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Hedging Strategies and the Economic Effects of Price Spikes in the Electricity Market

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ABSTRACT

This thesis concerns the newly deregulated Swedish electricity market. More specifically it concerns the large sudden increases in the spot price of electricity, i.e. price spikes, and what can be done in order to minimise the risk associated with price spikes by the use of hedging strategies. We have focused on smaller electricity trading companies. Our research questions are formulated below.

- Which of our constructed hedging strategies will be the most advantageous to use in terms of reducing the risk associated with price spikes and at the same time produce the best total result over the year?

- What are the most critical issues that will improve the performance of a smaller electricity trading company's hedging strategy?

Our results reveal that the strategy consisting of more precise hedging instruments is the most appropriate in terms of reducing the negative economic effects of price spikes. We also show that there is a need for electricity trading companies to put more emphasis on implementing a broader risk management strategy. Our research shows that the option strategy was successful and we recommend electricity traders to consider options as a tool in their hedging strategy.

KEYWORDS
Electricity hedging, Nordpool, risk management, electricity trading

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Gothenburg, January 7, 2002

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1. INTRODUCTION

This thesis deals with issues concerning the electricity market and hedging. More specifically it examines the phenomenon of price spikes and how small electricity trading companies can hedge themselves in order to minimise the risks associated with price spikes. It also examines if there is room for improvement of the hedging strategies that are used today. Finally, it presents our conclusion based on our analysis.

1.1 Background

January 1, 1996, the Swedish electricity market became deregulated and the production capacity was rationalised, meaning that unprofitable power stations were closed down. The purpose of the deregulation was to start a process of change towards increased competition and increased efficiency in the production and among the retailers, and also to give the consumer an opportunity to choose his/her electricity retailer (Lindblom, 1997). The deregulation meant that the production of electricity and the distribution/sales to customers were separated into two different legal entities. Production and distribution/sales will be on a competitive market, while the grid companies will be regulated and supervised in order to assure an efficient grid system (SOU, 1995:14).

Before the deregulation the cost for holding a reserve capacity in case of a sudden increase in demand were covered through a higher electricity price for the consumers. The consequence of the rationalisation is that there arose a greater risk for shortage of electricity, i.e. the capacity for electricity production would not be able to cover the total demand at times of peak load. The trend today is that the Swedish electricity consumption is increasing while the electricity production continues to decrease (Hammarstedt et al., 2001).

January 24, 2000, Svenska Kraftnät gave out warnings that there would be a lack of electricity capacity due to the fact that their calculations implied that there would not be enough electricity production capacity for Sweden's electricity consumption. This resulted in a skyrocketing electricity price, i.e. a price spike, to an extreme high from 10 öre per kWh to SEK 4 per kWh. This price increase wiped out several electricity trading companies yearly profit in a few hours (Energimagasinet 1, 2000).

1.2 Problem Discussion

The electricity trading companies in Sweden have two types of contracts with their customers. The electricity contract price is either fixed or floating during the specified time period (Svensk Elmarknadshandbok, 2001). The fixed contractual agreement makes the electricity trading companies vulnerable to the risk that the price will fluctuate, which could result in substantial losses for the companies. The situation today is that the electricity trading companies are usually facing the price risk, not the customers that have agreed to a fixed price electricity contract.

The research problem in our thesis stems from the fluctuation in the price of electricity. The problem is known as *electricity price spikes*, i.e. an unusually steep upward slope in the price curve, or in other words a large sudden increase in the price of electricity. This increase is mostly due to extreme weather conditions, such as unexpectedly cold weather. This sudden shift in the temperature will increase the demand and decrease the supply of electricity, thus pushing the price to a higher level (Case, 1999). The fact that it is very hard or perhaps impossible to forecast how the weather will develop in the future, or more specifically predicting the weather accurately before the market does, makes the problem of price spikes even harder to solve. Another factor that contributes to the enlargement of the problem is that the electricity market, unlike any other market, functions so that the consumer decides how much electricity to consume without specifying the usage in advance. The consumer does not have to pay more for the usage per kilowatt hour if the supply is scarce or in abundance (because of fixed price contracts), the consumer just turns the switch on in his home.

The phenomenon of price spikes became more of a concern for the participants in the electricity field after the deregulation in 1996. The deregulation contributed to a larger exposure of the price risk especially for electricity trading companies, since they have contracts with their customers to deliver electricity to a fixed price during a certain agreed time period (Jednell, 2001-09-11). The fixed price contractual agreement makes the electricity trading companies vulnerable to increases in the price of electricity since they need to buy the electricity from the supplier and then perhaps sell it to a lower price than they bought it for, thus making a loss. The electricity trading companies have a balance obligation, i.e. they have an obligation to deliver the electricity at the set price according to the terms in the contract (www.nordpool.com 2001-09-25). This responsibility implies that the electricity trading companies will be exposed to a greater amount of price risk. In order to get a better understanding of the problem it is worthwhile to briefly explain the overhanging problem that spawn price spikes. This involves the sensitive balance between supply and demand. The problem arises from peak load capacity, or very high levels of electricity consumption. There are in fact certain occasions when the peak load exceeds the limit for what is defined as available generation (Saele et al., 2001). The shortage of supply and the excess demand is a serious problem, generating an upward price fluctuation that eventually evolves into a large sudden increase in the price of electricity, i.e. price spike. The trend today is that the demand is increasing whereas the supply of electricity is decreasing. One reason for the decrease in supply is the fact that electricity producers do not find it profitable to run certain power stations and therefore let them stand inactive. Another reason is that nuclear power is being reduced, for instance the nuclear power station Barsebäck has already closed down one of its two reactors. The demand for electricity grows more and more (www.nordpool.com 2001-09-25). The main reason for this is the evolution in technology especially in the hi-tech industry, more people use the Internet and products that require electricity. Today several studies and proposals have been presented to find a solution to secure peak load capacity. Svenska Kraftnät together with Svensk Energi have arranged a three year plan to buy power (inactive power stations) in order to secure the capacity in times of peak load. This solution is only temporary and the hope is that there will eventually be a free market solution, i.e. a solution without government interference.

How serious the problem of price spikes is for the electricity trading company can easily be explained by the fact that a killer price spike could, in a few hours, wipe out a year's worth of profits (Energimagasinet 1, 2000). The price spike phenomenon is clearly an issue of great concern and a phenomenon that needs to be taken seriously. Electricity trading companies use different methods to hedge themselves against the price risk, and other risks. With the trend today of increased consumption and decreased production, it is of great importance that the electricity trading companies put a lot of time and effort into protecting themselves against the risks by implementing a broader financial risk management strategy (Kollberg & Elf, 1998). The electricity trading companies use financial contracts known as derivatives both on the Nordpool and on the bilateral OTC-market. The most commonly used contracts in Sweden are forwards and futures. Option contracts are also used but the option market is not as liquid. The contracts being used are obviously not for free and will be more expensive the closer one gets to the delivery period of the contract, therefore it could be too costly to hedge in order to cover possible losses in the future due to price spikes. This implies that it is critical to be correctly hedged, before the price is reflected in the financial derivatives. A critical issue for the electricity trading companies is to construct a well functioning hedging strategy. This is a difficult task since the price of a financial contract on the electricity exchange is highly sensitive to the volatile spot price of electricity. To find a hedging strategy that minimizes the risk of the negative economic effect of high electricity spot prices, and at the same time locks in an electricity price that does not exceed the actual spot price in the market, is one of the most difficult tasks, if not the most difficult task for an electricity trading company. Based on these issues, it would be interesting to investigate what kind of financial contracts can be combined into a hedging strategy which will protect the electricity trading company against the negative economic effects of price spikes.

1.3 Problem and Purpose

In order to research the phenomenon with price spikes we will try to construct hedging strategies by the use of the existing contracts on Nordpool, which will minimize the risks associated with price spikes. We will focus our research on a small fictitious electricity trading company, since smaller companies usually do not have their own production and will therefore be more vulnerable to large increases in the spot price. This can be evidenced by the fact that a couple of them have experienced substantial losses, such as Norigo and Borås Energi (ERA, 2001-02-28).

Our purpose is to solve the research questions stated below, which are formulated on the basis of the problem discussion. It concerns the matter of how to construct the most appropriate hedging strategy in order to reduce the negative economic effects due to price spikes and the possibility of improvements in risk management of electricity trading companies.

- Which of our constructed hedging strategies will be the most advantageous to use in terms of reducing the risk associated with price spikes and at the same time produce the best total result over the year?

- What are the most critical issues that will improve the performance of a smaller electricity trading company's hedging strategy?

1.4 Contribution

Our thesis will highlight the effect and the necessity of implementing a broader risk management strategy for companies within the electricity trading field. Much work has been done in the theoretical field of hedging and risk management, but not as regards different hedging scenarios for a smaller electricity trading company to shed light on the effects the price spikes can have and how these effects can be reduced through a well functioning hedging strategy. Another possible contribution is that our thesis will stimulate other authors to make further studies in order to investigate what type of combination of financial instruments that will be the most favourable protection against the problem of price spikes.

1.5 Delimitations

First of all we limit our research to a fictitious electricity trading company for the period January 1998 to March 31, 2001. The number of years is limited due to the fact that the critical data needed in order to make this thesis are only available for this specific time period. A fictitious company was used since it was not possible to gather data from different electricity companies due to confidentiality aspects, and the limited time period. The limited time to finish this thesis and the amount of calculations necessary to evaluate our hedging strategies, made us aware that we needed to limit the number of hedging strategies to apply in our research. The conclusion to be drawn from our work is, due to these issues, not a general one for the entire electricity industry or for any specific electricity trading company, but it will serve as guide for a smaller electricity trading company that wants to minimise the negative economic effect due to price spikes.

1.6 Disposition

This thesis is divided into seven chapters:

1. Introduction – Background, Problem Discussion, Problem and Purpose, Delimitations, Contributions, and Disposition.
2. Theoretical Framework – deals with the different underlying theories that concern our thesis. Forward, Future, and Option Theory, and the Efficient Market Hypothesis are discussed. It is important to understand these theories in order to understand our problem. This paves ground for chapter three.
3. Nordpool and Electricity Trading – describes and explains today's power market and the role of Nordpool. It also explains how electricity trading is performed and the risk associated with electricity trading. This chapter will give a more thorough insight into electricity trading and is intended to assist the reading of the thesis in its entirety.
4. Methodology – describes the research methodology that is used for our thesis. It explains the construction of our hedging strategies, collection of data, the research approach and discusses the reliability and validity of our thesis.
5. Our Model – describes our quantitative model. Since the model is complicated it is explained at length, for a better understanding of our analysis at the whole.
6. Analysis and Result- analyses the problem and provides us a basis for answers to our research questions.
7. Conclusion –presents the answers to our research questions and also gives concluding remarks to our thesis.

2. THEORETICAL FRAMEWORK

The purpose of this chapter is to present theories concerning electricity trading. More specifically Forward, Future and Option theory and the Efficient Market Hypothesis will be presented. This knowledge is necessary to obtain in order to understand the analysis of our thesis.

2.1 Derivative Instruments

According to the book Options, Futures & Other Derivatives by John C. Hull (1999), the theory behind forwards, futures and options can be explained in the following way:

2.1.1 Forwards

A *forward contract* is an agreement to buy or sell an asset S at a certain future date T for a certain price K. It is set up between two large financial institutions or between a financial institution and one of its clients and is traded in the over-the-counter market. The agent that agrees to buy the underlying asset is said to have a *long* position. The settlement date is called *delivery date* and the specified price is referred to as the *delivery price*. The *forward price* $f(t,T)$ is the delivery price, which would make the contract have zero value at time t. At the time the contract is set up , $t = 0$, the forward price therefore equals the delivery price, hence $f(0,T) = K$. The forward prices need not (and will not) necessarily be equal to the delivery K during the lifetime of the contract.

The payoff from a long position in a forward contract on one unit of an asset with the price $S(T)$ at the maturity of the contract is $S(T) - K$.

2.1.2 Futures

A *future contract*, like a forward contract, is an agreement to buy or sell an asset at a certain future date for a certain price. The difference is that futures are traded, and to make trading possible standardized features are built into the contract. The given price is now called the *futures price* and is paid via a sequence of installments over the contract's life. These payments reset the value of the futures contract after each trading interval; the contract is *marked to market*. Furthermore the default risk is removed from the parties to the contract and borne by the clearinghouse, which basically acts as an intermediate party and balances the long and short positions in such a way that it always has a zero net position.

