significance of the estimated correlation. The main reason for this is that the Z Variable is normally distributes. The standard deviation of Z can be found as

$$\sigma_z = \frac{1}{\sqrt{N - 3}} \quad \text{A.5.4}$$

In the above Equation N represents the number of pair wise observations among the energy carriers. A 95% confidence interval was created by using  $[Z - 1,96\sigma_z, Z + 1,96\sigma_z]$ . Lastly the values were transformed back to correlation coefficients. The result for the Cholesky matrix is shown below;

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0,0073 & 0,999 & 0 & 0 \\ 0,092 & 0,139 & 0,986 & 0 \\ 0,129 & 0,074 & 0,107 & 0,983 \end{bmatrix}$$

The determinant of the matrix is 0,985.

## **APPENDIX 6 - Hypothesis tests**

Hypothesis testing of the correlation between oil and electricity spot price

**Null hypothesis:** The correlation coefficient between electricity spot price and oil price  $\rho_{oil-e11}$  is zero, which means that there is no effect of correlation,  $H_0: \rho_{oil-e11} = 0$

**Alternative Hypothesis:** There exist a correlation between oil prices and electricity spot prices,  $H_1 \rho_{oil-e11} \neq 0$

<b>Level of significance</b>	<b>5 %</b>	
Quantiles in Z values	-1,96	1,96
Observations (n)	400	
Quantiles for correlation coefficient	-0,098	0,098
observed value	0,092	

The null hypothesis can not be rejected at a 5 % level of confidence.

<b>Level of significance</b>	<b>10 %</b>	
Quantiles in Z values	-1,65	1,65
Observations (n)	400	
Quantiles for correlation coefficient	-0,0828	0,0828
observed value	0,092	

The null hypothesis can be rejected at a 10% level of significance, and there is a correlation between the prices.

## APPENDIX 7 - Basic statistics

The moments of a distribution can give valuable information on probabilities for outcomes. By making the above assumptions, it is relatively easy to calculate the moments of a sample with T observations.

The first moment,  $\mu = E(X)$ , is often called the expected return, and is calculated by the sample mean

$$m = \hat{\mu} = \frac{1}{T} \sum_{i=1}^T x_i \quad \text{A.7.1}$$

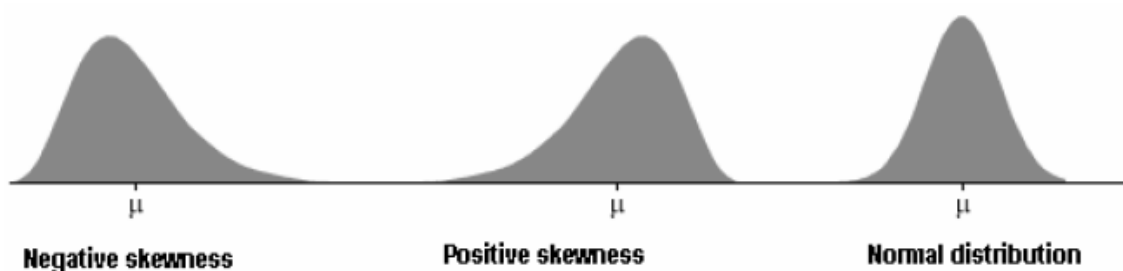
The second moment is called the *variance*,  $\sigma = E[(X - \mu)^2]$ , and can be estimated from the sample variance

$$s^2 = \hat{\sigma}^2 = \frac{1}{T-1} \sum_{i=1}^T (x_i - \hat{\mu})^2 \quad \text{A.7.2}$$

The standard deviation, often referred to as the volatility  $\sigma$ , is the square root of the VaRiance and holds the information about the spread around  $E(X)$ . Higher volatilities indicated a higher dispersion and uncertainty in outcomes for NPVs.

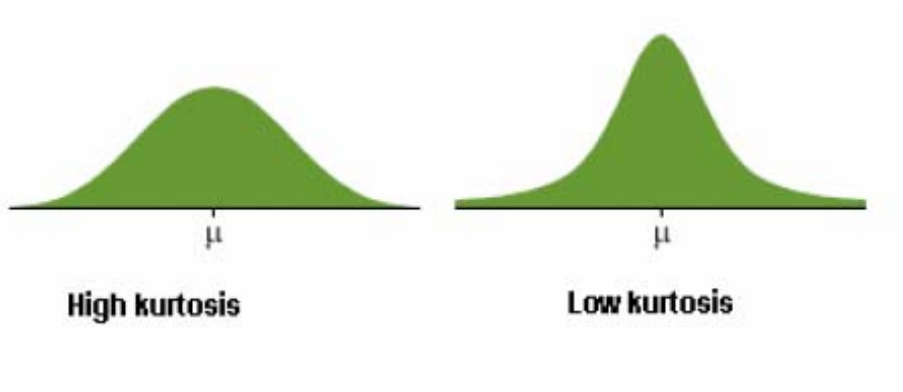
The third moment, called *skewness*, measures the divagation from symmetry in a distribution. A normal distribution with perfect symmetry has skewness 0. A negative skewness for a distribution will result in a long left tail and *higher possibility of loss or lower NPV, for the Energy investor*. If the skewness is positive. it results in a long right tail and higher probabilities of high income or higher NPV, for the Energy investor. The skewness can be calculated as

$$\gamma = \frac{1}{T-1} \sum_{i=1}^T (x_i - \hat{\mu})^3 / \hat{\sigma}^3$$



*Kurtosis* is the fourth moment and measures the flatness of the distribution. The kurtosis of a normal distribution is 3. For any distribution with a higher kurtosis the tails will decay slower than for a normal distribution which also gives higher probabilities for large positive or negative values. The kurtosis is calculated as

$$\hat{\delta} = \frac{1}{T-1} \sum_{i=1}^T (x_i - \hat{\mu})^4 / \sigma^4$$



## APPENDIX 8 - VAR for Parametric Distributions

The method presented in this chapter is an alternative method for calculation of VaR. If the distribution is known the computation can be considerably simplified. The VaR figure can then be derived directly from the standard deviation, of the portfolio considered, using a multiplicative factor that depends on the chosen confidence level. This method produces more accurate measures of VaR and is considerably simpler than the first method. The question here is ‘which distribution represents the data analyzed in this thesis?’ Once the distribution is found, the first step is to transform the general distribution  $f(w)$  in to a standard normal distribution  $\Phi(\varepsilon)$  where  $\varepsilon$  has mean zero and standard deviation of one. The meaning of  $W^*$  and  $R^*$  is the same as in method 1. Generally  $R^*$  is negative and can be written  $-|R^*|$ . Further  $R^*$  can be interpreted as a standard normal deviate  $\alpha > 0$  by setting

$$-\alpha = \frac{|-R^*| - \mu}{\sigma} \quad \text{A.8.1}$$

This is equivalent to setting

$$1 - c = \int_{-\infty}^{W^*} f(w)dw = \int_{-\infty}^{-|R^*|} f(r)dr = \int_{-\infty}^{-\alpha} \Phi(\varepsilon)d\varepsilon \quad \text{A.8.2}$$

The deviate  $\alpha$  is such that the area to the left of it in the distribution is equal to  $1 - c$  and can be found in the tables of the *cumulative standard normal distribution function*.  $R^*$  can then be found by rearranging Equation A.8.1.

VAR is the found as:

$$VAR(mean) = W_0 (R^* - \mu) = W_0 \alpha \sigma \sqrt{\Delta t}$$

This method can be generalised to other cumulative probability functions, as well as the normal, as long as all the uncertainty is contained in  $\sigma$ .



## APPENDIX 9- Correlation coefficients

This Appendix shows that the two correlation coefficients of equations (10.7) and (10.8) in the thesis are equal.

The starting point is to rearrange the two Equations (10.7) and (10.8), satisfying that the two  $dW_{el\epsilon}$  must be the same process in the two Equations, and at the same time that  $dW_{elx} \neq dW_{el\epsilon}$ . The last Equation is satisfied by regarding the first line in Equation (10.6) where  $a_{11}$  equals 1 and putting this in to the first line of equation (10.5). Doing this implies that  $dW_{elx} = d\xi_{elx}$ . Further, the two equations (10.7) and (10.8) are set equal to satisfy that  $dW_{el\epsilon}$  is the same in both Equations.

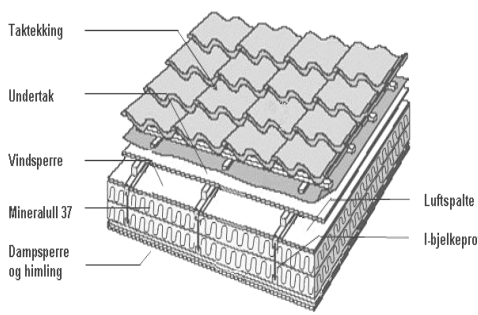
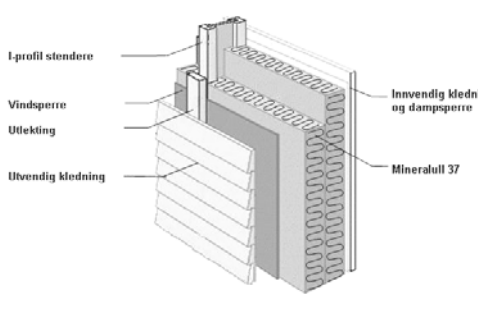
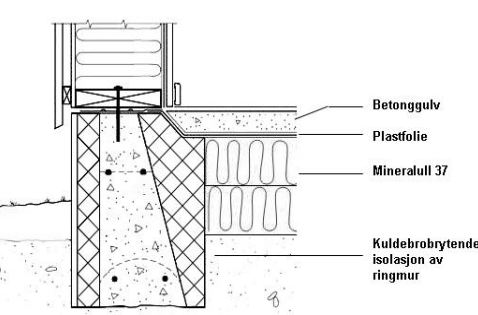
$$\frac{\rho^{*elx-el\epsilon} dt}{d\xi_{elx}} = \rho_{elx-el\epsilon} d\xi_{elx} + \sqrt{1 - \rho_{elx-el\epsilon}^2} d\xi_{el\epsilon} \quad A.9.1$$

The next step is to investigate whether ( $\rho^{*elx-el\epsilon} = \rho_{elx-el\epsilon}$ ). This can be seen by the fact that that  $d\xi_{elx}^2 = dt$  and also that  $d\xi_{elx} d\xi_{el\epsilon} = 0$  by using the equations presented in Shreve (2004) which means that the correlation coefficients are equal, hence  $\rho^{*elx-el\epsilon} = \rho_{elx-el\epsilon}$ . It is therefore viable to use the same correlation coefficient in both processes.

## APPENDIX 10 - Costs for upgrading building envelope

The two tables below are collected from Wigenstad (2006). The tables were used when analyzing the two buildings in the case regarding Svartlamoen.