2.1.3 Options

An *option* is a financial instrument giving one the right *but not the obligation* to make a specified transaction at (or by) a specified date at a specified price. *Call* options give one the right to buy. *Put* options give one the right to sell. *European* options (the type of option that is used in electricity hedging) give one the right to buy/sell on the specified date, the expiry date, on when the option expires or matures. American options give one the right to buy/sell at any time prior to or at expiry. Options are traded both on over-the-counter (OTC) and on all the major world exchanges, in enormous volumes. The *exercise price* or the *strike price* of an option, is the price on which the transaction to buy or sell the *underlying* asset on or by the expiry date (if exercised), is made. K is used for the strike price, time $t = 0$ for the initial time, time $= T$ for the expiry or final time. Consider, an European call option, with strike price K; $S(t)$ is the value or the price of the underlying at time t. If $S(t) > K$, the option is *in the money,* if $S(t) = K$, the option is said to be *at the money* and if $S(t) < K$, the option is *out of the money*. This terminology is motivated by the payoff from the option, which is $S(T) - K$ if $S(T) > K$ and 0 otherwise.

The derivative instruments previously explained are used by certain electricity trading companies as tools in their risk management strategy (Krapels, 2000). The aim for the electricity trading companies is to find the proper hedge by combining the various derivatives, so that they are fully protected from possible price movements during the particular time period. In our analysis we will test different hedging strategies in order to find out which one is the most efficient in terms of reducing the risk of a fluctuating electricity price.

2.2 The Efficient Market Hypothesis

This section is included since there are doubts concerning the liquidity of Nordpool. We believe that there is a strong connection between the efficiency and the liquidity in the market. The efficiency and the liquidity will influence the availability of contracts that can be used in order to construct a sufficient hedging strategy.

According to the book; Corporate Finance by Ross, Westerfield & Jaffe (1999), the efficient market hypothesis can be explained as follows:
In order for a market to be effective all actors in the marketplace need to have access to equivalent information. An effective market is distinguished by the fact that *all accessible and pertinent information is reflected in the market prices*. The measure of efficiency is seen in the extent to which the market reflects new information rapidly in the share price. Market efficiency, as reflected by the Efficient Market Hypothesis (EMH), may exist at three levels:

2.2.1 The Weak Form

The *weak form* of the EMH states that the current share prices fully reflect *all information contained in past price movements*. If this level holds, there is no value in trying to predict future price movements by analyzing trends in past price movements.

2.2.2 The Semi-Strong Form

The *semi-strong* form of the EMH states that current market prices reflect not only all past price movements, but *all publicly available information*. In other words, there is no benefit in analyzing existing information, such as that given in public accounts, after the information has been released; the stock market has already captured this information in the current share price.

2.2.3 The Strong Form

The *strong form* of the EMH goes beyond the previous two by stating that current market prices reflect *all relevant information*. The market price reflects the intrinsic or "true" value of the share based on the underlying future cash flows.

The electricity market, after the deregulation, is a relatively new market, which makes it quite undeveloped compared to the stock market. In an immature market there are issues yet to be resolved. One issue is the efficiency in the electricity market. This matter is important since it deals with information flow and determines whether some participants receive inside information, which would give those participants unfair advantages to the rest (Ross, Westerfield & Jaffe, 1999). Even though the efficiency of the electricity market is not the focus of our thesis, we believe that it is a critical issue that needs to be considered since it affects the outcome of electricity trading.

3. NORDPOOL AND ELECTRICITY TRADING

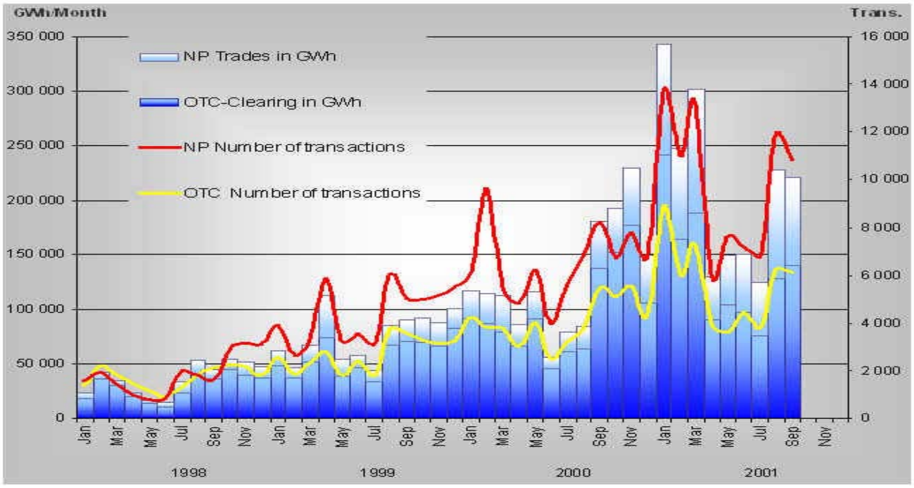
This chapter will explain Nordpool's role in the electricity market, the trading procedures, and the different types of contracts on Nordpool. The OTC market will also be explained briefly as well as the risks associated with electricity trading. Lastly, we will explain how hedging works in the electricity market. We have chosen to present this chapter early since electricity trading is a highly complex issue and an understanding of how the electricity market is functioning will greatly assist the reader throughout our thesis[1].

On January 1, 1996 Sweden joins Nordpool to create the worlds first multinational exchange for trading electricity. Now that Finland (June 15, 1998) and Denmark (October 1, 2000) have been fully integrated into the Nordic market, Nordpool consist of all the Nordic nations (www.nordpool.com 2001-10-08).

There are two major markets on Nordpool, the spot market and the futures market. The spot market is for physical delivery of electricity and the futures market is a purely financial market without physical delivery. The Physical market consists of Elspot, Elbas, and the regulating market. The financial market consists of the Electricity Forward and Futures Market (Eltermin) and the Electricity Option Market (Eloption). In addition to this Nordpool takes care of the clearing services for the financial contracts and thereby reduces financial counterpart risk, as Nordpool enters into the contracts as a contractual counterpart. The clearing services involve all the contracts traded on the spot and financial market (www.nordpool.com 2001-10-08). [2] There is also an Over The Counter market (OTC), which is a bilateral market between the different parties. However, Nordpool sometimes also clears these OTC contracts. In order to get an idea of how Nordpool has progressed we present this graph:

[1] The reader who has significant knowledge of the electricity trading industry might go on to the next chapter.
[2] The interested reader can read more at www.nordpool.com.

Figure 3.1: Development of financial trading on Nordpool.



Source: www.nordpool.com (2001-10-10)

As evidenced by this graph, the number of contracts traded and cleared by Nordpool is increasing significantly from year to year.

In the table below we can see some actual numbers on how the trading of electricity has increased on Nordpool over the years:

Table 3.1: Trading on Nordpool.

	2000		**1999**		**1998**		**1997**		**1996**	
	TWh	*Bill. Kr*	*TWh*	*Bill. Kr*	*TWh*	*Bill. Kr*	*TWh*	*Bill. Kr*	*TWh*	*Bill. Kr*
Elspot	96.2	11.1	75.4	8.9	56.3	7	43.6	6.3	40.6	10.5
Financial	358.9	43.3	215.9	27.7	89.1	12.5	53	8	42.6	10.5
Traded Vol.	452.1	54.4	291.3	36.6	145.4	19.5	96.6	14.3	89.1	22.5
Clearing (OTC)	1159.5	122.5	683.6	89	373.4	-	147.3	-	-	-
Total	1611.6	176.9	974.9	125.6	518.8	19.5	243.9	14.3	89.1	22.5

Source: restructured from www.nordpool.com, (2001-10-10).

The trading volume for the financial market in 2000 was 358,9 TwH. This was an increase by 66 % compared to 1999. A total of 73,726 transactions were conducted in the financial market in the year 2000 (up 72% from 1999).

In 2001 the volumes traded have increased even more. As of today (2001-11-20) the trading volume on the spot market for 2001 is 98 TWh (compared to 85 TWh at the same time in 2000). The financial market has a trading volume of 828 TWh (compared to 312 TWh in 2000).

3.1 OTC-Market

The OTC-market, also called the bilateral market, is not an exchanged based market. It is a market that exists as an alternative to Nordpool, or maybe vice versa since the electricity traded on Nordpool's spot market only accounts for 28.5 % of the electricity traded (Sandebjer, 2001-10-10). Trading on the OTC-market is performed mainly in financial contracts but also contracts for physical delivery are traded. Forward, futures, and options to some extent can be used on the OTC market (Bergman, 1994). The contracts traded can be standardized but can also simply be an agreement of choice between two parties. The pricing of the contract is done by using the spot price on Nordpool as a reference price.

In our thesis we use instruments that exist today in order to construct three hedging strategies. The OTC market contracts are often secret contracts between two parties and therefore it is difficult to get a clear picture of the volume and the price of these contracts. In the next section we explain the trading procedures on Nordpool, and not the OTC-market.

3.2 Trading Procedures on Nordpool

In this section we will explain how the trading of electricity is being conducted. We will start by explaining how the trading on the spot market is done and then the financial market (forward, futures, and options) is explained. We will also describe how the financial contracts work in the electricity market.

3.2.1 Spot Market (Elspot)

The spot market trading (physical) is organized so that the actors put in bids for how much they want to trade on the coming day on an hourly basis. Before noon, the actors send by facsimile or electronically, information of what they are committed to buy or sell on the spot market for every hour during the coming 24-hour period, and financial settlement is done immediately. The system price on Nordpool is calculated by grouping together the participants' collective bids and offers in an offer curve (sale) and in a demand curve (purchase). The trade price is set according to the balance price at the meeting point between offers and demand (the equilibrium point). There are different price areas within Nordpool. The reason for this is that the supply and demand situation can differ in certain areas of the Nordic Countries. There are nine different price areas, one for Sweden, one for Finland, five for Norway, and two for Denmark (www.nordpool.com, 2001-10-10).

The area prices work so that the price is reduced in the area where there is a surplus of electricity (supply) and increased in the area where there is a deficit in electricity until the transmission requirement has been reduced downward to reach the capacity limit (www.nordpool.com, 2001-10-10).

If there were unlimited distribution capabilities between the countries then there would be no need for different area prices. However this is not the case, hence different area prices.

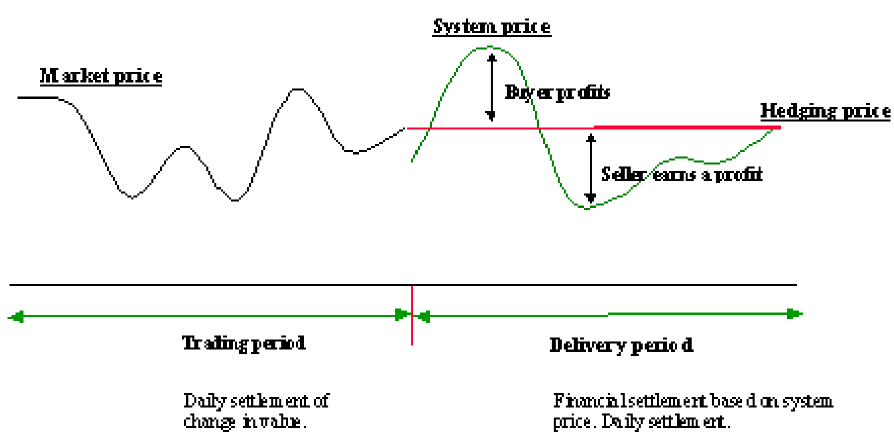
3.2.2 Electricity Forward and Futures Market (Eltermin)

The two main contracts that are being traded in the Electricity Forward and Futures Market are, futures and forwards[3]. This market provides an opportunity for the actors to hedge themselves against future variations in the price of electricity for up to three years (Svenska Kraftnät, 1997). The contracts that are

[3] To get an explanation of how futures and forwards works, see the chapter Theoretical Framework where this is explained in detail.

traded on Electricity Forward and Futures Market are purely financial contracts and no actual delivery of electricity, only the financial settlement, is made. The actors can make sure that they can buy or sell a certain volume, to a certain price in the future. These instruments can be used for speculation, but is mainly used as a risk management strategy in the electricity market (www.nordpool.com, 2001-10-10). The two contracts, futures and forwards are basically the same kind of contract, however one important difference is how the settlement is carried out during the trading period. The trading period is the period until their due date. For futures contracts, the value of the contract is calculated daily, reflecting market changes in the price of the contract. These changes are settled financially every day between the buyer and the seller (www.nordpool.com, 2001-10-10). To illustrate a futures contract we show the following graph:

Figure 3.2 Settlement of Trade for Futures Contracts



Source: www.nordpool.com, 2001-10-10

The delivery period is the specified time period for the contract, in which the settlement occurs daily but not against the futures market price, instead it is settled as the difference between the system price on the spot market and the hedging price. This implies that if the hedging price is higher than the system price then the seller earns a profit and if the hedging price is lower than the system price then the buyer of the contract is credited on his account. The actual amount that is changing hands is the difference multiplied by the volume of the contract.