Costs for upgrading building envelope in Residential buildings, tax is included in the costs

	Isolasjonstykkelse (mineralull, $\lambda=0,037$ W/mK)	I-profil dimensjon	Konstruksjonens U-verdi	Kalkylepris	
	[mm]	[mm]	[W/m <sup>2</sup> K]	[kr/m <sup>2</sup> tak]	Diff [kr/m <sup>2</sup> tak]
	300	300	0,15	1599	
	350	350	0,13	1638	39
	400	400	0,11	1680	81
	Isolasjonstykkelse (mineralull, $\lambda=0,037$ W/mK)	I-profil dimensjon	Konstruksjonens U-verdi	Kalkylepris	
	[mm]	[mm]	[W/m <sup>2</sup> K]	[kr/m <sup>2</sup> vegg]	Diff [kr/m <sup>2</sup> vegg]
	200	200	0,22	994	
	240	240	0,16	1084	90
	300	300	0,14	1129	135
	Isolasjonstykkelse (mineralull, $\lambda=0,037$ W/mK)		Konstruksjonens U-verdi	Kalkylepris	
	[mm]		[W/m <sup>2</sup> K]	[kr/m <sup>2</sup> gulv]	Diff [kr/m <sup>2</sup> gulv]
	200		0,15	671	
	200 mm + 30 mm kantiso		0,13	681	10
	250 MM + 50 mm kantiso.		0,11	701	30
<b>Rutetype</b>	U-verdi [W/m <sup>2</sup> K]	Differansepris [kr/m <sup>2</sup> vindu]			
V1 4-16-4	2,6	0			
V2 4-16-E4	1,6	0			
V3 4-16 Arg-E4	1,4	100			
V5 4E-12 Arg-4-12 Arg-E4	1,1	350			
<b>Ventilasjon. Småhus/blokk</b>	Kostnad [kr/enhet]	Differansekost n. [kr/enhet]			
Mekanisk avtrekk	15000	0			
Balansert m/ VVX 60 %	31000	16000			
Balansert m/ VVX 80 %	32000	17000			
Balansert m/ VVX 80 % + forbedret SFP-faktor (kanalnett)	34000	19000			
<b>Nattsenkning</b>		[kr/m <sup>2</sup> ]			
Automatisk el-varme		25			
<b>Infiltrasjon</b>	Lekkasjetall, n50 [oms/h]	Infiltrasjon [oms/h]	Differansepris [kr/m <sup>2</sup> yttervegg]		
Standard (naturlig avtrekk)	4	0.06			
Standard (med balansert ventilasjon)	4	0.28			

Meget god (balansert ventilasjon)	1,5	0,10	25
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### Costs for building upgrades in commercial building. Tax is included in the costs

	Isolasjonstykkelse (mineralull, $\lambda = 0,038$ W/mK)		Konstruksjonens U-verdi	Kalkylepris	
	[mm]		[W/m <sup>2</sup> K]	[kr/m <sup>2</sup> tak]	Diff
	300		0,15	1620	[kr/m <sup>2</sup> tak]
	300		0,13	1685	65
	400		0,11	1750	130
	Isolasjonstykkelse (mineralull, $\lambda = 0,037$ W/mK)	Stenderdim etc.	Konstruksjonens U-verdi	Kalkylepris	
	[mm]		[W/m <sup>2</sup> K]	[kr/m <sup>2</sup> vegg]	Diff
	[mm]				[kr/m <sup>2</sup> vegg]
	200	CY profil c/c 60 0,7 mm stål	0,23	854	
	250 (200+50)	"	0,17	955	101
300 (200+100)	"	0,14	1044	190	
	Isolasjonstykkelse (mineralull, $\lambda = 0,037$ W/mK)		Konstruksjonens U-verdi	Kalkylepris	
	[mm]		[W/m <sup>2</sup> K]	[kr/m <sup>2</sup> gulv]	Diff
	200		0,15	681	[kr/m <sup>2</sup> gulv]
	200 + 30 mm kantiso.		0,13	701	20
250 + 50 mm kantiso.		0,11	711	40	
<b>Rutetype</b>	U-verdi [W/m <sup>2</sup> K]	Differansepris [kr/m <sup>2</sup> vindu]			
V1 4-16-4 (TEK 97)	2,0				
V2 4-16-E4 (TEK 97)	1,6	0			
V3 4-16 Arg-E4 (moderat/medium)	1,4	100			
V5 4E-12 Arg-4-12 Arg-E4 (lavenergi)	1,1	350			
<b>Ventilasjon.</b>	Differansekostn. [kr/m <sup>2</sup> ]				
CAV 60 % vgjv. SFP 4 (TEK 97)	0	<b>Kalkyletall er justert for hver bygnings-kategori</b>			
CAV 70 % vgjv. SFP 2/1	200				
CAV 80 % vgjv. SFP 2/1	210				
VAV 80 % vgjv. SFP 3/1	300				
<b>Pumpestyring</b>		Differansekostn. [kr/m <sup>2</sup> ]			
Konstant drift		0			
Kapasitetsstyring		3			
<b>Infiltrasjon</b>	Lekkasjetall, n50 [oms/h]	Infiltrasjon [oms/h]	Differansepris [kr/m <sup>2</sup> yttervegg]		
Krav småhus/rekkehus (balansert vent.) (TEK 97)	4	0,28	Antatt lineær prisdiff 5 kr/m <sup>2</sup> pr. 0,5 bedring i lekkasjetall		
Krav bygninger inntil 2 etasjer (TEK 97)	3	0,21			
God (balansert ventilasjon)	2	0,14			
Krav bygninger over 2 etasjer (TEK 97)	1,5	0,10			
Svært god (lavenergistandard)	1	0,07			



## APPENDIX 11 - Svartlamoen

### Calculations for upgrades regarding building envelope

To be able to calculate the different costs, there were a few assumptions that had to be made. The first assumption was regarding the different areas or sizes of the walls. It is in the calculations assumed that, 15% of the wall areas consist of windows, and the rest of plain walls. Further It is assumed that both buildings are rectangular and have a outside height of 2,7 m, from the ground to the roof. Further it is assumed that the roof for both buildings are flat.

With the above assumptions, the distribution for wall and window surface for the two buildings was;

Commercial building		% of total wall surface	
Tot area (floor) [m <sup>2</sup> ]	3000		
Wall surface [m <sup>2</sup> ]	780		85 %
Window surface [m <sup>2</sup> ]	138		15 %

Table A111: Distribution for window and wall surface for the Commercial building

Residential building		% of total wall surface	
Tot area(floor) [m <sup>2</sup> ]	960		
Wall surface [m <sup>2</sup> ]	312		85 %
Window surface [m <sup>2</sup> ]	55		15 %

Table A112; distribution of window and wall surface for the Residential building

The two buildings had demand towards the U- value after investments in building envelope. By knowing the difference in U value before and after the investment it was possible to calculate the isolation thickness needed to satisfy the demand in U value. The formulas that were used for the calculations of isolation thickness are as below

$R = \frac{1}{U}$
R= Thermal resistance [W/m <sup>2</sup> K]
U= Measure of air to air heat transmission [m <sup>2</sup> K/W]

$d = \frac{\lambda}{U}$
d= Thickness of isolation needed [m]
λ= Thermal conductivity [W/mK]

After upgrading the buildings, the U value might be lower than requested by the building owners, this is due to the fact that in some cases isolation is delivered in predefined thickness that might not be exactly the calculated thickness. In those cases thickness that at least the meet the demands are chosen. The same fact applies for the commercial building. The following two tables show the calculation results for the different parts of the buildings that were improved.

Residential building								
Part of building	R before investment	R after investment	$\Delta R$ (R before investment - R after investment)	$\lambda$ (mineral wool)	$d_{\text{calculated}}$	$d_{\text{selected}}$	Cost/m <sup>2</sup> *	Cost
Wall	2,00	2,86	0,86	0,04	0,04	0,04	90,00	28 080,00
Roof	2,50	4,55	2,05	0,04	0,08	0,10	81,00	77 760,00
Glassing	0,63	0,90		0,04			350,00	19 250,00
Ventilation							16000/unit	384 000,00

Table A113 Calculations for improvements on the Residential building, \* Cost per m<sup>2</sup> of the building part that is considered, except for ventilation which is given per unit that is to be installed.

Commercial building								
Part of building	R before investment	R after investment	$\Delta R$ (R before investment - R after investment)	$\lambda$ (mineral wool)	$d_{\text{calculated}}$	$d_{\text{selected}}$	Cost/m <sup>2</sup> *	Cost
Wall	2,00	2,86	0,86	0,04	0,04	0,05	101,00	78 780,00
Roof	2,50	4,55	2,05	0,04	0,08	0,10	130,00	390 000,00
Glassing	0,63	0,71		0,04			100,00	13 800,00
Ventilation							300/m <sup>2</sup> <sub>(floor)</sub>	900 000,00

Table A114 Calculations for improvements on the Commercial building, \* Cost per m<sup>2</sup> of the building part that is considered, except for ventilation which is given per m<sup>2</sup> floor area.

## Constructing a baseline for Svartlamoen

The curve below was constructed from the base load by ranking the highest to the lowest energy demand for the two buildings at Svartlamoen. In addition the base load is plotted as a red line. The area above the red line represents the demand covered by the peak load, and the area below represents the energy demand covered by the base load. To calculate the different areas the curves has been split in smaller parts (triangles). The area was calculated for each part and then summed up for both the base load and the peak load.

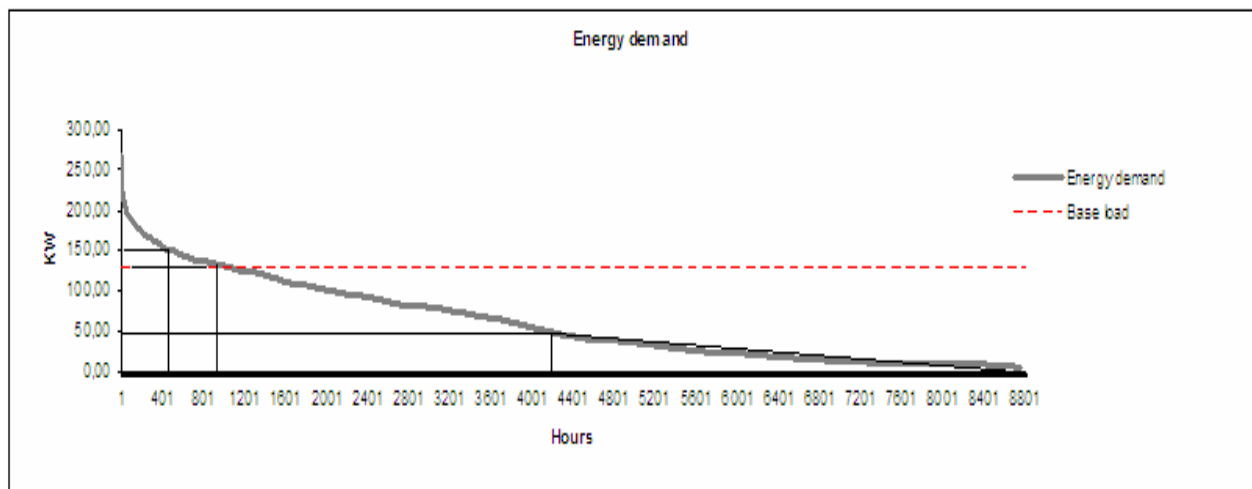


Fig:A114, duration curve for the two buildings at svartlamoen.

Calculations gave the following distribution among the base load and peak load:

52

Table A115: Heat demand for peak load and base load at Svartlamoen

	Total [Kwh]	[Kwh/m <sup>2</sup> ]
Base Load (PL)	551574,00	139,29
Peak Load (BL)	32470,00	8,20
Hot water (residential building)/(commercial building)	(24000)/(30000)	(25)/(10)
Space heating	530044,00	133,85
<b>Sum</b>	<b>584044,00</b>	<b>147,49</b>

<sup>52</sup> Sintef technology and samfunn calculated the old energy consumption to be 149Kwh/m<sup>2</sup>. This makes the energy consumption for the reference building a good approximation for the buildings at SvaRtlamoen.