The same profit and risk profile applies to a forward contract, however for a forward contract there is no cash settlement until the start of the delivery period. The settlement accumulates daily during the entire trading period and is realized in equal shares in every day in the delivery period.

In order to receive physical delivery of the electricity, the actor puts in a bid on the spot market. The electricity that is being bought or sold on the spot market is hedged to a certain price in the forward/futures contract, and the actor pays, or is being credited the difference between the spot price and the hedged price in the contract (www.nordpool.com, 2001-10-10).

There are different futures and forward contracts that can be traded on the Nordpool exchange. The contracts that are being offered today on Nordpool are:

- *Daily contract (futures).*
- *Weekly contract (futures).*
- *Block contract (futures); a block contract consists of four weeks.*
- *Seasonal contracts (forwards); can be for winter 1 (Jan 1- Apr 31), summer (May 1- Sept. 31), or winter 2 (Oct 1-Dec 31).*
- *Yearly contracts (forwards); up to three years ahead in the future.*

3.2.3 Electricity Option Market (Eloption)

An *option* is a financial instrument giving the right *but not the obligation* to make a specified transaction at (or by) a specified date at a specified price (Bingham and Kiesel, 1998). Options contracts traded and cleared via Nordpool are standardized i.e. they carry fixed terms and conditions. The contracts traded on the Electricity

Option Market are European options and Asian options. European options are characterized by the fact that the option holders can only exercise their right on the expiration date of the option (Hull, 1999). The underlying contract for a European option is a forward contract. The terms that are included in the contracts are:

- *Volume*
- *Specification*
- *Exercise date*
- *Exercise price*

Volume is referring to how many MWh will be traded if the option is exercised. An option contract's volume, measured in MWh, varies according to the underlying futures or forward contract. For example, the contract size of the underlying Futures Market forward contract is 1 MW. At start-up, there will be four different contract sizes, in MWh : (www.nordpool.com, 2001-10-11)

FWW1: *1 MW * 2,879 hours = 2,879 MWh*
FWSO: *1 MW * 3,672 hours = 3,672 MWh*
FWW2: *1 MW * 2,209 hours = 2,209 MWh*
FWYR: *1 MW * 8,760 hours = 8,760 MWh*

The contracts are always in 1 MW and then multiplied by the number of hours in the time period of the contract. Specification is just stating which specific underlying forward that the option is trading in. For example ECFWW2-2001, is a European call option and the underlying forward contract is winter 2 in 2001. Exercise date is the date on which the option must be exercised, in order for it not to become worthless (On Nordpool, options are automatically exercised unless orders to the contrary are expressly made). Exercise price is the price per MWh that option holders pay if and when they use their right.

The premium for an option is expressed as Norwegian kroner multiplied by the number of hours in the contract. For example, the option AC190FWW1-02 has a premium NOK 7.90 (2001-10-10), it is for 2,879 hours so the total premium would be *7,90*2,879= NOK 22,744*.

Asian options are a little bit different than European options. By definition, an Asian-style option is exercised and settled automatically, in retrospect, against the price of the underlying instrument during a given period. Asian-style electric power options are settled against the arithmetic average Spot Market (Elspot) system price in the settlement period (www.nordpool.com, 2001-10-11). The payoff is measured by the difference between the strike price and the *average* of the system price during the period of the option contract. These kinds of options are not as common as the European options on Nordpool. The underlying contract for this type of option (on Nordpool) is a futures contract. The contracts are standardized and the terms are the same as for the European style options, except for the specification where an A is used instead of an E. For example, AC105GB09-00 is an Asian call option with an exercise price of NOK 105, the underlying contract is block contract for September in year 2000. The Electricity Option Market is used as a market for managing risk. The actors can forecast future income and costs related to trading in electricity and thus the actors can choose what risk level they are willing to operate at.

The Electricity Option Market is not a very liquid market and the total number of options traded can be very small or even non-existent for some days and weeks. This is a real problem for Nordpool and in order for it to excel as an exchange the liquidity needs to become much better. In order for Nordpool to provide a good hedging market the Electricity Option Market needs to become more liquid so that the combination of Electricity Forward and Futures Market and Electricity Option Market can be used in a sufficient way, because the combined use of electric power options and futures and forwards offers the best opportunities to construct a sufficient hedging strategy that will minimize the risk for the power trading companies. There are a number of different strategies that can be used in hedging. Some of the ones that are used or could be used in the electricity market are[4]:

- *Straddle* – involves buying a call option and a put option with the same strike price and exercise price.
- *Spread* – involves taking a position of two or more options of the same type (two calls or two puts) with the same expiration date but with different strike prices.

3.2.4 The CFD Market

To avoid the basis risk when trading electricity a new type of contracts was created. They are called Contracts For Difference, or CFD-contracts (Enron, 1995). A CFD contract is basically a future or a forward for a certain price area other than the system price. In return for a premium the seller of the contract agrees to pay to the buyer the difference between the system price and the contract price specified in the CFD contract (Enron, 1995). For Swedish electricity trading companies there is a need to hedge themselves in the same price area as the one they deliver the electricity in. For example if they are hedged on Nordpool to system price and they need to deliver the electricity in Sweden there might be a price difference between the hedging price and the price for Sweden. To illustrate what could happen we show what happened in January 24, 2001. The example applies to an electricity trading company with a hedge on 3.2 GWh for a day in system price. The price on the spot market was very high, due to cold weather conditions, and the price difference between the system price and the

[4] For a more thorough explanation of the different option combinations see Hull, J "Option theory and Pricing" (1999).

price for Sweden was large. This generated a cost of not being hedged in the right price area of SEK 2,007,000 for 24 hours (Hammarstedt et al, 2000).

In addition to the contracts traded on Electricity Option Market, the OTC-market provides different contracts such as “brukstidskontrakt”, “dagkraftskontrakt”, and various specially designed contracts between the two parties. The contract that is mostly used is the “dagkraftkontrakt”, a future contract only for the hours during the day (07.00-19.00). This contract is used to hedge a potentially large increase in the price during the critical hours during a 24-hour period. This is the “finest” instrument that can be used i.e. hedging one or two hours is not possible. The smallest time period is for one day. There is certainly a need for “finer” instruments but as of today no parties are willing to sell such a contract. A combination of the instrument described above will be used in our hedging strategies.

3.3 Risks Associated with Electricity Trading

3.3.1 Risk Management

In order to understand the concept of risk management it is important to define risk. Risk can be defined as the volatility of unexpected outcomes (Jorion & Khoury, 1996). There are two types of risks; business risk and financial risk. Business risk refers to the product market where the firm operates and involves technology changes, marketing, and innovations. Financial risk concerns movements in financial variables, such as fluctuations in the stock price. Industrial corporations seek to manage business risk while financial institutions (and electricity trading companies) mainly try to manage financial risk (Jorion & Khoury, 1996).

Today after the deregulation Nordic power companies are exposed to more risk, especially the risk of a volatile electricity price. Power companies are now organising proper risk management strategies by the use of different financial derivatives (Krapels, 2000). The exposure to risk that the electricity trading companies are facing is growing, and the trend today as previously explained, is that the demand of electricity increases while the electricity production decreases. This makes the electricity trading companies more sensitive to a fluctuation in the market price. Hence, it is critical for electricity trading companies to put a lot of emphasis on hedging strategies. Companies in the electricity industry will need to successfully implement a broader financial risk management strategy than the average industrial industry. As a consequence, it is important to develop financial risk management into a tool to select a desired risk profile and to determine the trade-off between risk and return (Kollberg & Elf, 1998). The beginning of a financial risk management strategy is to develop a manual for policy and procedure in derivatives trading. This is important so that uncontrolled speculation can be avoided, which can lead to bankruptcy for electricity trading companies (Kollberg & Elf, 1998).

3.3.2 Price Risk

Price risk involves the fact that the future price is uncertain and that the participants in the electricity market face the risk of not being able to predict the future price of electricity. The risk comes from the fluctuation in the electricity price, this affects both the physical and the financial trade. Since the start of Nordpool the volatility in the electricity price has decreased, this has to do with an increasing liquidity and that the participating traders have become more familiar with the market. The electricity trading company can enter a contractual agreement to sell electricity at a future date to a certain fixed price. Then, if the electricity price is higher than the fixed agreed price, the electricity company will make a loss. "The electricity trading company cannot eliminate the price risk so the company should calculate, value and report positions that the company have taken. The company's electricity price risk should be apparent" (Svensk Energi, 2001).

3.3.3 Volume Risk

Volume risk involves the scenario that the purchased electricity volume deviates from the sales volume, which has to do with factors such as changing weather conditions. An example of volume risk is an electricity trading company who knows how much electricity they should deliver during a certain time period, for example a period of one year, to its customers, and enter a contract to deliver that amount at a fixed price, but they do not know exactly at what time during that year the electricity should be delivered. This means that the company needs to, at a lower consumption rate than predicted, sell back electricity to a lower price than they bought it for, or at a higher consumption rate than predicted, buy the extra amount at a higher price than they sold it for.

3.3.4 Liquidity Risk

Liquidity risk means taking the risk that the market place will face unforseen events, such as low turnover.(Hammarstedt et al., 2001). This risk will decrease as the turnover on Nordpool increases. Since the electricity market is quite new after the deregulation, the market is not as liquid compared to for example the stock market, which is an older and more mature marketplace. The situation today is that there are not enough derivative contracts to trade with, due to lack of counterparts to the contracts (Raab, 2001-09-19). The liquidity will decrease the more individually tailored the contracts are, and increase the more standardized the contracts are. The more people becoming active traders at Nordpool and in the OTC-market, the more liquid the electricity trading will be, which will lead to a more efficient marketplace. The trend today is that the liquidity is increasing since the number of traders at Nordpool is growing (www.nordpool.com, 2001-10-11).

3.3.5 Basis Risk

Basis risk occurs when the company trades with financial contracts that have different reference prices. When operating in various price areas, the electricity price can be hard to predict and the company will face variations in the outcome of their trades (Risk Publications, 1995). There are tailored financial contracts available in order to tackle the risk involved with trading in different price areas, those contracts are called Contracts for Difference or CFD contracts (www.nordpool.com, 2001-10-11). "The electricity trading company cannot eliminate the basis risk, so it should calculate, value and report positions that the company has taken. The company basis risk should be apparent" (Hammarstedt et al. 2000).

3.3.6 Exchange Rate Risk

Exchange rate risk is the risk that the traded currency will get an unfavorable development when payments occur in another currency (Tegin, 1997). The changes in exchange rates will produce the risk that the seller will receive less payments from the end customer, to pay for the electricity. All derivative trading that takes place at Nordpool is in Norwegian kroner, therefore all actors, who receive their sales revenue in another currency will have to consider the exchange rate risk.

3.3.7 Comments to the Risks

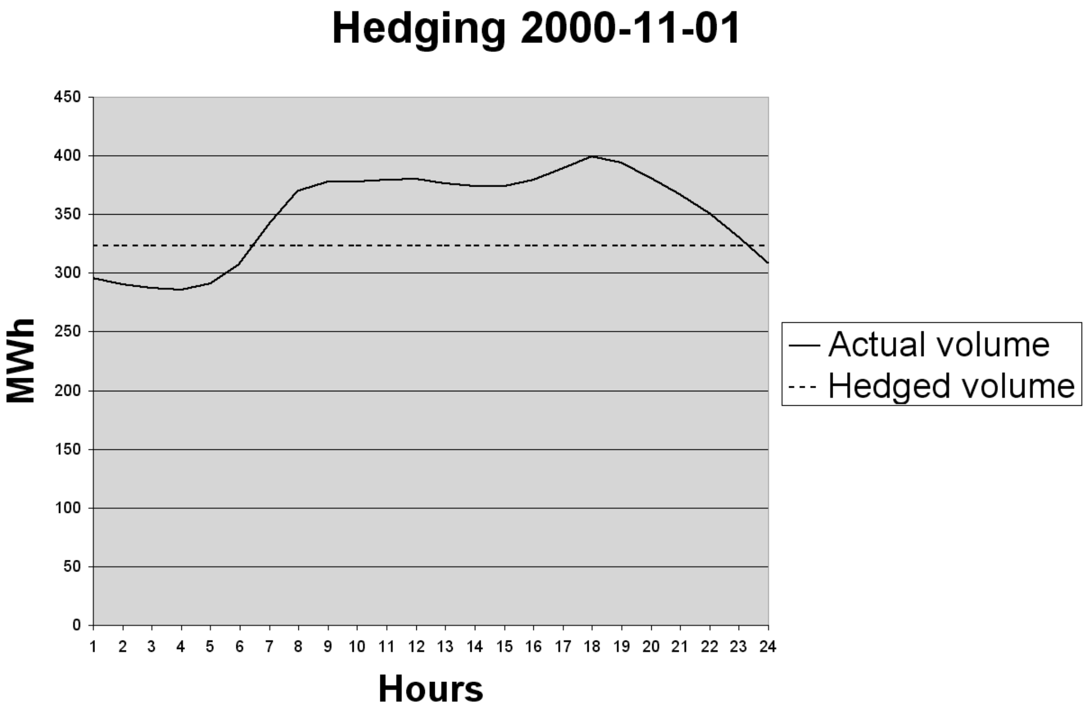
The risks explained above affect the companies in the electricity industry in different ways. The price risk and the volume risk will have the largest effect on the electricity trading companies. According to Kollberg & Elf (1998), the risk of a fluctuating price will influence the electricity trading companies in a way that forces them to implement a broader hedging strategy by focusing on developing a proper risk management strategy. The volume risk requires the company to put more emphasis in conducting a more profiled and accurate forecast of the future electricity consumption.

A large risk concerning the electricity industry is the weather. This implies that a change into a colder temperature will, as previously explained, generate the risk of a fluctuating electricity price and the risk of deviation in the forecasted consumption of the trading company (volume risk). The weather is however hard to predict and is certainly the most critical factor that determines the price of electricity. Other more general risks are electricity production difficulties, such as operational problems with power stations and generators and transmission complications, such as damaged grid systems.

3.4 How Hedging Works in the Electricity Market

The foundations of hedging in the electricity market are the same as for the purely financial market. However, since the market is not as liquid and developed yet, the contracts being offered are not as extensive as one would want. This has certain implications, for instance, with the "finest instrument" the total volume for one day can be hedged and the measurement is on an hourly basis. This means that at certain hours the volume will be underhedged and at certain hours the volume will be overhedged, but the total hedged volume is correct. This means that at almost every hour there will be a volume difference between the hedging volume and the actual volume that specific hour. This can be seen on figure 4.2.

Figure 3.2: Volume difference



Source: The quantitative model

The volume difference will be positive if overhedged and negative if underhedged. The result of the volume difference will be calculated as a cost or as a gain depending on if you are underhedged or overhedged. It is calculated in the following manner:

*(Spot Price – Average Hedge Price) * Volume difference.*

The result of the volume difference is positive if overhedged, i.e. the amount (MWh) that is overhedged is financially settled with Svenska Kraftnät. However, as evidenced by the calculation only the difference between the spot price and the hedging price is received. There would even be a loss if the spot price is less than the hedging price. The result of the volume difference is negative if underhedged, i.e. additional cost to buy the electricity on the spot market. It is calculated in the same manner: *(spot price – average hedge price) * volume difference*. These costs or gains are additional to the hedged volume and costs. Worth mentioning is that these costs/gains apply if the forecast of consumption is completely accurate and equals the actual consumption. If not, then regulating prices will go into effect. It means that if an error in the forecast is made, the amount (MWh) of electricity you have misjudged your forecast by to a either up has to be bought or sold at either upwards or downwards regulating price. Svenska Kraftnät decides if there is a regulating price on certain hours based on the aggregate supply and demand for Sweden.

4. METHODOLOGY

The purpose of this chapter is to describe our intended approach of answering the research questions stated above. We will explain the theory behind our method and also how we conducted this thesis from start to finish. This will include issues such as collection of data, interviews and the reasoning of our hedging strategies.

4.1 Scientific Approach

Our thesis is a blend of a *quantitative* and *qualitative* study. The quantitative part is constructed through a model in MS Excel. The model is designed with different variables and will measure the eventual cost of using a specific hedging strategy, the main variables are electricity price in the spot and in the financial market, forecasted consumption figures and hourly settlement figures. The qualitative part is composed of empirical facts from the electricity industry, which we will use as tools for making comparisons and give recommendations on how to solve the problem.

The approach that we conduct is *deductive*, i.e. an approach, which is used when the problem area can be derived from theory, and the theory forms the basis for the empirical study. An *inductive* approach is preferable to use when the problem issue has no connection to any theory and when facts speak for themselves and seek regularity in events (Halvorsen, 1992).

4.2 Strategic Approach

The strategy that is used when conducting a thesis depends on how much information or knowledge the author has about the specific research problem and also on how the problem is organized and formulated. There are three strategic approaches: *exploratory*, *descriptive* and *explanatory* approach (Halvorsen, 1992). The approach that is used depends on, as mentioned above, the amount of information the researcher has about the problem area. The exploratory approach is used when there exists little or no knowledge of the problem area. The descriptive approach assumes that there already exists knowledge of the problem area and that the formulation of the problem is fairly well structured. The explanatory approach is used when the researcher has a wide knowledge of the problem area and there exists theories in the area. Our strategic approach is explanatory since we have a good understanding of the problem and there exists theories that we intend to rely on and we aim to implement these theories on the problem in order to achieve significant results.

4.3 Research Design

The design of the research is one of the most vital parts to determine, when starting a research process. The design of the research, functions as the basis for how the process should proceed and in what form the report will be presented (Holme & Solvang, 1997).

When deciding to start a research study there are several different research strategies to choose from. Each strategy has its own advantages and disadvantages. Depending on what the researcher wants to investigate, the researcher has to determine which strategy best suits the purpose of the study. We decided to choose the scenario analysis, since it is the most appropriate research approach for our type of study. The reason for choosing this research approach is that we want to examine which strategy is the most favourable in terms of hedging for an electricity trading company. We believe that the scenario analysis will be suitable as it will test different scenarios and from those we will be able to draw our conclusions.

4.5 The Approach of our Thesis

Our thesis work started with a discussion with our professor Ted Lindblom who had received an inquiry from Elforsk about a possible thesis work within the financial side of the electricity market. We took an interest to the subject and started to research it more closely and after gaining more insight we scheduled a meeting with Ted Lindblom and Peter Fritz at Elforsk were we decided to write about price spikes in the electricity market. Since we both have a thorough interest in the financial market we decided to investigate what can be done to minimize the risk of price spikes by the use of financial contracts. In order to investigate this we constructed a quantitative model in MS Excel, which will be explained in detail in the next chapter. As described above we use a blend of a quantitative method and a qualitative method. The reason for this is that the quantitative approach will measure, describe, and explain the phenomenon of our problem and it will be used to explore numerical information, and based on these, analysis will be made. The qualitative approach will gather information and will help us to gain a deeper insight of the problem we are researching (Eriksson & Weidersheim-Paul, 1991). In qualitative methods it is the thesis writer's understanding or interpretation that is in focus (Holme & Solvang, 1997). Our belief is that a mix of these two methods will provide an excellent base for a thesis.

After deciding on which method to use we started to research and gather material for our thesis. We searched various databases in the Economic Library at the School of Economics and Commercial Law in Gothenburg and we also searched extensively on the Internet. The specific databases we used were ABI/Informal Global, Academic Search Elite, Affärsdata, Financial times, and JSTOR. The reasons for choosing these data bases were that they cover the largest journals and that these databases provide articles in full text and have the best scientific material. Our search methods included searching on various phrases and keywords such as; electricity market, Nordpool, electricity hedging, electricity and risk, risk management, power trader, hedging and derivatives, electricity risk management. We performed the search using both English and Swedish key words. Our Internet research has been very helpful in our thesis work. We searched using the same key words and phrases on the Internet, which gave us valuable information on what web pages to visit. Among the web sites that have been useful to us are; Svenska Kraftnät, NUTEK, Svensk Energi, Nordel, Energimyndigheten (stem), Elforsk, and Nordpool. It is worth mentioning that Nordpool's website has been especially useful to us in finding out various important aspects of the electricity market. Since the electricity market is changing at a rapid pace and much of the published material goes out of date we have also focused on interviews with people that actually work in this field in order to get a deeper understanding and to be more up to date with the latest innovations in the electricity market, especially in the financial sector.

4.5.1 Interviews

We choose to make interviews with experienced people in the electricity industry, we aimed especially to meet with people who had a lot of knowledge of the electricity trading sector. Therefore we scheduled several meetings with Mikael Jednell, power trader at Plusenergi in Gothenburg. He provided us with useful insight in electricity trading and answered questions related to our thesis. In order to gain a wider knowledge we decided to meet with more people in the electricity trading field. We contacted Stefan Andersson, analysts at Vattenfall Supply & Trading in Stockholm. At Vattenfall we were able to interview several other electricity analysts and traders who gave their specific view of how trading is performed today and how different hedging strategies could be constructed. Since our fictitious company is a smaller electricity trading company we met with Håkan Kånge at Mölndal Energi, from whom we obtained a deeper understanding of how smaller actors operate and how they perform their hedging. Furthermore, we felt a need to get a closer perspective and talk to someone at Nordpool, the electricity exchange. At Nordpool in Stockholm we met with Håkan Sandebjer at clearing, risk management. He explained the financial contracts and the process of hedging. Together with these interviews we have had contact with Peter Fritz at Eme-Analys, our company supervisor and Ted Lindblom, our supervisor at the School of Economics. Furthermore, we have gained knowledge by making connections with people in the electricity field by e-mail and phone conversations. Some people we have contacted are Ulf Sävström and Annica Lindahl at Svensk Energi and Agata Persson and Yvonne Härdelin at Svenska Kraftnät.

In the beginning the structure of our interviews were focused on obtaining as much information as possible concerning the function of the electricity market and how electricity trading is being performed. The questions were intended to give us answers so that we would get a wider knowledge of the financial side as well as the non-financial side of the electricity market. We believe it was important for us to understand the entirety of the market in order get a clearer idea of how to approach the problem of price spikes. After the first interviews we felt that the focus on further interviews should strictly concern our thesis topic and the questions were posed so that we would attain a deeper knowledge of our specific problem and on how an effective hedging strategy could be constructed. In order to attain the necessary knowledge needed to create a hedging strategy we prepared a questionnaire[5]. The idea with our questionnaire was to include questions that would systematically lead us to the development of our hedging strategies. There are different types of interviews to use, one can either conduct a structured interview with predetermined questions or one can conduct a more discussion-like interview without any predetermined questions (Merriam, 1994). We used both types of interviews, in the beginning when we wanted to gain a wider knowledge of the electricity market, thus we used a more structured interview approach. Later on we had a more discussion-like interview approach where we aimed at focusig more on our objective of the thesis.

[5] See appendix 9.1

After various interviews and discussions with industry representatives we decided to focus on how to minimize the risk for the electricity trading companies by the use of the financial instruments that exists in the market today. After realizing that many electricity trading companies will face a tougher market situation, especially the smaller ones, we decided to focus our thesis on small trading companies that do not have any production of electricity of their own. The reason for this is that these companies are much more exposed to the various risks that are associated with electricity trading, especially the risk associated with price spikes.

4.6 Our Hedging Strategies

The electricity trading companies are using some kind of hedging strategy in order to be insured against the risk of electricity price fluctuations. We have, by interviewing electricity trading companies and by listening to people who are familiar with electricity trading, acquired an idea of how hedging is conducted in Sweden. We have also read literature concerning electricity trading and visited websites, such as Nordpool, to obtain a better understanding of how to properly construct a functioning risk reducing strategy. We have learnt that the most ordinary contract to use is the forward and the future contract with different time periods, such as day, week, block, season and year. Another contract being used is the option contract, but unfortunately the electricity option market is not very liquid, thus limiting the use of options. Even though the market is not liquid we decided to test options as one of our strategies. We have decided on testing the contracts that exists in the market today in order to illustrate how the smaller electricity trading companies can minimize the negative economic effects due to price spikes.