BL%	0,94
PL%	0,06

By using the efficiencies rates from SINTEF(2005), a heating system (water based distribution) based on electricity and bio fired boiler has an efficiency rate of 0,95 and 0,77.

Improvements on the building envelope give a reduction of the heat demand as shown below

Svartlamoen Commercial [kWh/m <sup>2</sup> ]	Svartlamoen Residential [kWh/m <sup>2</sup> ]	Total (weighted) [kWh/m <sup>2</sup> ]
101	117	104,9

By taking the efficiency rates for the different heating systems together with the distribution among the peak load and base load in to consideration, the different energy savings was calculated as:

Table A116: The heat reduction in percent for the four investment alternatives in the Svartlamoen case

	Calucaltions	Results
<b>Electricity</b>		
Heat efficiency		0,95
Energy cosumption after investment	104,9/0,95	110,42
Reduction in Energy consumption %	$((147,5-110,4)/147,5)*100$	<b>25,15</b>
<b>Electricity + Bio</b>		
Heat efficiency (weighted average)	$(0,95*0,4)+(0,96*0,77)^*$	0,78
Energy consumption after investment	104,9/0,78	134,49
Reduction in Energy consumption %	$((147,5-134,48)/147,5)*100$	<b>9,01</b>
<b>Electricity + Bio + Sun</b>		
Heat efficiency (weighted average, sun excluded)	$(0,95*0,06)+(0,96*0,77)^*$	0,78
Energy consumption after investment (sun excluded)	104,9/0,78	134,49
Reduction in energy consumption pr m <sup>2</sup> for hot water (due to the sun)	$(0,5*((10*3000)+(25*960)))/3960$	6,82
Reduction in heat demand pr m <sup>2</sup> due to the sun	$((584044-(54000))*0,05)/3960$	7,37
Reduction in energy consumption %	$((147,5-(134,48-7,4-6,8))/147,5)*100$	<b>18,45</b>
<b>Electricity + Sun</b>		
Heat efficiency (sun excluded)		0,95
Energy consumption after investment (sun excluded)	104,9/0,95	110,42
Reduction in energy consumption pr m <sup>2</sup> for hot water (due to the sun)	$(0,5*((10*3000)+(25*960)))/3960$	6,82
Reduction in heat demand pr m <sup>2</sup> due to the sun	$((584044-(54000))*0,05)/3960$	7,37
Reduction in energy consumption %	$((147,5-(110,44-7,4-6,8))/147,5)*100$	<b>34,77</b>

\* It is assumed that the percentage distribution between the base load and peak load is the same before and after the investments in building envelopes are conducted.

The Energy from the Sun is set to cover half of the energy demand for hot water together with 5% of the heating demand in the buildings. With the above calculations Figure A117 shows how the energy consumption varies through the year for svartlamoen.

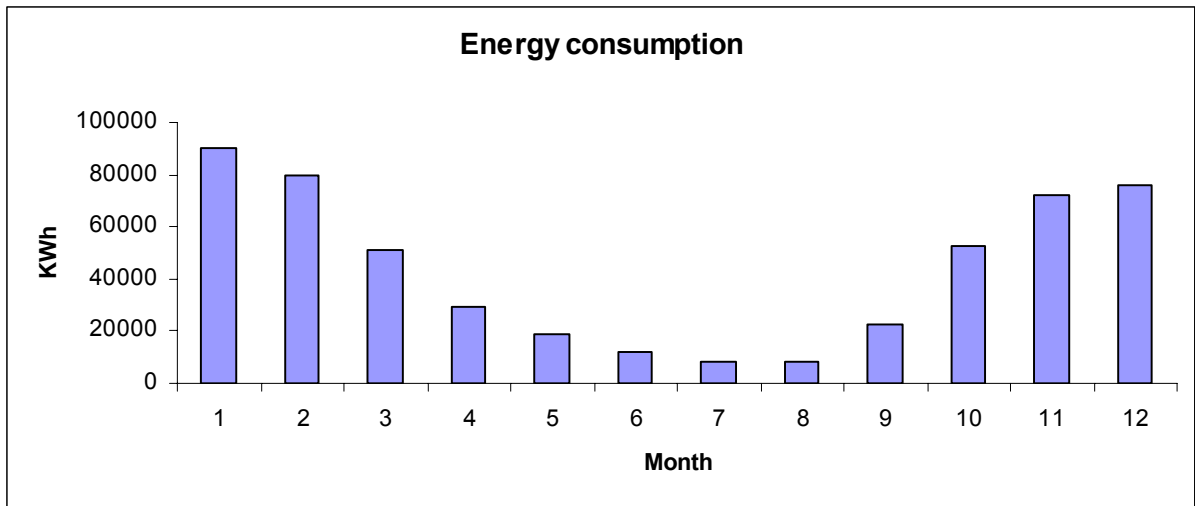


Table A117: The calculated energy consumption at Svartlamoen



## **APPENDIX 12 - Calculation of heat supply**

Equation below shows the method for calculating the heat supply in the building analysed COWI (2005<sup>a</sup>)

$$E_{\text{supply}} = \frac{E_{\text{demand}}}{\eta_{\text{system}}}$$

Further the total efficiency rate ( $\eta_{\text{system}}$ ) for an energy system is calculated from [31];

$$\eta_{\text{system}} = \eta_{\text{distribution}} * \eta_{\text{combustion}} * \eta_{\text{regulation}}$$

Where  $\eta_{\text{distribution}}$ : represents the losses due to transmission of the energy carrier in the building. If the energy system is water based, heat loss will be present in the pipes carrying the warm water to the different rooms. Losses will also occur in valves and heat tanks which needs to be included in the efficiency rate for distribution.

$\eta_{\text{combustion}}$ : is the combustion efficiency or the coefficient of performance for a heat pump. In addition, the coefficients of performance for solar systems are also included in this factor. When solar systems are analysed, the heat supplied by the solar system is divided by the energy needed for the supporting system, e.g. circulation pumps.

$\eta_{\text{regulation}}$ : reflects the systems dynamic abilities to set and keep the right temperatures in the different areas of the building analysed.

## APPENDIX 13 - VBA Code

In this part the main code will be shown. All the macros used in the model are divided into small macros so that each can be edited for future adjustment. However it is recommended that the user, rather than taking a look at the program attached to the thesis, hence all the macros will be provided on the CD. However interested readers can view the code below

### CODE FOR CHECKING INPUT DATA

```
*****
'Gets the information regarding the type of contract that is used
*****
Sub TypeContracting()

    Dim TypeContract As String

    TypeContract = Worksheets("Project Data").Cells(8, (2))
    If TypeContract = "Guaranteed Savings" Then
        Worksheets("Project Data").Cells(8, (3)).Value = 1
    ElseIf TypeContract = "Shared Savings" Then
        Worksheets("Project Data").Cells(8, (3)).Value = 2
    ElseIf TypeContract = "Energy Service Contract" Then
        Worksheets("Project Data").Cells(8, (3)).Value = 3
    Else:
        Worksheets("Project Data").Cells(8, (3)).Value = 4
    End If

End Sub

*****
' Stores the information regarding what type of new energy that is selected by the user,
'and gets the right prices for the simulation. The prices are collected from the
'from the different energy carriers respective model
*****
Sub TypeEnergyCarrier()

    Worksheets("Simulation price").Select
    'Call ClearContentsSimulationprice 'Deletes old values, that the new prices can be collected

    Dim EnergyCarrier As String

    EnergyCarrier = Worksheets("Upgrading Energysystem").Cells(5, (2))

    If EnergyCarrier = "Oil" Then
        ' Call ImportDataOil
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 1 'oil
    ElseIf EnergyCarrier = "Gas" Then
        'Call ImportDataGas
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 2 'gas
    ElseIf EnergyCarrier = "Electricity" Then
        'Call ImportDataEl
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 3 'el
    ElseIf EnergyCarrier = "Pellet" Then
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 4 'pellet
        'Call CalculateDataPellet
    ElseIf EnergyCarrier = "Pellet/Electricity" Then
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 6 'pellet /El
        'Call CalculateDataPellet_Electricity
    ElseIf EnergyCarrier = "Oil/Electricity" Then
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 7 'oil /El
        'Call CalculateDataOil_Electricity DENNE ER IKKE LAGET ENDA
    ElseIf EnergyCarrier = "Pellet/Oil" Then
        Worksheets("Upgrading Energysystem").Cells(6, (3)).Value = 8 'pellet /oil
        'Call CalculateDataPellet_Oil DENNE ER IKKE LAGET ENDA
    Else
        Worksheets("Project Data").Cells(6, (3)).Value = 5 'other
        Call ImportDataOther
    End If

End Sub

*****
'Checks the input values, that the client does not benefit from savings until the
'contract period is over
*****
Sub ShareESC()
```

```

If Worksheets("Project Data").Cells((8), (3)).Value = 3 And Worksheets("Project Data").Cells((7), (5)).Value > 0 Then
    MsgBox "With the contract type Energy Service Contract, the client does not benefit from the energy savings until the contract period is
over, and share of income must therefore be 0 for the client. Once this is fixed run the simulation again"
    Worksheets("Project Data").Select
Else
    End If

```

```

End Sub
'*****
'Checks input values, that the investment is done by the client, if the contract type is guaranteed savings
'*****
Sub ShareGS()
    If Worksheets("Project Data").Cells((8), (3)).Value = 1 And Worksheets("Project Data").Cells((4), (6)).Value > 0 Or
Worksheets("Project Data").Cells((4), (7)).Value > 0 Then
        MsgBox "With the contract type: Guaranteed Savings, the client takes on the investment for upgrading the building or energy system
which sets the clients share for investment to 100%."
    Else

```

```

    End If
End Sub

```

```

'*****
'Hides all sheets but the one that matches the selected form of contract, here Guaranteed Savings
'*****
Sub HideSheetsGS()

    Worksheets("NPVSharedSavings").Visible = False
    Worksheets("NPVGuaranteedSavings").Visible = True
    Worksheets("NPVEnergyServiceContract").Visible = False

```

```

End Sub

'*****
'Shows all sheets for programming
'*****
Sub ShowSheets()

    Worksheets("NPVSharedSavings").Visible = True
    Worksheets("NPVGuaranteedSavings").Visible = True
    Worksheets("NPVEnergyServiceContract").Visible = True

```

```

End Sub

SIMULATING ENERGY PRICES

```

```

PELLET
'*****
'This calculates the price for pellets, the price is modelled as linear decreasing function, and is differend dependent on choises
'of senarios and scale of application
'*****
Sub CalculatePellet()

```

```

    Dim z As Integer 'both z and x are counting variables, years, while x counts the cells and months
    Dim x As Integer
    Dim EnergyPrice As Integer
    z = 0
    x = 2
While z < 15
    While x < 182
If Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bulk" And Worksheets("Upgrading Energysystem").Cells((7), (6)) = "High"
Then
    EnergyPrice = (250 - 3.31 * 1 * z) / 1000
    ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bulk" And Worksheets("Upgrading Energysystem").Cells((7),
(6)) = "Middle" Then
    EnergyPrice = (250 - 2.19 * 1 * z) / 1000
    ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bulk" And Worksheets("Upgrading
Energysystem").Cells((7), (6)) = "Low" Then
    EnergyPrice = (250) / 1000
    ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bag" And Worksheets("Upgrading
Energysystem").Cells((7), (6)) = "High" Then
    EnergyPrice = (375 - 4.86 * 1 * z) / 1000
    ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bag" And
Worksheets("Upgrading Energysystem").Cells((7), (6)) = "Middle" Then
    EnergyPrice = (375 - 2.73 * 1 * z) / 1000