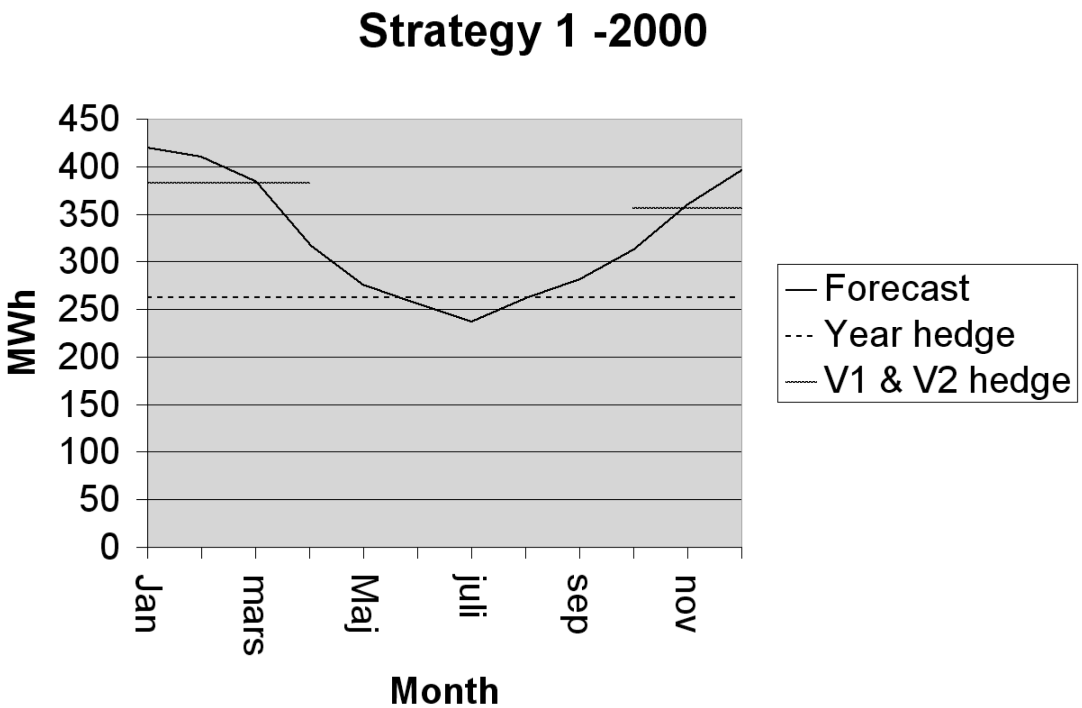
As a consequence of our gathered knowledge we realised that our quantitative model would include three different hedging strategies. This was due to the limited time and the amount of calculations necessary to evaluate our hedging strategies. The idea with our strategies is to start out with one hedging strategy and then make the next strategy more sophisticated, i.e. make a finer hedge with more contracts entered at different dates. We put more emphasis on hedging the winter periods, due to the greater risk of price spike to occur when there is a colder temperature. The strategies were composed by a mixture of contracts, based on how electricity trading is actually performed today and also on our own ideas of how to structure an effective hedging strategy. We decided on being hedged to 100 % of the forecasted consumption. This is due to the fact that we believe that an electricity trading company should at least hedge the forecasted consumption, so that they will not be too exposed to price fluctuations over the year. The thought of our strategies is to start out with one hedging strategy and then make the next strategies more sophisticated, i.e. make a finer hedge with more contracts entered at different dates. Another idea we had concerning the strategies was that we should put more emphasis on hedging the winter periods, due to the greater chance of price spike to occur when there is a colder temperature.

4.7 Composition of the Strategies

4.7.1 Strategy 1 –FWYR, W1 and W2

In this strategy we used three forward contracts in order to hedge the yearly volume. The strategy is to have a yearly hedge based on the average consumption over the summer season and then to fully hedge the remaining seasons, winter 1 (W1) and winter 2 (W2) also by forward contracts.

Figure 4.1 Strategy 1



We started out by calculating an average consumption for the summer season, by adding the MWh per hour to a total and dividing it by the number of hours during the period. This gave us an average MWh usage per hour for the summer season. In order to be fully hedged over summer season we used this average as a straight hedge over the whole year. (This was needed due to the reason that if we had taken the average over the whole year and hedged that average we would be overhedged during the summer season). This straight hedge is the straight line that goes from January till December on graph X. Then, we hedged the remaining winter seasons, W1 and W2. We wanted to be fully hedged (100%) in both seasons, so we calculated an average consumption for those seasons and then we deducted that average by the yearly average level for W1 and W2. This gave us a new average, which we could hedge by a forward W1 and a forward W2 contract. By doing this we had a full hedge over the year and the critical winter seasons were covered by a double hedge, the straight underlying yearly hedge and the winter hedge, on top of that.

4.7.2 Strategy 2 –Block Contracts

In this strategy we aimed to hedge the entire year by the use of block contracts (a four week forward contract). There are 13 block contracts over a year (B01-B13) and each block contract covers 28 days or four weeks. We decided to be fully hedged the whole year so we hedged each block to 100% of the forecasted consumption.

Figure 4.2: Strategy 2

The problem with hedging the entire year with block contracts is that it is not possible to enter all contracts in August the year before. This is due to the fact that there exist no block contracts in August for the whole year. The only blocks that can be hedged in August are block B01-B04. In order to hedge the entire year with blocks one must enter the first four blocks in August and then enter the remaining blocks after about four months. We decided to enter the first four blocks in August, but we did not want to be underhedged and face the risk of price fluctuations, so we covered the remaining seasons, summer and winter with regular forward contracts for summer and W2. The plan was to enter the remaining block contracts in February and sell the summer and W2 contracts simultaneously.

4.7.3 Strategy 3 –Block Contracts plus Asian Call Options

This strategy is based on the second strategy where we had block contracts. The difference with this strategy is that we included Asian call options as an additional hedge. We intended to have an extra hedge during the critical winter seasons when there is a greater chance of price spikes to occur due to the colder temperature.

The reason for choosing Asian options rather than European options is that an Asian-style option is exercised and settled automatically, in retrospect, against the price of the underlying instrument during a given period. The Asian options are settled against the arithmetic average Spot Market (Elspot) system price in the settlement period (www.nordpool.com). This makes the engagement in Asian options less risky compared to entering a European option. This is because the reference price is not, as in the European option, the spot on just one day, rather it is the average price during a block (four weeks). This makes the trader less exposed to large price fluctuations, thus the risk of losing the premium is reduced.

We made the assumption to hedge 20 % of the volume each block, which gave us an additional hedge and it would hopefully protect our fictitious electricity trading company from future electricity price increases during the winter period. The reason for assuming 20 % of the volume is that it was difficult to get an idea of what is customary in the industry today since there is almost no liquidity at all in the option market. Furthermore, since the premiums are high it is important not to expose the electricity trading company to the risk of losing a large premium. The Asian options have forward block contracts as underlying instruments, so we decided to hedge block 1-4 for the first winter season, W1 and block 10-13 for the second winter season, W2. Next we had to decide which contracts to choose and since there were only contracts available for the years 2000 and 2001 we were limited to test the strategy only on those years. This implies that we were only able to compare all three strategies in the last two years of our chosen time period. This will affect our results in the way that it will be more difficult to distinguish the best strategy over the entire time period we were measuring. Due to the reason that there were no contracts available on Nordpool for the first four blocks in the year 2000, we had to use contracts from the OTC market. The rest of the contracts were taken from Nordpool. In order to decide what date and to what strike price to enter, we used the first contracts that were available to trade on Nordpool and on the OTC market. For example, we took the first three blocks in year 2000 on the 24th of November 1999 and block four in year 2000 was entered 17th of February the same year. These contracts had only one strike price so we did not have to decide what level to enter. When we had different strike prices to choose from we decided to enter the contract with the average strike price. For example, the 26th of July 2000 the strike prices of the contracts were as follows; 100, 105, 110, 115 and 120. The average strike price was then 110 and the contract we decided to enter. By doing this we are always operating in the middle and never on the extreme high or low price level.

4.8 Collection of Data

Our sample of data consists of observations between the years 1998 to 2001. The data that we have used in our thesis are; electricity prices per hour, regulating electricity prices per hour, electricity consumption per hour (measured in MWh), prices of financial contracts (forwards, futures and options) and consumption forecast figures per hour. We intended to measure a period from 1996 to 2001 but due to the limited availability of data for the years 1996 and 1997 we could only measure the years mentioned above. This will affect our results in a way that it will reduce the number of years that we will base our results on and the conclusions drawn will be less general.

Most of the data was collected from the electricity exchange Nordpool through a file, which was accessible by permission from Jan Foyn at the International desk at Nordpool in Oslo. This file was very useful since we could easily go in and pick up spot prices and prices for financial contracts any given day of the year. The regulating prices were given to us by Svenska Kraftnät. Other valuable knowledge was obtained by interviews, company visits and literature from the library of economics at the School of Economics in Gothenburg.

4.8.1 Reliability and Validity

The validity and reliability of our research depends both on what material has been collected and also on how the data is treated once received. The validity of the data concerns whether the chosen data is appropriate for the specific research. The reliability of the study depends on how reliable the measurement, literature and all other information collected are.

The reliability and validity of the data is a critical issue since it will determine the quality of the input in our quantitative model and this will in turn affect the result of our research. Therefore, we believe it was essential to gather all the data from reliable sources. Our main source that we gathered information from was Nordpool. Since Nordpool is the electricity exchange in Scandinavia the data that has been collected is very reliable. Svenska Kraftnät is another source that we have used for the collection of regulating prices. They are the national grid operator and have the balance responsibility in Sweden, this implies that they are a very trustworthy source. Since our objective of this thesis is to apply different strategies to hedge electricity prices we have chosen data that is relevant to use for that specific purpose, thus we believe that our data is valid and is useful in our quantitative model.

All the material and data collected for this thesis are based on facts and original data. This implies that if another researcher would investigate the same problem that we investigate, using the same model, and started from the same basic conditions, the researcher would come up with the same results and answers. This implies that our thesis has high reliability.

5. THE QUANTITATIVE MODEL

The purpose of this chapter is to give a thorough explanation of the quantitative model used in the thesis. Input variables and assumptions we have made will be explained. The objective of our model is to measure and compare the costs of different hedging strategies. This chapter will include a description of how we reached our numerical results.

5.1 Overview

The purpose of our model is to measure and compare the costs of different hedging strategies. In order to construct such a model we had to perform extensive research and conducted several interviews with industry representatives. Since we had to perform our calculations on an hourly basis for a whole year, the amount of inputs used and the amount of calculations necessary to reach a final result were extensive. The major difficulty with the model was its size (over 100 Mb). This made the model very sensitive to simple miscalculations, which could have a large effect on the end result. To make sure the model was correctly constructed and the calculations were correct, we repeatedly checked and corrected possible miscalculations. This, together with the construction of the model required a great deal of time and effort, but eventually all the aspects of the model were functioning properly and the obtained results are valid.

We have tested three strategies on a fictitious electricity trading company with a market share of 2 % of the Swedish electricity market. Furthermore, we have calculated a forecast of the consumption and based on this forecast we will hedge the necessary volume.

In our quantitative model we will calculate a total cost (physical purchase plus or minus hedging result) and a total income (electricity sale to customers). These total costs will then be compared to the total income in order to reach a total result for the each strategy. The reason for this approach is that we focus strictly on hedging and not on speculation. We will focus on the total result for the entire year rather than focusing on the result of the financial settlement. This has to do with the fact at the time we are locking in a price for the hedging contracts we are setting a sale price to the end consumer. The sale price to the consumer will be based on the price of hedging the whole year with a forward contract. This implies that the hedge price and the sale price (without the cost of volume difference and balance cost) will be the same. This will also protect the electricity trading company from the risk of a negative financial settlement, since the income from the end consumer will compensate the loss on the financial settlement. Futhermore, this can be regarded as a "double-hedge" in the way that the electricity trading company is hedging their forecasted consumption as well as they hedge the income from the end consumer by setting a fixed sale price. The objective of this hedge is to reach a neutral result, i.e. neither a positive nor a negative result. We will compare the three strategies for every year from 1998-2001, i.e. each strategy will be tested on the years 1998-2001. The reason for this is to see if it was only coincidental that the strategy was working in one year or not. We intended to measure the years after the deregulation, 1996-2001, but due to limitations such as lack of data, we were not able to measure the years 1996 and 1997.

5.2 Inputs

The input variables in our model are as follows:

- Spot prices of electricity - The actual price per hour for every year
- Actual consumption of electricity - 2 % market share
- Forecasted consumption of electricity - We have calculated a forecast using forecast factors that we have calculated in cooperation with Mikael Jednell at Plusenergi. This forecast is used as a basis for our hedging volume.
- Hedge price - The actual price we lock in for the time period, prices from Nordpool.

- Hedge volume - The actual hourly volume we hedge, based on the forecast.
- Hourly financial settlement of the hedge.
- Financial result - Sum of the hourly settlement for each time period that is hedged.
- Volume difference - The difference for each hour between the hedged volume and the actual volume (this arises because that the total volume is hedged for the time period and that the instrument used is an average of this volume i.e. the total that is underhedged equals the total that is overhedged).
- Hedge price for a year - When we have estimated the price of electricity to the end customer, we consider the cost of hedging a one year period
- Result volume difference - The amount that you pay or receive as a result of where you are placed in terms of the hedge.
- Result hedge - The sum of the financial settlements.
- Physical power purchased - Amount of power bought on the spot market each hour, without considering the hedge.
- Total physical cost - The cost of the physical power purchased on spot plus the cost of power bought on the regulating market.
- Total cost - The cost of power purchased plus or minus the result of the hedge.
- Deviating forecast - Consumption forecast that does not agree with the actual consumption.
- Corrected deviated forecast - We made a correction for each deviating hour not to exceed a yearly deviation of 7 %.
- Absolute corrected forecast - Absolute value of the deviation in the forecasted electricity consumption.

- Up and down regulating price - The prices of electricity bought on the regulating market.
- Regulating cost - The cost of buying or "selling" electricity on the regulated market.
- Balance cost - An extra cost included in the sale price to the end consumer, which is the total regulating cost divided by the total forecasted volume.