```

```

Else 'this is the case for low price path and smale scale of application or Bag
    EnergyPrice = (375) / 1000 'price (kr/kwh)
End If
    Worksheets("Simulation price").Cells(x, (254)) = EnergyPrice

If x = 13 Or x = 25 Or x = 37 Or x = 49 Or x = 61 Or x = 73 Or x = 85 Or x = 97 Or x = 109 Or x = 121 Or x = 133 Or x = 145 Or x = 157
Or x = 169 Or x = 181 Then
    z = z + 1
    x = x + 1
    Else
    x = x + 1
    z = z + 0
        End If
    Wend
Wend

End Sub

HEATING OIL
*****
'Simulates prices for heating oil
*****
Sub simulating_heatingoil()
Application.ScreenUpdating = False
Application.Calculation = xlCalculationManual

Column = 2
    For y = 1 To 250
        For w = 5 To 185
            If Worksheets("priceOil").Cells((w), (13)).Value = 1 Then
                y = y - 1
                Worksheets("priceOil").Calculate
            GoTo A
        Else
            End If
        Next w
        Range("L5:L185").Select
        Selection.Copy
        Worksheets("simulationOil").Cells((2), (Column)).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False

        Column = Column + 1
        Worksheets("priceOil").Calculate

    A:
        Next y

    Column = 2
    For y = 251 To 500
        For w = 5 To 185
            If Worksheets("priceOil").Cells((w), (13)).Value = 1 Then
                y = y - 1
                Worksheets("priceOil").Calculate
            GoTo B
        Else
            End If
        Next w
        Range("L5:L185").Select
        Selection.Copy
        Worksheets("simulationOil").Cells((200), (Column)).PasteSpecial Paste:=xlPasteValues,
        Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False

        Column = Column + 1
        Worksheets("priceOil").Calculate

ELECTRICITY
*****
'simulating electricity prices, long term-short term model
*****

```

```

Sub simulation_elmonth()
    Application.ScreenUpdating = False
    Application.Calculation = xlCalculationManual
    Column = 2
For y = 1 To 250
    For w = 5 To 185
        If Worksheets("priceel").Cells(w, (14)).Value = 1 Then
            y = y - 1
            Worksheets("priceel").Calculate
        GoTo A
        Else
            End If
    Next w
    Range("M5:M185").Select
    Selection.Copy
    Worksheets("simulationel").Cells(2, (Column)).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks
:=False, Transpose:=False

    Column = Column + 1
    Worksheets("priceel").Calculate
A:
Next y

    Column = 2
    For y = 251 To 500
    For w = 5 To 185
        If Worksheets("priceel").Cells(w, (14)).Value = 1 Then 'When using the random function to generate random numbers, excel
will sometimes
'generate to lagre numbers and NUM may appear in the cell, by doint this test, check if the cell is one,
'this is avoided.
y = y - 1
        Worksheets("priceel").Calculate
    GoTo B
    Else
        End If
    Next w
    Range("M5:M185").Select
    Selection.Copy
    Worksheets("simulationel").Cells((200), (Column)).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
    SkipBlanks _
:=False, Transpose:=False

    Column = Column + 1
    Worksheets("priceel").Calculate
B:
    Next y

    Worksheets("simulationel").Activate
    Call FiksEl
    Application.Calculation = xlCalculationManual
End Sub

Sub Correlationel()
Worksheets("priceel").Select
Worksheets("priceel").Range("H5:H785").Select
Selection.Copy
Worksheets("Correlationel").Cells((1), (1)).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False

    End Sub

GAS
*****
'The below macro simulates the gas prices
*****
'Simulates gas prices
Sub simulating_gas()
Application.ScreenUpdating = False
Application.Calculation = xlCalculationManual
Column = 2
    For y = 1 To 250
        For w = 5 To 185

```

```

                If Worksheets("priceGas").Cells((w), (13)).Value = 1 Then
y = y - 1
Worksheets("priceGas").Calculate
                GoTo A
                Else
                End If

        Next w
                Range("L5:L185").Select
                Selection.Copy
                Worksheets("simulationGas").Cells((2), (Column)).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
                SkipBlanks_
                :=False, Transpose:=False

Column = Column + 1
Worksheets("priceGas").Calculate
A:

Next y

Column = 2
                For y = 251 To 500
                        For w = 5 To 185
                                If Worksheets("priceGas").Cells((w), (13)).Value = 1 Then
y = y - 1
                                Worksheets("priceGas").Calculate
                                GoTo B
                                Else
                                End If
                        Next w
                Range("L5:L185").Select
                Selection.Copy
                Worksheets("simulationGas").Cells((200), (Column)).PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
                SkipBlanks_
                :=False, Transpose:=False

Column = Column + 1
Worksheets("priceGas").Calculate
B:

Next y
        Application.Calculation = xlCalculationAutomatic
End Sub

```

#### OTHER

```

*****

```

```

'If the energy carrier is something other than specified in the
'the user then needs to specify the price of the energy carrier

```

```

*****

```

#### Sub Other()

```

        If Worksheets("Upgrading Energysystem").Cells((5), (3)) = 1 Then
                Set checkCell = Worksheets("Upgrading Energysystem").Cells((2), (6)) '
                If IsEmpty(checkCell) = True Or checkCell.Value = 0 Then 'checks that price is specified for the energy carrier
                        MsgBox "Specification of energy carrier and price is needed."
                Else
                End If
                Else
                End If
        End Sub

```

#### Sub ImportDataOther()

```

        For x = 2 To 182

                EnergyPrice = Worksheets("Upgrading Energysystem").Cells((2), (6))
                Worksheets("Simulation price").Cells((x), (254)) = EnergyPrice
        Next
End Sub

```

PELLETS/ELECTRICITY

\*\*\*\*\*

Calculates combination with pellet and electricity

\*\*\*\*\*

Sub CalculateDataPellet\_Electricity()

'Finds the current path

Name = ActiveWorkbook.Path

'Opens Electricity price simulations file, gets the electricity datas before the pellet datas

Workbooks.Open Filename:=Name & "\Elmontecarlosmonth", UpdateLinks:=True

Worksheets("Simulationel").Activate

Cells.Select

Selection.Copy

Windows("InvestmentModel.xls").Activate

Worksheets("Simulation price").Select

Cells.Select

Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks \_

:False, Transpose:=False

Range("B2:IQ395").Select

Selection.NumberFormat = "0.0000"

'Closes the El simulation file, hvordan gjøres dette

Application.DisplayAlerts = False

Workbooks("Elmontecarlosmonth").Close

'Gets the pellet datas, and calculated them in the cell beside the electricity prices

'A new macro will decide which cell to pick from at each time interval according to the users preferences

z = 0

x = 2

While z < 14

While x < 182

If Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bulk" And Worksheets("Upgrading Energysystem").Cells((7), (6)) = "High"

Then

EnergyPrice = (250 - 3.31 \* 1 \* z) / 1000

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bulk" And Worksheets("Upgrading Energysystem").Cells((7), (6)) =

"Middle" Then

EnergyPrice = (250 - 2.19 \* 1 \* z) / 1000

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bulk" And Worksheets("Upgrading Energysystem").Cells((7), (6)) =

"Low" Then

EnergyPrice = (250) / 1000

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bag" And Worksheets("Upgrading Energysystem").Cells((7), (6)) = "High"

Then

EnergyPrice = (375 - 4.86 \* 1 \* z) / 1000

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (6)) = "Bag" And Worksheets("Upgrading Energysystem").Cells((7), (6)) =

"Middle" Then

EnergyPrice = (375 - 2.73 \* 1 \* z) / 1000

Else 'this is the case for low price path and small scale of application or Bag

EnergyPrice = (375) / 1000 'price (kr/kwh)

End If

Worksheets("Simulation price").Cells(x), (255) = EnergyPrice

If x = 13 Or x = 25 Or x = 37 Or x = 49 Or x = 61 Or x = 73 Or x = 85 Or x = 97 Or x = 109 Or x = 121 Or x = 133 Or x = 145 Or x = 157

Or x = 169 Or x = 181 Then

z = z + 1

x = x + 1

Else

x = x + 1

z = z + 0

End If

Wend

Wend

Application.DisplayAlerts = True

End Sub

CALCULATES THE ENVIRONMENTAL GRAPH

\*\*\*\*\*

'This macro calculates and constructs the Environmental graph

```

*****

Sub Environmental_graph()

'Gets the different environmental variables and stores them
  Dim TotalEnergyconsumption As Double
  Dim EnergyCarrier As String
  Dim EnvironmentalOil As Double
  Dim EnvironmentalGas As Double
  Dim EnvironmentalPellet As Double
  Dim EnvironmentalElectricity As Double
  Dim n As Integer 'counting variable that calculates where to put the result, max five alternatives can be stored in the environmental graph
at once

  TotalEnergyconsumption = Worksheets("Current Situation").Cells((24), (3))
  EnergyCarrier = Worksheets("Project Data").Cells((2), (5))
  EnvironmentalPellet = Worksheets("Environmental graph").Cells((2), (20))
  EnvironmentalGas = Worksheets("Environmental graph").Cells((3), (20))
  EnvironmentalOil = Worksheets("Environmental graph").Cells((4), (20))
  EnvironmentalElectricity = Worksheets("Environmental graph").Cells((5), (20))

  EnergyCarrier = Worksheets("Upgrading Energysystem").Cells((5), (2))
  If Worksheets("Project Data").Cells((17), (3)).Value = 1 Then
    n = 4

    While n < 10

      If Worksheets("Environmental graph").Cells((n), (3)).Value = 1 Then

        If EnergyCarrier = "Oil" Then

          Worksheets("Environmental graph").Cells((n), (2)) = TotalEnergyconsumption * EnvironmentalOil
          Worksheets("Environmental graph").Cells((n), (1)) = EnergyCarrier

GoTo E

        ElseIf EnergyCarrier = "Gas" Then
          Worksheets("Environmental graph").Cells((n), (2)) = TotalEnergyconsumption * EnvironmentalGas
          Worksheets("Environmental graph").Cells((n), (1)) = EnergyCarrier

GoTo E

        ElseIf EnergyCarrier = "Electricity" Then
          Worksheets("Environmental graph").Cells((n), (2)) = TotalEnergyconsumption * EnvironmentalElectricity
          Worksheets("Environmental graph").Cells((n), (1)) = EnergyCarrier

GoTo E

        ElseIf EnergyCarrier = "Pellet" Then
          Worksheets("Environmental graph").Cells((n), (2)) = TotalEnergyconsumption * EnvironmentalPellet
          Worksheets("Environmental graph").Cells((n), (1)) = EnergyCarrier

GoTo E

          End If
        Else
          n = n + 1
        End If
      Wend
    End If

  End Sub

  *****

  'This clears the sheet for price simulation, so the new price
  'Simulationso the new price can be moddeled and pasted in to the program
  *****
  Sub ClearContentsSimulationprice()
  'Worksheets("Simulation price").Range("A1:IV394").Select
  ' Selection.ClearContents

  End Sub

  *****

  'This deletes the chart between each simulation, so that a new one can
  ' be created
  *****

```



```

Sub DeleteChart()
'ActiveSheet.ChartObjects("Diagram " & chart_no & " ").Activate
'chartname = Worksheets("Fuel_costs").Cells((19), (7)).Value
Worksheets("Fuel_costs").Activate

```

```

On Error Resume Next

```

```

ActiveSheet.ChartObjects(1).Delete
ActiveSheet.ChartObjects(2).Delete
ActiveSheet.ChartObjects(3).Delete
ActiveSheet.ChartObjects(4).Delete
ActiveSheet.ChartObjects(5).Delete
'Charts(chartname).Activate
'ActiveChart.Location Where:=xlLocationAsObject, Name:="fuel_costs"
'myChart = ActiveChart.Name
'chart_no = Right(myChart, Len(myChart) - 11) 'collects parts of a string
'Arket må hete fuel_costs
'ActiveSheet.ChartObjects(chart_no).Select
'ActiveWindow.Visible = False
'Selection.Delete
End S

```

```

CALCULATES VALUE AT RISK

```

```

*****

```

```

'This macro calculated the value step in the Value at risk graph

```

```

*****

```

```

Sub graph_Var()

```

```

    Dim valueStep As Double
    Dim n As Integer 'this is a counting variable
    Dim MinValueNPV As Double
    Dim Size As Double 'takes care of the size of the income
    Worksheets("VaR").Activate

```

```

    MinValueNPV = Worksheets("VaR").Cells((400), (6))

```

```

    valueStep = Worksheets("VaR").Cells((402), (5))

```

```

    For n = 12 To 42

```

```

        Worksheets("Distribution_of_NPV").Cells((n), (1)) = MinValueNPV + valueStep * (n - 12)

```

```

    Next n
End Sub

```

```

*****

```

```

'The processes of calculating var is divided in to calculating 2*250 Simulations, this is to be able to fit the prices on one sheet

```

```

*****

```

```

Sub Varfirst250()

```

```

Worksheets("VaR").Activate
Dim n As Integer
Dim w As Integer
Dim t As Integer
Dim y As Integer
Dim x As Integer
Dim o As Integer
Dim OldEnergyCost As Double
Dim OldEnergyConsumption As Double
Dim ReductionEnergyConsumption As Double
Dim ShareOfIncomeEnergyInvestor As Double
Dim EnergyPricemonth As Double
Dim Incomemonth As Double

```

```

Range("B2:IQ198").Select
    Selection.ClearContents

```

```

Application.Calculation = xlCalculationManual

```

```

'Simulation of first 250 of 500 NPV, for calculating VaR

```

```

n = Worksheets("Project Data").Cells((4), (3)) 'This variable takes care the information for which month (number) the project starts

```

```

' The o is a variable that picks which cell the Energycost is taken from, this much match the current cell or month project counts for. Denne variabelen gjør slik at verdi for energikostnad samsvarer med måned, det er laget en liste i ark 5 som den plukker fra, alt etter hvor den begynner teller den også over de 180 cellene.

```

```

For w = 2 To 182
    If Worksheets("Project Data").Cells((4), (3)) = Worksheets("Simulation price").Cells((w), (253)) And
        Worksheets("Project Data").Cells((3), (3)) = Worksheets("Simulation price").Cells((w), (256)) Then
    Start_Date = w
        Else
        End If
    Next w
t = Worksheets("Project Data").Cells((10), (2)) 'Project_lenght

    For y = 2 To 251 'denne skal gaa til 251
    x = Start_Date
    o = Worksheets("Project Data").Cells((4), (3))
    't = 2 ' De cellene som det skal klippes inn i
        While x < 12 * t + 2 '182denne forandret jeg naa og maa sees paa!!
            While o < 12 * t + n

OldEnergyCost = Worksheets("Sheet5").Cells((o), (3))
OldEnergyConsumption = Worksheets("Sheet5").Cells((o), (2))
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6)) / 100
'YearofIncome = t - 1
        If Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 3 Then
EnergyPricemonth = Worksheets("Simulation price").Cells((x), (y)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This adds the
cost of nettleie if electricity is chosen
            Else
                EnergyPricemonth = Worksheets("Simulation price").Cells((x), (y))
        End If
    Incomemonth = (OldEnergyCost - ((EnergyPricemonth * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeEnergyInvestor)

Worksheets("VaR").Cells((x), (y)).Value = Incomemonth

x = x + 1
o = o + 1

Wend
Wend

Next
End Sub

Sub VARsecond250()
Worksheets("VaR").Activate
Range("B200:IQ396").Select
Selection.ClearContents
Application.Calculation = xlCalculationManual
'Simulation of second 250 of 500 NPV, for calculating VaR
n = Worksheets("Project Data").Cells((4), (3)) 'This variable takes care the information for which month (number) the project starts

' The o is a variable that picks which cell the energycost is taken from, this much mach the current cell or month project counts for. Denne
variablen gjør slik at verdi for energikostnad samsvarer med måned, det er laget en liste i ark 5 som den plukker fra, alt etter hvor den
begynner teller den også over de 180 cellene.
For w = 200 To 380
    If Worksheets("Project Data").Cells((4), (3)) = Worksheets("Simulation price").Cells((w), (253)) And Worksheets("Project Data").Cells((3),
(3)) = Worksheets("Simulation price").Cells((w), (256)) Then 'this compares the dates(months ad years)so that the program is flexible when
it comes to start date.
    Start_Date = w
    Else
    End If
    Next w
t = Worksheets("Project Data").Cells((10), (2)) 'Project_lenght

For y = 2 To 251 'denne skal gaa til 251

x = Start_Date
o = Worksheets("Project Data").Cells((4), (3)) 'This variable takes care the information for which month (number) the project starts
't = 2 ' De cellene som det skal klippes inn i
While x < 12 * t + 200
While o < 12 * t + n
'While t < 17

```

```

OldEnergyCost = Worksheets("Sheet5").Cells(o, (3))
OldEnergyConsumption = Worksheets("Sheet5").Cells(o, (2))
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells(40, (3)) 'Percentage/100
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells(7, (6))
'YearofIncome = t - 1
If Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 3 Then
EnergyPricemonth = Worksheets("Simulation price").Cells(x, (y)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This adds the
cost of nettleie if electricity is chosen
Else
EnergyPricemonth = Worksheets("Simulation price").Cells(x, (y))
End If
Incomemonth = (OldEnergyCost - ((EnergyPricemonth * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeEnergyInvestor / 100)

Worksheets("VaR").Cells(x, (y)).Value = Incomemonth
't = t + 1
x = x + 1
o = o + 1
Wend
    Wend

Next

End Sub

Dim var As String
Dim t As Integer
Dim TotalVar As String
Dim y As Integer
Application.Calculation = xlCalculationManual
Dim MaintenanceCosts As Double
Dim OperatingCosts As Double
Dim ShareOperatingMaintenanceCosts As Double
Dim AdministrationCosts As Double
Dim CostOfUpgradingEnergySystem As Double
Dim CostOfUpgradingBuilding As Double
Dim Rent As Double
Dim Costs As Double
Dim YeraOfIncome As Integer
Dim Depreciation As Double
Dim r As Double
Dim Investment As Double
Dim ShareInvestment As Double
Dim InvestmentCost As Double
Dim CashflowEnergyInvestorcell
p = 183
s = 2
q = 2
y = Worksheets("Project Data").Cells((10), (2))
r = Worksheets("Project Data").Cells(3, (4)) 'foramdret til der hvor if setn er
While q < 252
    While p < 197
        While s < 167
            Investment = Worksheets("Upgrading Energysystem").Cells((24), (4)) + Worksheets("Upgrading Building").Cells((33), (4))
            ShareInvestment = Worksheets("Project Data").Cells(4, (6)) / 100
            CostOfUpgradingBuilding = Worksheets("Upgrading Building").Cells((33), (4))
            CostOfUpgradingEnergySystem = Sheets("Upgrading Energysystem").Cells((24), (4))
            AdministrationCosts = Sheets("Operating Costs").Cells((19), (4))
            MaintenanceCosts = Sheets("Operating Costs").Cells((19), (2))
            OperatingCosts = Sheets("Operating Costs").Cells((19), (3))
            ShareOperatingMaintenanceCosts = Sheets("Project Data").Cells((10), (6)) / 100
            InvestmentCost = Investment * ShareInvestment
            Rent = Sheets("Project Data").Cells(9, (2)) / 100

            Costs = (MaintenanceCosts + OperatingCosts) * ShareOperatingMaintenanceCosts + AdministrationCosts
            YearofIncome = Worksheets("VaR").Cells(p, (1)).Value
            Depreciation = (1 + Rent) ^ YearofIncome
            varyear = "=SUM(R[" & s - 183 & "]C:R[" & s - 172 & "]C)/ " & Depreciation & " - " & Costs & ""

            Worksheets("VaR").Cells(p, (q)).Activate
            ActiveCell.FormulaR1C1Local = varyear

            p = p + 1

```

s = s + 11

Wend

Wend

q = q + 1

Wend

TotalVar = "=SUM(R[" & r - 15 & "]C:R[" & y - 15 + r & "]C) - " & InvestmentCost & ""

Worksheets("VaR").Cells((198), (2)).Activate

ActiveCell.FormulaLocal = TotalVar

Worksheets("VaR").Range("B183:B198").Select  
Selection.AutoFill Destination:=Range("B183:IQ198"), Type:=xlFillDefault

Application.Calculation = xlCalculationAutomatic

Dim var As String

Dim t As Integer

Dim TotalVar As String

Dim y As Integer

Application.Calculation = xlCalculationManual

Dim MaintenanceCosts As Double

Dim OperatingCosts As Double

Dim ShareOperatingMaintenanceCosts As Double

Dim AdministrationCosts As Double

Dim CostOfUpgradingEnergySystem As Double

Dim CostOfUpgradingBuilding As Double

Dim Investment As Double

Dim ShareInvestment As Double

Dim Rent As Double

Dim Costs As Double

Dim YeraOfIncome As Integer

Dim Depreciation As Double

Dim InvestmentCost As Double

Dim r As Double

r = Worksheets("Project Data").Cells((3), (4))

p = 381

s = 200

q = 2

y = Worksheets("Project Data").Cells((10), (2)) 'Project\_lenght

While q < 252

While p < 395

While s < 365

CostOfUpgradingBuilding = Worksheets("Upgrading Building").Cells((33), (4))

CostOfUpgradingEnergySystem = Sheets("Upgrading Energysystem").Cells((24), (4))

AdministrationCosts = Sheets("Operating Costs").Cells((19), (4))

MaintenanceCosts = Sheets("Operating Costs").Cells((19), (2))

OperatingCosts = Sheets("Operating Costs").Cells((19), (3))

ShareOperatingMaintenanceCosts = Sheets("Project Data").Cells((10), (6)) / 100

Investment = Worksheets("Upgrading Energysystem").Cells((24), (4)) + Worksheets("Upgrading Building").Cells((33), (4))

ShareInvestment = Worksheets("Project Data").Cells((4), (6)) / 100

Rent = Sheets("Sheet4").Cells((9), (3))

Costs = (MaintenanceCosts + OperatingCosts) \* ShareOperatingMaintenanceCosts + AdministrationCosts

YearofIncome = Worksheets("VaR").Cells((p), (1))