5.3 Assumptions

In order to construct our model and to measure the hedging result of the strategies we had to make certain assumptions. The aim of these assumptions is to be able to conduct the research and at the same time to affect the end result insignificantly. In order for our assumptions to be valid we researched and discussed them with industry representatives. The assumptions we made are as follows:

I. As mentioned, we agreed upon constructing a fictitious electricity trading company, and in order to determine the size of the company we took 2 % of the total Swedish electricity consumption in a year, so our fictitious company is assumed to have a *2 % market share of the Swedish electricity consumption for every year*.

II. This is one of the major assumptions of our thesis and concerns our forecasted consumption for a year. We assumed that *the total forecasted consumption is equal to the total actual consumption for every year we measure*. This is because we could not adjust our forecast on a daily basis that is customary in the daily operation of an electricity trading company. So the total will always be equal but the hourly consumption will be different, since we have calculated percentage factors, which we multiply with the total forecasted consumption.

III. Due to the lack of data for some time periods we had to make some assumptions. Since we had calculated percentage factors for the forecast for the years 2000 and 2001, but were not able to do that for the remaining years, we assumed that *the hourly forecasted percentage factors for the year 2000 are the same for the years 1999 and 1998*. In other words the forecasted consumption profile was assumed be equal for those years.

IV. Price spikes are hard to predict, making them hard to hedge, since they could appear at any time of the year. We looked at historic facts and saw that there was a greater possibility of upward price fluctuations during wintertime, due to colder temperature, so we assumed that *the winter periods should be hedged more carefully for every year*.

V. The deviation in the forecasted electricity consumption per hour relative to the actual electricity consumption per hour should according to Mikael Jednell at Plusenergi not exceed 5-7 % in a year. So we assumed *our forecasted electricity consumption did not exceed 7 % during a year*, *for every year* and included that correction in our model.

VI. When hedging the Elspot system price using financial market electricity contracts, market participants remain exposed to the basis risk, which is the possibility that the local area price and the system price will differ. This is, as previously explained, solved through the use of CFD contracts. Since there were no CFD contracts available until 27th of November 2000, we made the assumption that *the hedging price used is in fact a CFD contract*. We made this assumption because we believe that it is vital to be hedged in the right price area and every serious power trader should use CFD contracts as part of their hedging strategy.

5.4 Proceedings

The plan with all the strategies is to set up the coming year's hedging strategy the first trading day in August if there exist closing prices for the contracts that specific day of trade. As mentioned, we take all the prices from Nordpool's list of closing prices. These prices were at first in Norwegian kroner but we converted them into Swedish kronor by the use of Riksbankens records of previous exchange rates. We are aware of the fact that there exists an exchange rate risk, since all derivatives trading on Nordpool is in Norwegian kroner. But we decided not to hedge the exchange rate due to the limited time we had to complete this thesis. If there were no contracts to enter the first trade day of August, we entered the contracts later on, when we had closing prices. The idea is to hedge the entire year, preferably at one date, when the spot price is not reflecting the price of the financial contract. The closer one gets to the hedging period, the higher price the financial contract could have, thus being too expensive to enter. This can be avoided by entering the hedge early on when the hedge price is not reflected by a high spot price.

Our purpose with this thesis is to focus on how to hedge in order to cover possible price spikes. Therefore, we need to measure an entire year, i.e. plan hedging strategies and calculate various costs. This is due to the fact that one can never know when the price spike will occur or if it occurs at all, thus one needs to be hedged more or less the whole year. We assumed that price spikes are more likely occur in the winter season due to cold temperature. The winter season is divided in two parts, first there is W1, which is the period from January 1st till the last day of April. The second period W2, starts October 1st and continues till the last day of December. Even though price spikes can occur in the summer period between W1 and W2, due to for example price manipulation or disturbance in the production from malfunctions, we looked at the historic facts, which showed that there was a much greater risk of large increases in the electricity price during the winter periods. Therefore we put more emphasis on hedging those seasons.

In all strategies we have used the actual spot price and the actual consumption per hour, collected from Nordpool, as a base for further calculations of our three different strategies. By multiplying the spot price per hour by the actual consumption per hour we obtain the physical power that the electricity trading company needs to purchase. This volume is actually the amount oh MWh the end consumer is using and it is the amount of electricity the trading company is obliged to deliver to their customers due to their contractual agreement. The physical amount of electricity will be used to compare with our forecast, the closer we are with our forecast to the actual electricity consumption per hour the better off the trading company is since it will not have to settle the deviating forecast in the regulating market, thus saving money.

As previously explained we have a forecast, which we base our hedging on. This forecast is a prediction of how much the electricity consumption will be per hour during a whole year. The forecast is typical for a small electricity trading company who does not have too many large industrial customers. The forecast is based on a percentage factor per hour, prepared by Mikael Jednell at Plusenergi, and is compiled by several issues that will affect the coming years electricity consumption. Some issues are weather conditions, supply of water, prices on oil and coal and the degree of downsizing in the nuclear power sector. These issues will certainly affect the consumption of electricity and we were fortunate to obtain forecasts for the years 2000 and 2001. For the rest of the years we were not able to get such forecasts, so we used the forecast for the year 2000 as a base for our hedging decisions. As mentioned in our section assumptions, we assumed that total actual consumption is equal to total forecasted consumption. This means that we multiplied the forecasted percentage per hour by the total actual consumption for the specific year, which gave us a forecasted MWh consumption per hour. It is the consumption we are hedging and it tells us the amount of electricity we need to hedge per hour and year.

For each hedged time period we have calculated the financial settlement per hour, which is basically the result of the hedge each hour, which is added up to a total result of the hedge. Another calculated variable in our model is the result of the volume difference, which is also a financial settlement and it shows how we are placed with our hedged consumption compared to what the actual consumption is. This will result in either a positive or a negative cash flow, computed by taking the difference between the spot price and the average hedge price and multiplying it with the volume difference. Next we have the total cost, which is the sum of the total cost of physical power purchase.

The part we will explain now concerns the regulating market and the cost of having an inaccurate forecast, i.e. having a forecast that is not following the actual consumption profile. This deviation is very ordinary and there is almost always a deviating forecast every single hour of the year. This has to do with the fact that it is extremely difficult to know the exact amount of electricity that will be consumed for all the hours in the year. The forecast an electricity trading company performs is firstly done for an entire year or perhaps a longer time period. But the closer the trading company gets to the hedged time period, the more adjustments will be made. Due to obvious reasons we are not able to adjust our forecast on a daily basis, since it will require us to make an adjustment every day during an entire year, which is not possible due to the limited time we have to complete our thesis. For this reason, as previously mentioned, we have made the total consumption equal to the total forecasted consumption. The total deviating forecast is not to exceed 7 % for a year. This is due to the fact that we, as explained, are not adjusting the forecast and we have, for a more real trading scenario, corrected the deviating forecast to lie in the interval 6.5 – 7 %. This corrected forecast is then reformulated into an absolute value, so that we can see the exact number of MWh needed to be settled in the regulating market. The deviated amount of MWh will always, if there are regulating prices, be costly for the electricity trading company. We will now explain the calculations concerning the regulating market in our model, which will lead to the regulating cost per hour and is included in the variable total cost.

In the case of an incorrect forecast the following scenarios could take place in the regulating market:
Scenario 1, if *the forecasted volume is too low* and there is a positive deviation of the forecast (forecasted consumption is less than the actual consumption) and there exists an upwards regulating price at the specific hour, the amount of deviating MWh is multiplied with the upwards regulating price, thus a financial loss since the upwards regulating price is always higher than the spot price. If there is no upwards regulating price at the specific hour the amount of deviating MWh is multiplied with the spot price, thus no financial loss.

Scenario 2, if the *forecasted volume is too high* and there is a need to financially settle the excess of power, the following will take place. If there is a negative deviation of forecast (forecasted consumption is higher than the actual consumption) and there exists a downwards regulating price at the specific hour, the amount of deviating MWh is multiplied with the downwards regulating price. The financial loss is the difference between the spot price and the down-regulating price multiplied with the deviating consumption. If there is no downwards regulating price that specific hour there will be no loss, since the spot price is used and there will be no difference in between the two prices.

In order to show our calculated costs of hedging and buying electricity we decided to compare the total cost with the income from the sale of electricity to the end consumer. This makes the research easier to relate to since it will give us a result (total income-total cost). To obtain the income from the consumers we need to determine a sale price to the electricity trading company's customers. This price will be estimated based on the assumptions previously explained. We started by calculating the previous year's average spot price by adding all the spot prices for the specific year and then dividing the sum with the number of hours of the year. Then we calculated the balance cost, the cost that the electricity trading company will include in the sale price to their customers due to their responsibility to stay on track with their stated forecast, i.e. they will have an extra cost which stems from their operations in the regulating market. To obtain the balance cost we divided the total regulating cost with the total forecasted volume. The next variable we needed to include was the price to hedge a one year period. This price was taken from Nordpool. The last variable to compute was the volume weighted spot price for the previous years volume, which is computed by taking the hourly forecasted volume divided by the total forecasted volume, thus getting a percentage factor. Next we multiplied that factor with the spot price and added it up to a total price. Now we had all the necessary variables for calculating the sale price of electricity. The end customer price (sale price) is calculated in the following way.

Hedge Price for one year + (Volume Weighted Spot Price – Average Spot Price) + Balance Cost

When the end consumer price was calculated we were able to obtain an income from the sale of electricity to the end consumers. This income was then set against the total cost of purchasing power, and as a result we obtained yearly results for the fictitious electricity trading company. These results will be discussed later on in the result section.

5.5 Simulations

In order to show the importance of having a serious approach to risk management and hedging we decided to simulate spot prices according to two different scenarios of what the future might look like. With the trend today that the Swedish electricity consumption is increasing while the electricity production is decreasing or staying the same, the risk is that the electricity production will not be enough to cover the total demand at times of peak load. This will increase the spot price as well as the number and amplitude of price spikes. We made the simulations in cooperation with Kaj Forsberg at EME - Analys. The first scenario is for one year, two or three years ahead in the future, and is based on the year 2000 when there was a serious price spike. This means that the consumption is the same as in year 2000 and the increase in the spot price is for this fictitious year, based on the spot price in year 2000. We assume that the production will not be able to cover the total demand and that reserve capacity has to be used to a larger extent than in 2000. This implies that the price spike will be of larger amplitude, i.e. that it will be a steeper price spike. This is due to the fact that the reserve capacity will be used at an earlier stage than in 2000. We calculated the spot prices so that when the spot price in 2000 was between SEK 200 and SEK 500, the coal condensation (electricity from coal) was in effect, so we multiplied the price for the hours in this interval by a factor of three. Then, if the spot price was between SEK 500 and SEK 1000, the oil condensation (electricity from oil) was in effect so we multiplied that factor with three as well. Finally, if the spot price was over SEK 1000 then Svenska Kraftnät had to disconnect parts of the grid system and these hours' price was multiplied by a factor of three. The reason we used a factor of three is that the specific reserve effect used will approximately multiply the specific price level three times. The second scenario we simulated is more of an extreme case. We assumed that the actual price spike in January 2000 would occur at five more dates during Winter 1 and Winter 2. We applied the same spot prices as in January 24th and 25th on the following dates: February 8th and 9th, March 15th and 16th, April 10th and 11th, November 15th and 16th, and December 17th and 18th.

6. ANALYSIS AND RESULTS

In this chapter we will start by describing our three strategies and then we will analyze the strategies and compare them for the years we are measuring. Finally, we will look at the total result and give concluding remarks on our results.