Depreciation = (1 + Rent) ^ YearofIncome

InvestmentCost = Investment \* ShareInvestment

var = "=SUM(R[" & s - 380 & "]C:R[" & s - 371 & "]C) / " & Depreciation & " - " & Costs & ""

Worksheets("VaR").Cells((p), (q)).Activate

ActiveCell.FormulaR1C1Local = var

p = p + 1

s = s + 11

Wend

Wend

q = q + 1

Wend

TotalVar = "=SUM(R[" & r - 15 & "]C:R[" & y - 15 + r & "]C) - " & InvestmentCost & ""

```
Worksheets("VaR").Cells((396), (2)).Activate
ActiveCell.FormulaLocal = TotalVar

Worksheets("VaR").Range("B381:B396").Select
Selection.AutoFill Destination:=Range("B381:IQ396"), Type:=xlFillDefault

Application.Calculation = xlCalculationAutomatic
```

End sub

## THE CASH FLOWS FOR THE VARIOUS PARTIES

Sub CashflowEnergyInvestor()

```
Application.Calculation = xlCalculationManual
Dim CashflowEnergyInvestorcell As Double
Dim E As Integer
Dim w As Integer
Dim o As Integer
Dim BaseLoad As Double
Dim OldEnergyCost As Double
Dim OldEnergyConsumption As Double
Dim ReductionEnergyConsumption As Double
Dim Start_Date As Integer
Dim A As Integer
Dim WF As Double
Dim EnergyPricePeakLoad As Double
Dim PeakLoad As Double
'Dim BaseLoad As Double
Dim EnergyPrice As Double
Dim CashflowEnergyInvestor As Double
```

```
Worksheets("Fuel_costs").Activate
Range("B5:B184").Select
```

```
Selection.ClearContents
For w = 2 To 182
```

```
    If Worksheets("Project Data").Cells((4), (3)) = Worksheets("Simulation price").Cells((w), (253)) And
    Worksheets("Project Data").Cells((3), (3)) = Worksheets("Simulation price").Cells((w), (256)) Then 'this compares the
    dates(months ad years)so that the program is flexible when it comes to start date.
```

```
Start_Date = w
Else
```

End If

```
Next w
```

```
t = Worksheets("Project Data").Cells((10), (2)) 'Project_lenght
'This calculates the saved costs in energyexpenes for the client
```

```
A = 5 'Counts cells in Fuel_Costs
```

```
n = Worksheets("Project Data").Cells((4), (3)) 'This variable takes care the information for which month (number) the project starts, this is a
constant
```

```
o = Worksheets("Project Data").Cells((4), (3)) ' Finds which month the project starts, this will variate
```

```
E = Start_Date 'Counts cells in Simulation where the average price is for all time, starts at the one that maches the start date
```

```
While E < 15 * 12 'byttet ut t med 15
```

```
While o < 15 * 12 + n
```

```
While A < 15 * 12 + 5
```

```
'These are independent of energy carrier chosen and are therefore defined outside the if sentences maching the energy carrier chosen
BaseLoad = Worksheets("Upgrading Energysystem").Cells((100), (1)) 'this gets the value of the base load, the value of the base load is
calculated in a hidden cell A100
```

```
OldEnergyCost = Worksheets("Sheet5").Cells((o), (3))
```

```
OldEnergyConsumption = Worksheets("Sheet5").Cells((o), (2))
```

```
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3))
```

```
'This If sentence gets the right Weight factor.(WF), for the present month, this is because each peak load month has its own weight factor
```

```
If Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((11), (6)) Then
```

```
WF = Worksheets("Upgrading Energysystem").Cells((11), (7))
```

```
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((12), (6)) Then
```

```
WF = Worksheets("Upgrading Energysystem").Cells((12), (7))
```

```
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((13), (6)) Then
```

```
WF = Worksheets("Upgrading Energysystem").Cells((13), (7))
```

```
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((14), (6)) Then
```

```
WF = Worksheets("Upgrading Energysystem").Cells((14), (7))
```

Else: End If

'end

If Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 6 Then 'this is a combination of bio and electricity,  
where bio serves the baseload and electricity the peak load  
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells(E, (255))

'Measures the load, if the load is bigger than the base load the Investment model gets the peak load and vice versa

If OldEnergyConsumption > BaseLoad Then

EnergyPricePeakLoad = Worksheets("Simulation price").Cells(E, (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This  
adds the cost of nettleie if electricity is chosen

PeakLoad = OldEnergyConsumption - BaseLoad

'calculations of the cahsflow when OldEnergyConsumption > Baseload and the peak load is used

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100  
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6))  
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPriceBaseLoad \* BaseLoad) + (WF \* EnergyPricePeakLoad \* PeakLoad) + ((1 -  
WF) \* (EnergyPriceBaseLoad \* PeakLoad))) \* (1 - ReductionEnergyConsumption)) \* (ShareOfIncomeEnergyInvestor / 100)  
Worksheets("Fuel\_costs").Cells(A, (2)).Value = CashflowEnergyInvestorcell

Else

PeakLoad = 0  
EnergyPricePeakLoad = 0  
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100  
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6))  
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPriceBaseLoad \* OldEnergyConsumption) \* (1 - ReductionEnergyConsumption)))  
\* (ShareOfIncomeEnergyInvestor / 100)  
Worksheets("Fuel\_costs").Cells(A, (2)).Value = CashflowEnergyInvestorcell

End If

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 7 Then 'oil and el, here oil is peak load electricity is base  
load  
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells(E, (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This  
adds the cost of nettleie if electricity is chosen

If OldEnergyConsumption > BaseLoad Then

EnergyPricePeakLoad = Worksheets("Simulation price").Cells(E, (255)) 'needs to be oil nytt ark og bare kopiere inn den ene raden  
PeakLoad = OldEnergyConsumption - BaseLoad

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100  
ShareOfIncomeEnergyInvestor = Worksheets("Sheet4").Cells((7), (6))  
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPriceBaseLoad \* BaseLoad) + (WF \* EnergyPricePeakLoad \* PeakLoad) + ((1 -  
WF) \* (EnergyPriceBaseLoad \* PeakLoad))) \* (1 - ReductionEnergyConsumption)) \* (ShareOfIncomeEnergyInvestor / 100)  
Worksheets("Fuel\_costs").Cells(A, (2)).Value = CashflowEnergyInvestorcell

Else

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100  
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6))  
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPriceBaseLoad \* OldEnergyConsumption) \* (1 - ReductionEnergyConsumption)))  
\* (ShareOfIncomeEnergyInvestor / 100)  
Worksheets("Fuel\_costs").Cells(A, (2)).Value = CashflowEnergyInvestorcell

End If

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 8 Then  
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells(E, (255)) 'must be pellet

If OldEnergyConsumption > BaseLoad Then

EnergyPricePeakLoad = Worksheets("Simulation price").Cells(E, (254)) 'must be oil

PeakLoad = OldEnergyConsumption - BaseLoad

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100  
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6))  
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPriceBaseLoad \* BaseLoad) + (WF \* EnergyPricePeakLoad \* PeakLoad) + ((1 -  
WF) \* (EnergyPriceBaseLoad \* PeakLoad))) \* (1 - ReductionEnergyConsumption)) \* (ShareOfIncomeEnergyInvestor / 100)  
Worksheets("Fuel\_costs").Cells(A, (2)).Value = CashflowEnergyInvestorcell

```

Else
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6))
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption)))
* (ShareOfIncomeEnergyInvestor / 100)
Worksheets("Fuel_costs").Cells((A), (2)).Value = CashflowEnergyInvestorcell

End If

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 3 Then
'This adds the cost of nettleie if electricity is chosen

EnergyPrice = Worksheets("Simulation price").Cells((E), (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2))

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6))
CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPrice * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeEnergyInvestor / 100)
Worksheets("Fuel_costs").Cells((A), (2)).Value = CashflowEnergyInvestorcell

Else
EnergyPrice = Worksheets("Simulation price").Cells((E), (254))

ShareOfIncomeEnergyInvestor = Worksheets("Project Data").Cells((7), (6)) / 100

CashflowEnergyInvestorcell = (OldEnergyCost - ((EnergyPrice * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
ShareOfIncomeEnergyInvestor
Worksheets("Fuel_costs").Cells((A), (2)) = CashflowEnergyInvestorcell

End If

A = A + 1

o = o + 1
E = E + 1

Wend
Wend
Wend
For d = 12 * t + 5 To 185 'this hides all the income that is not relevant
Cells((d), (2)).Font.ColorIndex = 35
Next d
Application.Calculation = xlCalculationAutomatic
End Sub

Sub CashflowClient()

Application.Calculation = xlCalculationManual
Dim BaseLoad As Double
Dim OldEnergyCost As Double
Dim OldEnergyConsumption As Double
Dim EnergyPriceBaseLoad As Double
Dim EnergyPricePeakLoad As Double
Dim PeakLoad As Double
'Dim BaseLoad As Double
'Dim EnergyPricePeakLoad As String
'Dim ShareOfIncomeClient As String
'Dim CashflowClientcell As String
'Dim WF As Object
'Dim RedductionEnergyConsumption As Double
Range("D5:D184").Select
Selection.ClearContents

For w = 2 To 182

If Worksheets("Project Data").Cells((4), (3)) = Worksheets("Simulation price").Cells((w), (253)) And
Worksheets("Project Data").Cells((3), (3)) = Worksheets("Simulation price").Cells((w), (256)) Then 'this compares the
months(months ad years)so that the program is flexible when it comes to start date.
Start_Date = w

```

```

Else
End If
Next w
t = Worksheets("Project Data").Cells((10), (2)) 'Project_lenght
'This calculates the saved costs in energyexperiences for the client
A = 5 'Counts cells in Fuel_Costs
n = Worksheets("Project Data").Cells((4), (3)) 'This variable takes care the information for which month (number) the project starts, this is a
constant
o = Worksheets("Project Data").Cells((4), (3)) ' Finds which month the project starts, this will variate
E = Start_Date 'Counts cells in Simulation where the average price is for all time, starts at the one that maches the start date
While E < 15 * 12 'byttet ut t med 15
While o < 15 * 12 + n
While A < 15 * 12 + 5

'These are independent of energy carrier chosen and are therefore defined outside the if sentences maching the energy carrier chosen
BaseLoad = Worksheets("Upgrading Energysystem").Cells((100), (1)) 'this gets the value of the base load, the value of the base load is
calculated in a hidden cell A100
OldEnergyCost = Worksheets("Sheet5").Cells((o), (3))
OldEnergyConsumption = Worksheets("Sheet5").Cells((o), (2))

'This If sentence gets the right Weight factor,(WF), for the present month, this is because each peak load month has its own weight factor
If Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((11), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((11), (7))
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((12), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((12), (7))
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((13), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((13), (7))
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((14), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((14), (7))
Else: End If
'end

If Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 6 Then 'this is a combination of bio and electricity, where bio serves the
baseload and electricity the peak load
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells((E), (255))

'Measures the load, if the load is bigger than the base load the Investment model gets the peak load and vise versa

If OldEnergyConsumption > BaseLoad Then

EnergyPricePeakLoad = Worksheets("Simulation price").Cells((E), (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This
adds the cost of nettleie if electricity is chosen

PeakLoad = OldEnergyConsumption - BaseLoad

'calculations of the cahsflow when OldEnergyConsumption > Baseload and the peak load is used

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = ((OldEnergyCost - (EnergyPriceBaseLoad * BaseLoad + (WF * (EnergyPricePeakLoad * PeakLoad)) + ((1 - WF) *
(EnergyPriceBaseLoad * PeakLoad))) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeClient / 100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

Else

PeakLoad = 0
EnergyPricePeakLoad = 0
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeClient / 100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

End If

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 7 Then 'oil and el, here oil is peak load electricity is base load
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells((E), (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This
adds the cost of nettleie if electricity is chosen

If OldEnergyConsumption > BaseLoad Then
EnergyPricePeakLoad = Worksheets("Simulation price").Cells((E), (255)) 'needs to be oil
PeakLoad = OldEnergyConsumption - BaseLoad