6.2 Year by Year Analysis

6.2.1 Strategy 1 –FWYR, W1 and W2

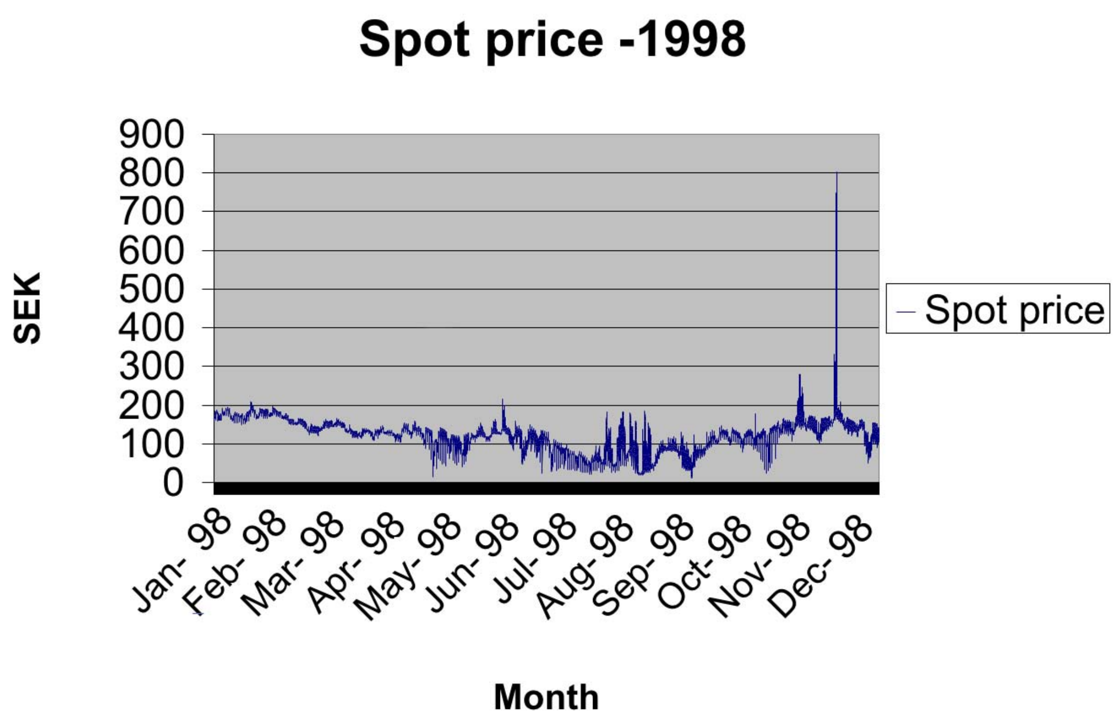
In 1998 the total result of strategy 1 was SEK 82,805,553. The cost of buying the electricity on the spot market was SEK 356,128,934, and the income from customers was SEK 524,532,116. This implies that if the electricity trader would have decided to disregard all the risks and not hedged his volume at a certain price, there would be a positive outcome of SEK 168,403,183 instead of SEK 82,805,553 as in our strategy (see table 6.2.1). However, one has to bear in mind that there is a significant risk associated with not hedging and if the electricity trader would engage in such a strategy for this year, the risk would have paid off.

Table 6.2.1: Result Strategy 1, Year 1998 (All figures in SEK).

1998	Strategy 1
Physical cost (spot)	- 356 128 934
Result hedge	- 85 597 553
Income Customer	524 532 116
Total result	82 805 629
Unhedged result	168 403 183

The reason for being better off unhedged is that the actual spot price was on average lower than the hedge price over the year. The market had predicted the average spot price to be SEK 180.24 when in fact it turned out to be SEK 128.57. The loss due to the financial settlement is offset by the income received from the end consumer, and this is due to the fact that the price the end consumer pays for the electricity is higher than the price the electricity trading company has locked in through the forward contracts. The total result was however, positive and included a hedge that reduced the risk significantly. The 12th of December 1998 (see Figure 6.1) there were some upwards price fluctuations, which generated a total result for those hours of SEK –755,196. This can be compared to the total result of SEK –1,185,282, if being unhedged during the hours of high prices[6].

Figure 6.1: Spot price of electricity, Year 1998



Source: Nordpool

Clearly, it can be seen that there is an advantage to be hedged during those hours, but if one looks at the result of the hedge over a the whole year period one can determine that the hedge result itself was not successful, since it was SEK -85,597,553 in the end of the year. This hedge result is due to the fact that the hedge price was a lot higher than the actual spot price over the year. The predicted average spot price for 1998 was SEK 180,24 and the actual average spot price

[6] See appendix 9.3

turned out to be SEK 128,58, which implies that the spot price was quite inaccurately forecasted.

In 1999 our fictitious electricity realised a positive total result of SEK 5,980,201, and this was due to that the income from consumer was SEK 450,628,091. The total cost was SEK 343,463,226, thus a positive result.

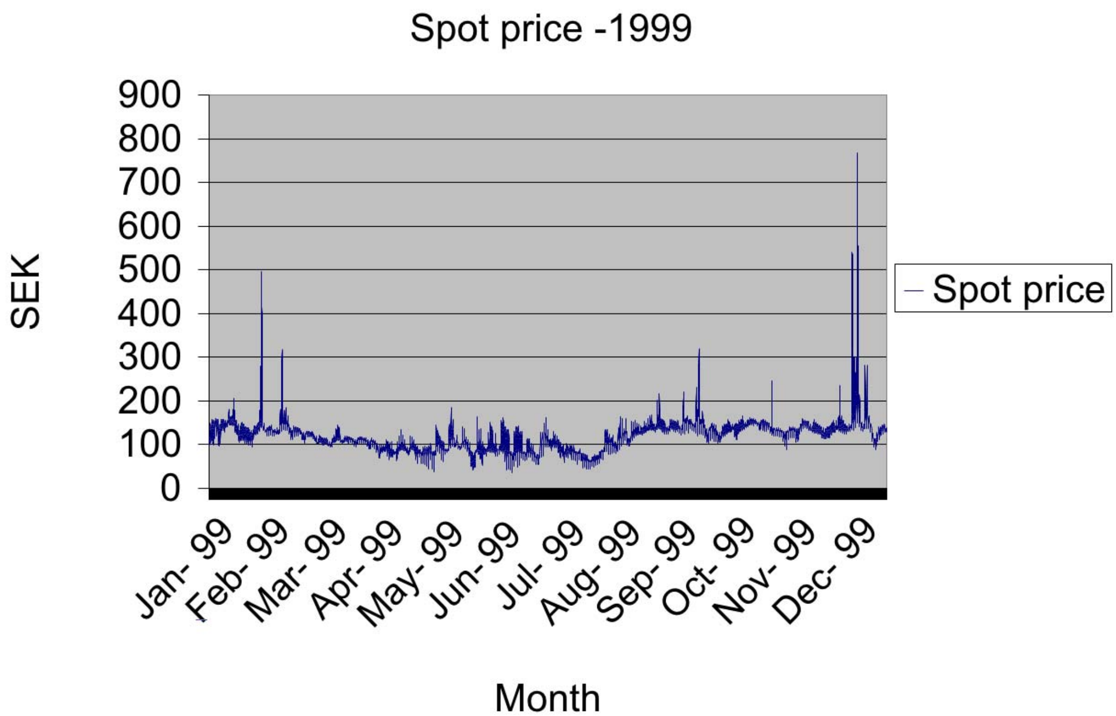
Table 6.2.2: Result Strategy 1, Year 1999 (All figures in SEK).

1999	Strategy 1
Physical cost (spot)	- 343 463 226
Result hedge	- 101 184 664
Income Customer	450 628 091
Total result	5 980 201
Unhedged result	107 164 865

The hedge result was SEK –10,184,663, which is a quite large negative financial settlement for the company. This has to do with the fact that the spot price of SEK 154,75 was, as in 1998, not accurately predicted for the year, it turned out to be SEK 125,64 and this difference generated the large financial settlement loss, which affected the total result to become negative for the year. If the company had chosen not to be hedged at all the result would have been much more satisfying, the unhedged result would have been SEK 107,164,865. Compared to 1998, we can see that the income from customer was significantly less in 1999, and that the cost of buying electricity on the spot market had not declined in the same proportion. This implies that there was notably more risk involved in not hedging this year. This can also be evidenced by the fact that when the price increased a lot on the Dec 16th for 13 hours (see figure 6.2) not a price spike but a significant increase in the spot price, the total result of being hedged was SEK –856,133 and the total result of being unhedged during the hours of the price increase was SEK –1,136,230[7].

[7] See appendix 9.4

Figure 6.2: Spot price of electricity, Year 1999 (all figures in SEK).



Source: Nordpool

In year 2000 the total result was SEK –18,710,226, which was, as in 1999, due to the fact that the income received from consumers was lower than the physical cost of electricity together with the negative result of the financial settlement. The income was SEK 405,125,917, the result of the hedge (financial settlement) was SEK –58,770,673 and the physical cost of buying electricity was SEK 365,065,471.

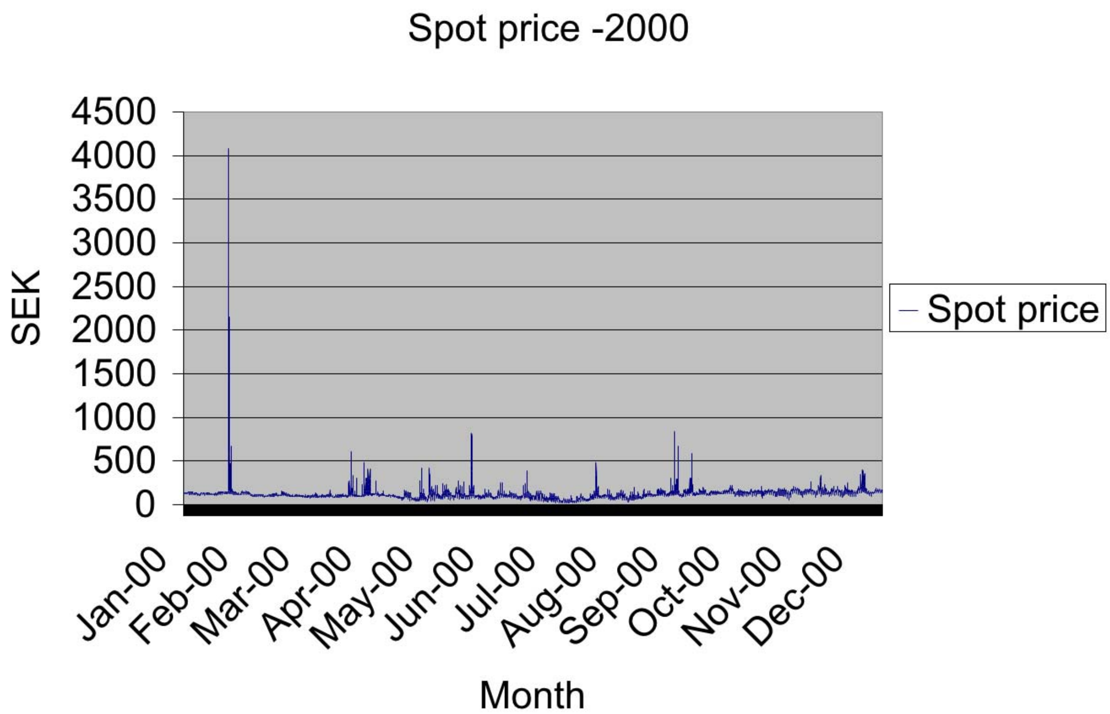
Table 6.2.3: Result Strategy 1, Year 2000 (all figures in SEK)..

2000	Strategy 1
Physical cost (spot)	- 365 065 471
Result hedge	- 58 770 672
Income Customer	405 125 917
result options	
Total result	- 18 710 226
Unhedged result	40 060 446

In 2000 there was significant volatility in the spot price for 13 hours on January 24th (see figure 6.3), this was in fact a tremendous price spike, the spot price increased by more than 3000 %. The financial settlement for these hours was SEK 5,981,938[8]. This means that the electricity company would be SEK 5,981,938 better off with this hedge strategy compared to not hedging the volume. The total result for the strategy for these hours was SEK –5,078,967, this can be compared to a result of SEK –11,690,186 if being unhedged. During these hours the underhedged volume was 1376 MWh and this volume has to be acquired in the spot market at extremely high prices. Another reason, although not as contributing to the total result is the regulating cost. The regulating cost is due to the fact that our company has forecasted a consumption that was higher than the actual consumption for these hours. The deviation in volume has to be financially settled with Svenska Kraftnät, which will generate a loss of SEK 841,664. Evidently, it was advantageous to be hedged during the hours of the price spike since it reduced the loss significantly.

[8] See appendix 9.5

Figure 6.3: Spot price of electricity, Year 2000.



Source: Nordpool

In 2001 the total result with this strategy was SEK –2,187,120, this was due to the fact that the income received from customers together with the positive financial settlement of SEK 143,555,766 was lower than the physical cost of purchasing electricity on the spot market, which was SEK 424,187,312.