```



```

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = ((OldEnergyCost - (EnergyPriceBaseLoad * BaseLoad + (WF * (EnergyPricePeakLoad * PeakLoad)) + ((1 - WF) *
(EnergyPriceBaseLoad * PeakLoad))) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeClient / 100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

Else
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeClient / 100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

End If

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 8 Then
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells((E), (255)) 'must be pellet

If OldEnergyConsumption > BaseLoad Then
EnergyPricePeakLoad = Worksheets("Simulation price").Cells((E), (254)) 'must be oil

PeakLoad = OldEnergyConsumption - BaseLoad

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = ((OldEnergyCost - (EnergyPriceBaseLoad * BaseLoad + (WF * (EnergyPricePeakLoad * PeakLoad)) + ((1 - WF) *
(EnergyPriceBaseLoad * PeakLoad))) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeClient / 100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

Else
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeClient / 100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

End If

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 3 Then
'This adds the cost of nettleie if electricity is chosen

EnergyPrice = Worksheets("Simulation price").Cells((E), (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2))

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = (OldEnergyCost - ((EnergyPrice * OldEnergyCost) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeClient /
100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

Else
EnergyPrice = Worksheets("Simulation price").Cells((E), (254))
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeClient = Worksheets("Project Data").Cells((7), (5))
CashflowClientcell = (OldEnergyCost - ((EnergyPrice * OldEnergyCost) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeClient /
100)
Worksheets("Fuel_costs").Cells((A), (4)).Value = CashflowClientcell

End If

A = A + 1

o = o + 1
E = E + 1

Wend
Wend
Wend
For d = 12 * t + 5 To 185 'this hides all the income that is not relevant
Cells((d), (4)).Font.ColorIndex = 35

```

```

Next d
Application.Calculation = xlCalculationAutomatic
End Sub

Sub CashflowThirdParty()

Application.Calculation = xlCalculationManual
Range("F5:F184").Select
Selection.ClearContents
For w = 2 To 182

If Worksheets("Project Data").Cells((4), (3)) = Worksheets("Simulation price").Cells((w), (253)) And Worksheets("Project Data").Cells((3), (3)) = Worksheets("Simulation price").Cells((w), (256)) Then 'this compares the dates(months ad years)so that the program is flexible when it comes to start date.
Start_Date = w
Else
End If
Next w
t = Worksheets("Project Data").Cells((10), (2)) 'Project_lenght
'This calculates the saved costs in energypences for the client
A = 5 'Counts cells in Fuel_Costs
n = Worksheets("Project Data").Cells((4), (3)) 'This variable takes care the information for which month (number) the project starts, this is a constant
o = Worksheets("Project Data").Cells((4), (3)) ' Finds which month the project starts, this will variate
E = Start_Date 'Counts cells in Simulation where the average price is for all time, starts at the one that maches the start date
While E < 15 * 12 'byttet ut t med 15
While o < 15 * 12 + n
While A < 15 * 12 + 5

'These are independent of energy carrier chosen and are therefore defined outside the if sentences maching the energy carrier chosen
BaseLoad = Worksheets("Upgrading Energysystem").Cells((100), (1)) 'this gets the value of the base load, the value of the base load is calculated in a hidden cell A100
OldEnergyCost = Worksheets("Sheet5").Cells((o), (3))
OldEnergyConsumption = Worksheets("Sheet5").Cells((o), (2))

'This If sentence gets the right Weight factor,(WF), for the present month, this is because each peak load month has its own weight factor
If Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((11), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((11), (7))
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((12), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((12), (7))
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((13), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((13), (7))
ElseIf Worksheets("Simulation price").Cells((E), (253)) = Worksheets("Upgrading Energysystem").Cells((14), (6)) Then
Set WF = Worksheets("Upgrading Energysystem").Cells((14), (7))
Else: End If
'end

If Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 6 Then 'this is a combination of bio and electricity, where bio serves the baseload and electricity the peak load
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells((E), (255))

'Measures the load, if the load is bigger than the base load the Investment model gets the peak load and vise versa

If OldEnergyConsumption > BaseLoad Then

EnergyPricePeakLoad = Worksheets("Simulation price").Cells((E), (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This adds the cost of nettleie if electricity is chosen

PeakLoad = OldEnergyConsumption - BaseLoad

'calculations of the cahsflow when OldEnergyConsumption > Baseload and the peak load is used

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells((7), (7))
CashflowThirdPartycell = ((OldEnergyCost - (EnergyPriceBaseLoad * BaseLoad + (WF * (EnergyPricePeakLoad * PeakLoad)) + ((1 - WF) * (EnergyPriceBaseLoad * PeakLoad)))) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells((A), (6)).Value = CashflowThirdPartycell

Else

PeakLoad = 0
EnergyPricePeakLoad = 0
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100

```

```

ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

End If

```

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 7 Then 'oil and el, here oil is peak load electricity is base load
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells(E, (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2)) 'This
adds the cost of nettleie if electricity is chosen

```

```

If OldEnergyConsumption > BaseLoad Then
EnergyPricePeakLoad = Worksheets("Simulation price").Cells(E, (255)) 'needs to be oil nytt ark og bare kopiere inn den ene raden
PeakLoad = OldEnergyConsumption - BaseLoad

```

```

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = ((OldEnergyCost - (EnergyPriceBaseLoad * BaseLoad + (WF * (EnergyPricePeakLoad * PeakLoad)) + ((1 - WF)
* (EnergyPriceBaseLoad * PeakLoad)))) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

Else

```

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

End If

```

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 8 Then
EnergyPriceBaseLoad = Worksheets("Simulation price").Cells(E, (255)) 'must be pellet

```

```

If OldEnergyConsumption > BaseLoad Then
EnergyPricePeakLoad = Worksheets("Simulation price").Cells(E, (254)) 'must be oil

```

```

PeakLoad = OldEnergyConsumption - BaseLoad

```

```

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = ((OldEnergyCost - (EnergyPriceBaseLoad * BaseLoad + (WF * (EnergyPricePeakLoad * PeakLoad)) + ((1 - WF)
* (EnergyPriceBaseLoad * PeakLoad)))) * (1 - ReductionEnergyConsumption))) * (ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

Else

```

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = (OldEnergyCost - ((EnergyPriceBaseLoad * OldEnergyConsumption) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

End If

```

ElseIf Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 3 Then
'This adds the cost of nettleie if electricity is chosen

```

```

EnergyPrice = Worksheets("Simulation price").Cells(E, (254)) + Worksheets("Upgrading Energysystem").Cells((6), (2))

```

```

ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = (OldEnergyCost - ((EnergyPrice * OldEnergyCost) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

Else

```

EnergyPrice = Worksheets("Simulation price").Cells(E, (254))
ReductionEnergyConsumption = Worksheets("Upgrading Energysystem").Cells((40), (3)) 'Percentage/100
ShareOfIncomeThirdParty = Worksheets("Project Data").Cells(7, (7))
CashflowThirdPartycell = (OldEnergyCost - ((EnergyPrice * OldEnergyCost) * (1 - ReductionEnergyConsumption))) *
(ShareOfIncomeThirdParty / 100)
Worksheets("Fuel_costs").Cells(A, (6)).Value = CashflowThirdPartycell

```

```

End If

A = A + 1

o = o + 1
E = E + 1

Wend
Wend
Wend
For d = 12 * t + 5 To 185 'this hides all the income that is not relevant
Cells(d, (6)).Font.ColorIndex = 35
Next d

Application.Calculation = xlCalculationAutomatic

End Sub

,

'*****
'Simulates the project with the necessary macros by calling them, this is the one without change in
'energy carrier or date, just in share, contract type or costs (all though not all the macros are shown above
'*****
Sub SimulationOne()

Application.ScreenUpdating = False

Call BlackFont

Call ShowSheets
Call DeleteChart
If Worksheets("Project Data").Cells((7), (8)).Value <> 100 And Worksheets("Project Data").Cells((4), (8)).Value <> 100 And
Worksheets("Project Data").Cells((10), (7)).Value <> 100 Then
    MsgBox "Total share of income must add up to 100 %.(Chr(13))Total share of costs for investment must add up to 100 %.(Chr(13))Total
share of maintenance must add up to 100 %,change the values and try again"
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells((4), (8)).Value <> 100 And Worksheets("Project Data").Cells((10), (7)).Value <> 100 Then
    MsgBox "Total share of costs for investment must add up to 100 %.Total share of maintenance must add up to 100 %, change the values
and try again."
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells((10), (7)).Value <> 100 And Worksheets("Project Data").Cells((7), (8)).Value <> 100 Then
    MsgBox "Total share of maintenance must add up to 100 %.Total share of income must add up to 100 %, change the values and try
again."
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells((7), (8)).Value <> 100 And Worksheets("Project Data").Cells((4), (8)).Value <> 100 Then
    MsgBox "Total share of income must add up to 100 %.Total share of costs for investment must add up to 100%, change the values and try
again.."
    Worksheets("Sheet4").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells((7), (8)).Value <> 100 Then
    MsgBox "Total share of income must add up to 100 %, change the values and try again."
    Worksheets("Project Data").Select
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells((4), (8)).Value <> 100 Then
    MsgBox "Total share of costs for investment must add up to 100 %, change the values and try again."
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells((10), (7)).Value <> 100 Then
    MsgBox "Total share of maintenance must add up to 100 %, change the values and try again."
    Worksheets("Project Data").Select
    GoTo E
Else
End If

Call Other
Call TypeContracting
Call TypeEnergyCarrier

```

```

If Worksheets("Project Data").Cells(8, (3)).Value = 1 Then

    Call DeleteChartGS
    Call ShareGS
    'sjekk den gj: den neste linjen likevel.. ikke bra. legge inn stopp her om mulig
    Worksheets("Project Data").Cells(4, (5)) = 100 ' guarantees that it is the client that pays the investment costs
    Worksheets("Project Data").Cells(4, (6)) = 0
    Worksheets("Project Data").Cells(4, (7)) = 0

    Call UpdatingFormulasGS
    Call NPVGuaranteedSavings
    Call GraphGuaranteedSavings
    Call HideSheetsGS
ElseIf Worksheets("Project Data").Cells(8, (3)).Value = 2 Then
    'Worksheets("NPVSharedSavings").Select
    Call DeleteChartSS
    Call UpdatingFormulasSS
    Call NPVSharedSavings
    Call GraphSharedSavings
    Call HideSheetsSS
ElseIf Worksheets("Project Data").Cells(8, (3)).Value = 3 Then
    Worksheets("NPVEnergyServiceContract").Select
    Call DeleteChartESC
    Call ShareESC
If Worksheets("Project Data").Cells(8, (3)).Value = 3 And Worksheets("Project Data").Cells(7, (5)).Value > 0 Then
    GoTo E 'Lagt inn et stopp i simulering helt til dette er fikset
    Else
    End If
    Call UpdatingFormulasESC
    Call NPVEnergyServiceContract
    Call GraphEnergyServiceContract
    Call HideSheetsESC
Else
'Call UpdatingFormulasL
'Call NPVLeasing
'Call HideSheetsL
End If
Worksheets("Fuel_costs").Select
Call CashflowEnergyInvestor
Call CashflowClient
Call CashflowThirdParty
Call GraphCashflow
Call Environmental_graph
E:

End Sub
*****
'Simulates the project and calls the necessary functions, this is the one with change in date or price
'then simulation of price for energy carrier needs to be done
*****
Sub SimulationTwo()

Application.ScreenUpdating = False

Call BlackFont
Call ClearContentsSimulationprice 'Deletes old values, that the new prices can be collected

Call ShowSheets
Call DeleteChart

'Maa og progge inn her at alle charts skal delites fra der med kontraktstype.
'Call TotShare
'Sub TotShare()

If Worksheets("Project Data").Cells(7, (8)).Value <> 100 And Worksheets("Project Data").Cells(4, (8)).Value <> 100 And
Worksheets("Project Data").Cells(10, (7)).Value <> 100 Then
    MsgBox "Total share of income must add up to 100 %.(Chr(13))Total share of costs for investment must add up to 100 %.(Chr(13))Total
share of maintenance must add up to 100 %"
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells(4, (8)).Value <> 100 And Worksheets("Project Data").Cells(10, (7)).Value <> 100 Then
    MsgBox "Total share of costs for investment must add up to 100 %.Total share of maintenance must add up to 100 %."
    Worksheets("Project Data").Select
    GoTo E
ElseIf Worksheets("Project Data").Cells(10, (7)).Value <> 100 And Worksheets("Project Data").Cells(7, (8)).Value <> 100 Then
    MsgBox "Total share of maintenance must add up to 100 %.Total share of income must add up to 100 %."

```

```

Worksheets("Project Data").Select
GoTo E
ElseIf Worksheets("Project Data").Cells(7, (8)).Value <> 100 And Worksheets("Project Data").Cells(4, (8)).Value <> 100 Then
    MsgBox "Total share of income must add up to 100 %.Total share of costs for investment must add up to 100 %."
Worksheets("Project Data").Select
GoTo E
ElseIf Worksheets("Project Data").Cells(7, (8)).Value <> 100 Then
    MsgBox "Total share of income must add up to 100 %"
Worksheets("Project Data").Select
GoTo E
ElseIf Worksheets("Project Data").Cells(4, (8)).Value <> 100 Then
    MsgBox "Total share of costs for investment must add up to 100 %"
Worksheets("Project Data").Select
GoTo E
ElseIf Worksheets("Project Data").Cells(10, (7)).Value <> 100 Then
    MsgBox "Total share of maintenance must add up to 100 %"
Worksheets("Project Data").Select
GoTo E
Else
End If

Call Other
Call ClearContentsSimulationprice "Deletes old values, that the new prices can be collected
Set EnergyCarrier = Worksheets("Upgrading Energysystem").Cells(5, (2))

If EnergyCarrier = "Oil" Then

    Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 1 'oil
'Finds the current path
Name = ActiveWorkbook.Path
'Opens Oil price simulations file
Workbooks.Open Filename:=Name & "\Oil_Montecarlo1", UpdateLinks:=True
Worksheets("priceOil").Activate

'Gets correlation coeffecients

'Opens EL price simulations file
Workbooks.Open Filename:=Name & "\ELmontecarlosmonth", UpdateLinks:=True
Worksheets("priceel").Activate
Worksheets("priceel").Range("D5:D185").Select
Selection.Copy

    Windows("Oil_Montecarlo1").Activate
Worksheets("priceOil").Range("B5:B185").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
Windows("ELmontecarlosmonth").Activate
Worksheets("priceel").Range("O5:O185").Select
Selection.Copy
Windows("Oil_Montecarlo1.xls").Activate
Worksheets("priceOil").Range("E5:E185").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
'closes the el-workbook
Application.DisplayAlerts = False
Workbooks("ELmontecarlosmonth.xls").Close
Application.DisplayAlerts = True

Call simulating_heatingoil
Worksheets("SimulationOil").Activate
Cells.Select
    Selection.Copy
Windows("InvestmentModel.xls").Activate
Worksheets("Simulation price").Select
Cells.Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
    Range("B2:IQ395").Select

    Selection.NumberFormat = "0.0000"
'closes the workbook
Application.DisplayAlerts = False

```

```

Workbooks("Oil_Montecarlo1.xls").Close
Application.DisplayAlerts = True

    ElseIf EnergyCarrier = "Gas" Then

        Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 2 'gas
'Finds the current path
Name = ActiveWorkbook.Path
'Opens Gas price simulations file
Workbooks.Open Filename:=Name & "\GAS_Montecarlo", UpdateLinks:=True
Worksheets("priceGas").Activate
'Opens Oil price simulations file
Workbooks.Open Filename:=Name & "\Oil_Montecarlo1", UpdateLinks:=True
Worksheets("priceOil").Activate
Worksheets("priceOil").Range("C5:C185").Select
Selection.Copy
Windows("GAS_Montecarlo.xls").Activate
Worksheets("priceGas").Range("G5:G185").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
Application.DisplayAlerts = False

Workbooks("Oil_Montecarlo1.xls").Close
Application.DisplayAlerts = True

'Opens El price simulations file
Workbooks.Open Filename:=Name & "\ELmontecarlosmonth", UpdateLinks:=True
Worksheets("priceel").Activate
Worksheets("priceel").Range("D5:D185").Select
Selection.Copy

    Windows("GAS_Montecarlo.xls").Activate
Worksheets("priceGas").Range("B5:B185").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
Windows("ELmontecarlosmonth.xls").Activate
Worksheets("priceel").Range("O5:O185").Select
Selection.Copy
Windows("GAS_Montecarlo.xls").Activate
Worksheets("priceGas").Range("D5:D185").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
'closes the elworkbook
Application.DisplayAlerts = False
Workbooks("ELmontecarlosmonth.xls").Close
Application.DisplayAlerts = True

Call simulating_gas
Worksheets("SimulationGas").Activate
Cells.Select
    Selection.Copy
Windows("InvestmentModel.xls").Activate
Worksheets("Simulation price").Select
Cells.Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
Range("B2:IQ395").Select

    Selection.NumberFormat = "0.0000"

'closes the workbook

Application.DisplayAlerts = False

Workbooks("GAS_Montecarlo.xls").Close
Application.DisplayAlerts = True

    ElseIf EnergyCarrier = "Electricity" Then
        Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 3 'el

'Finds the current path
Name = ActiveWorkbook.Path
'Opens El price simulations file

```

```

Workbooks.Open Filename:=Name & "\ELmontecarlosmonth", UpdateLinks:=True
Worksheets("priceel").Activate

Call simulation_elmonth
Worksheets("Simulationel").Activate
Cells.Select
    Selection.Copy
Windows("InvestmentModel.xls").Activate
Worksheets("Simulation price").Select
Cells.Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone, SkipBlanks _
:=False, Transpose:=False
    Range("B2:IQ395").Select

    Selection.NumberFormat = "0.0000"
'closes the workbook
Application.DisplayAlerts = False
Workbooks("ELmontecarlosmonth.xls").Close
Application.DisplayAlerts = True

ElseIf EnergyCarrier = "Pellet" Then
Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 4 'pellet
    ElseIf EnergyCarrier = "Pellet/Electricity" Then
Worksheets("Project Data").Cells((6), (3)).Value = 6 'pellet/el
Call CalculateDataPellet_Electricity
ElseIf EnergyCarrier = "Other" Then
Worksheets("Project Data").Cells((6), (3)).Value = 5 'other
Call ImportDataOther
End If
    Call TypeContracting

If Worksheets("Project Data").Cells((8), (3)).Value = 1 Then

    Call DeleteChartGS
    Call ShareGS
'sjekk den gj:r den neste linjen likevel.. ikke bra. legge inn stopp her om mulig
Worksheets("Project Data").Cells((4), (5)) = 100 ' guarantees that it is the client that pays the investment costs
Worksheets("Project Data").Cells((4), (6)) = 0
Worksheets("Project Data").Cells((4), (7)) = 0

    Call UpdatingFormulasGS
    Call NPVGuaranteedSavings
    Call GraphGuaranteedSavings
    Call HideSheetsGS
ElseIf Worksheets("Project Data").Cells((8), (3)).Value = 2 Then
    Worksheets("NPVSharedSavings").Select
    Call DeleteChartSS
    Call UpdatingFormulasSS
    Call NPVSharedSavings
    Call GraphSharedSavings
    Call HideSheetsSS
ElseIf Worksheets("Project Data").Cells((8), (3)).Value = 3 Then
    Worksheets("NPVEnergyServiceContract").Select
    Call DeleteChartESC
    Call ShareESC
If Worksheets("Project Data").Cells((8), (3)).Value = 3 And Worksheets("Project Data").Cells((7), (5)).Value > 0 Then
    GoTo E 'Lagt inn et stopp i simulering helt til dette er fikset
Else
    End If
    Call UpdatingFormulasESC
    Call NPVEnergyServiceContract
    Call GraphEnergyServiceContract
    Call HideSheetsESC
Else

End If
Worksheets("Fuel_costs").Select
Call CashflowEnergyInvestor
Call CashflowClient
Call CashflowThirdParty
Call GraphCashflow
Call Environmental_graph
E:

```



```

End Sub
'Creates the graph for the value at risk by calling the below sub macros
Sub ValueAtRisk()
Application.ScreenUpdating = False
If Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 4 Or Worksheets("Upgrading Energysystem").Cells((6), (3)).Value = 5
Then
MsgBox " Value at risk can only be caculated for electricity, gas and heating oil."
GoTo B
Else
Call Varfirst250
Call VARsecond250
Call VARYearFirst250NPV
Call VARYearSecond250NPV
Call graph_Var
End If
Worksheets("Distribution_of_NPV").Select
B:
End Sub

```

#### CALCULATION OF PEAK LOAD/BASE LOAD

\*\*\*\*\*

'This macro calculates the distribution between the Base load and Peak load for all  
'time periods

\*\*\*\*\*

```

Sub BaseLoad_PeakLoad()

```

```

    Dim MaxEnergyConsumption As Integer ' Takes care of the maximum load demand by the user
    Dim PercentBaseLoad As Integer 'Dimension of the base load

```

```

    If Worksheets("Upgrading Energysystem").Cells((19), (6)).Value = 1 Then
        MsgBox "The base load and Peak load must add up to 100%." 'Checks the inputs for the base load and peak load
    
```

```

Else
End If
MaxEnergyConsumption = Worksheets("Current Situation").Cells((15), (6))
PercentBaseLoad = Worksheets("Upgrading Energysystem").Cells((17), (6)) / 100
BaseLoad = PercentBaseLoad * MaxEnergyconsumption
End Sub

```

```

Sub UpdatingFormulasGS()

```

```

    Worksheets("NPVGuaranteedSavings").Select
    Worksheets("NPVGuaranteedSavings").Range("G22:G36").Select
    Selection.Copy
    Worksheets("NPVGuaranteedSavings").Range("G6:G20").Select
    Selection.PasteSpecial Paste:=xlPasteFormulas, Operation:=xlNone, SkipBlanks _
        :=False, Transpose:=False

```

```

End Sub

```