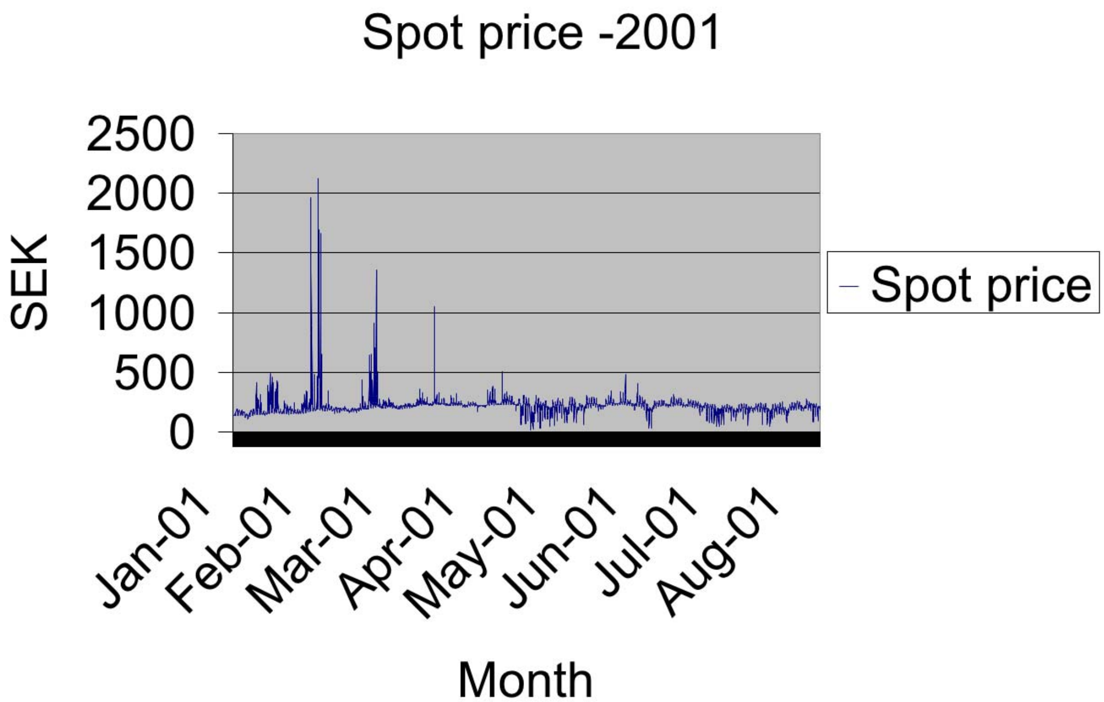
Table 6.2.4: Result Strategy 1, Year 2001 (all figures in SEK).

2001	Strategy 1
Physical cost (spot)	- 424 187 312
Result hedge	143 555 767
Income Customer	278 444 425
Results options	
Total result	- 2 187 120
Unhedged result	- 145 742 887

It is notable that the physical cost of buying electricity on the spot market has increased tremendously in 2001 compared to 2000. We are measuring only until the end of August 2001 and the physical cost is higher at that point than the total physical cost was for the entire 2000. The reason for this is that the spot price increased a lot and in February 5th and 6th the spot price jumped up by more than 1000 % within a 37 hours time interval (see figure 6.4). The result of being hedge during these hours generated a total result of SEK –3,406,115 while being unhedged would have generated a total result of SEK –9,467,789[9]. The negative result was due to the fact that we were underhedged during these hours by 2461 MWh and this volume had to be purchased at very high spot prices. Another large increase in the spot price occurred on March 1st when the spot price increased 650 % (see figure 6.4). The result of being hedged during the five hours of peak prices was SEK –445,966 and the unhedged result would have been SEK –1,731,394[10]. The underhedged volume during these hours was 300 MWh, which also was purchased at very high spot prices.

[9] See appendix 9.6
[10] See appendix 9.7

Figure 6.4: Spot price of electricity, Year 2001 (all figures in SEK)



Source: Nordpool

6.2.2 Strategy 2- Block Contracts.

In 1998 the total result of the block contract strategy was SEK 39,554,655. The cost of buying the electricity on the spot market was SEK 356,128,934, and the income from customers was SEK 524,532,116. This implies that if the electricity trader would have decided to disregard all the risks and not hedged his volume at a certain price, there would be a positive outcome of SEK 168,403,183 instead of SEK 39,554,655 in our strategy. However, one has to bear in mind that there is a significant risk associated with not hedging and if the electricity trader would engage in such a strategy for this year, the risk would have paid off.

Table 6.2.5: Result Strategy 2, Year 1998 (all figures in SEK).

1998	Strategy 2
Physical cost (spot)	- 356 128 934
Result hedge	- 128 848 517
Income Customer	524 532 116
Total result	39 554 665
Unhedged result	168 403 183

The reason for achieving a better result unhedged was that the actual spot prices were declining to lower levels than expected . The market had predicted the average spot price to be SEK 180.24, when in fact it turned out to be SEK 128,57. The 12th of December 1998 (see figure 6.1) there were some upwards price fluctuations, which generated a total result for those hours of SEK –365,219[11]. This can be compared to the total result of SEK –1,185,282, if being unhedged during the hours of high prices. This shows the importance of being hedged if a price spike occurs. Even if the result of being unhedged was larger, the total result was however, substantially positive and that included a hedge that reduced the risk significantly.

In 1999 the total result was SEK 3,007,031. The cost of buying the electricity on the spot market was SEK 343,463,226, and the income from customer was SEK 450,628,091. If the total volume would have been unhedged then there would have been a positive outcome of SEK 107,164,865.

Table 6.2.6: Result Strategy 2,Year 1999 (all figures SEK).

1999	Strategy 2
Physical cost (spot)	- 343 463 226
Result hedge	- 104 157 834
Income Customer	450 628 091
Total result	3 007 031
Unhedged result	107 164 865

[11] See appendix 9.8

As in 1998 the reason for this is that the predicted average spot price by the market was SEK 154,75 but the actual average spot price turned out to be SEK 125,64. Compared to 1998, we can see that the income from customer was significantly less in 1999, and that the cost of buying electricity on the spot market had not declined in the same proportion. This implies that there was notably more risk involved in not hedging this year. This can also be evidenced from the fact that when the price increased a lot (see figure 6.2) on the Dec 16th for 13 hours[12] (not a price spike but a significant increase in the spot price) the result of financial settlement from the hedge these hours was SEK -435,935. The cost of buying the electricity in the spot market was SEK 2,147,590 so the total cost for these hours was SEK 1,447,295. However, this has to be compared to the income from customers for these hours which was SEK 1,011,360, to get a total result for this strategy of SEK -435,935, compared to a total result of – SEK 1,136,230 if the volume would have been unhedged. The problem is that the electricity trading company can never know when these price increases will occur. If there would have been more and larger price increases then the positive result of not being hedged could have turned out to be negative but as it turned out this year it was better not to hedge, but then there is in essence speculation and not hedging.

In 2000, the total result of the block strategy was SEK 13,510,870. The cost in the spot market was SEK 365,065,471 and the income from customer was SEK 405,125,917. If the electricity trader chooses to engage in risk loving behaviour (unhedged volume) then the total result would be SEK 40,060,446. As in the other years this is due to the fact that the average spot price declined from an expected SEK 136,57 to an actual SEK l 127,08.

[12] See appendix 9.9

Table 6.2.7 : Result Strategy 2, Year 2000 (all figures in SEK).

2000	Strategy 2
Physical cost (spot)	- 365 065 471
Result hedge	- 26 549 576
Income Customer	405 125 917
Result options	
Total result	13 510 870
Unhedged result	40 060 446

Comparing 2000 with 1998 and 1999, we can see that the difference between the result of the strategy and the result of not being hedged has declined significantly, from almost 129 million in 1998 to about 27 million in 2000. As mentioned before, in 2000 there was significant volatility in the spot price for 13 hours on January 24th (see figure 6.3), the spot price increased by over 3000 %. The financial settlement for these hours was SEK 7,569,744[13]. This means that the electricity company would be SEK 7,569,744 better off with this hedge strategy compared to not hedging the volume. The result for the strategy for these hours was SEK -4,120,442. This is due to that you have locked in an average hedge for one month and at these hours when the price spike occurs you are in fact underhedged by a volume of 884 MWh. This volume has to be acquired in the spot market at extremely high prices. Another reason, although not as contributing to the total result is the regulating cost. The regulating cost is due to the fact that our company has forecasted a consumption that was higher than the actual consumption for these hours. The difference in volume has to be sold back to Svenska Kraftnät at a much lower price generating a loss of SEK 841,664. However, the strategy softens the economic impact of the price spike tremendously, if we would have been unhedged then the result would have been a loss of SEK 11,690,186, compared to the already mentioned SEK -4,120,442 and that is only for 13 hours of a whole year. If this would happen at more dates then

[13] See appendix 9.10

the impact would be disastrous to an electricity trading company, which decides to not hedge the volume at a certain price.

In 2001, the total result for the strategy was SEK -4,798,868. The cost to acquire the electricity in the spot market was SEK 424,187,312 and the income from customer was SEK 278,444,425. If our company would have decided not to hedge the volume at the hedge price for this year then it would have resulted in a loss of SEK 145,742,887.

Table 6.2.8 : Result Strategy 2, Year 2001 (all figures in SEK)

2001	Strategy 2
Physical cost (spot)	- 424 187 312
Result hedge	140 944 019
Income customer	278 444 425
Results options	
Total result	- 4 798 868
Unhedged result	- 145 742 887

Compared to all the other years, when the results of being unhedged have been significantly positive there is a tremendous difference between the results. This is due to the fact that the predicted average spot price by the market for 2001 was SEK 137.85 when in fact it turned out to be SEK 228,48. The trend for the other years was that the predicted spot price was significantly higher than what the actual average spot price turned out to be and this created the large difference between the results of being unhedged. As in 2000, there were large sudden increases in the spot price in 2001. More precisely the price spikes occurred on February 5th and 6th and on March 1st (see figure 6.4) During the price spike in February, the spot price increased by more than 1000 %, and our company was SEK 7,161,464 better off by hedging according to the block strategy compared to being unhedged[14]. The total result for the strategy for these 37 hours was SEK – 2,306,325, and this was due to the fact that we were underhedged by a volume of

[14] See appendix 9.11

1157 MWh (because of an average hedge for a month), which we had to acquire in the spot market at high prices. The regulating cost was only SEK 73,668 so the main reason for the cost was that we were underhedged for these specific hours. In the March price spike, the spot price increased by 650 %, and the result of being hedged compared to being unhedged was a positive SEK 1,388,553[15]. We were underhedged by 232 MWh for these five hours and the total result for our strategy generated a loss of SEK 342,842, compared to a total result of SEK –1,731,394 when not hedging. There was no regulating cost during this price spike. The results of this year highlights the risks involved in electricity trading and the importance of having a risk management strategy that secures the right volume at a certain price, so that the electricity trader will not be exposed to the large volatility in the spot price of electricity.

6.2.3 Strategy 3 - Block Contracts Plus Asian Call Options

The result for this strategy is based on the results for the block strategy. As mentioned earlier, this strategy could only be applied on the years 2000 and 2001.

In 2000, the Asian call options generated an income of SEK 242,247. The options for block 01, block 04, block 10, and block 11 provided all the income while, block 02, block 03, block 12, and block 13 generated a loss[16]. The reason for a total gain on the options was that the average spot price for a specific month was in fact higher than the exercise price. Block 10 for instance, had an exercise price of 110, but the average spot price during block 10 was SEK 143,17. This generated a financial gain of SEK 1,282,282, but the premium of SEK 400,846 has to be deducted, to achieve a total result for this Asian block option of SEK 881,436. The result of this strategy depends considerably on what strike price you will receive on your option and what premium it has attached to it. During the

[15] See appendix 9.12
[16] See Appendix 9.13

time period for block 01, the price spike occurred and this created a gain of SEK 339,227 for this block option, however this is not as large as some of the other blocks, but is due to the fact that the strike price for this particular option is rather high. The result for the total strategy was that it generated an income of SEK 13,753,117.

Table 6.2.9 Result Strategy 3, Year 2000 (all figures in SEK)

2000	Strategy 3
Physical cost (spot)	- 365 065 471
Result hedge	- 26 549 576
Income customer	405 125 917
Result options	242 247
Total result	13 753 117
Unhedged result	40 060 446

In 2001, the options generated an income of SEK 13,028,098[17]. All the blocks had a positive result, especially block 03 when the second price spike occurred. It generated a financial gain of SEK 6,510,637, and had a premium of SEK 646,924, to create an income of SEK 5,863,713. The option for Block 02, which was in effect during the more severe price spike in February also created a significant gain but the strike price for Block 03 was considerably lower, 130 for block 03 compared to 160 for block 02. The result for the whole strategy was that it generated an income of SEK 8,229,229. The options part of the total strategy changed a negative result to a positive result, and even though the premiums of the options are high significant benefits can be made. If comparing the result of not being hedged at all and this strategy we can clearly see that risk management is a very important aspect of electricity trading. The strategy of not hedging generated a loss of SEK -145,742,887, while this strategy produced an income of SEK 8,229,229.

[17] See Appendix 9.14

Table 6.2.10: Result Strategy 3.Year 2001 (all figures in SEK).

2001	Strategy 3
Physical cost (spot)	- 424 187 312
Result hedge	140 944 019
Income Customer	278 444 425
Results options	13 028 098
Total result	8 229 230
Unhedged result	- 145 742 887

6.3 Simulated Year

As mentioned earlier, we simulated spot prices for a future year based on the same conditions as in year 2000. We did this in order to determine what could happen to the result if the spot price increased more than the actual outcome. This scenario is something that could be a reality in a few years time, thus we think it is important to show how it will affect the results.

6.3.1 Strategy 1 –FWYR, W1 and W2

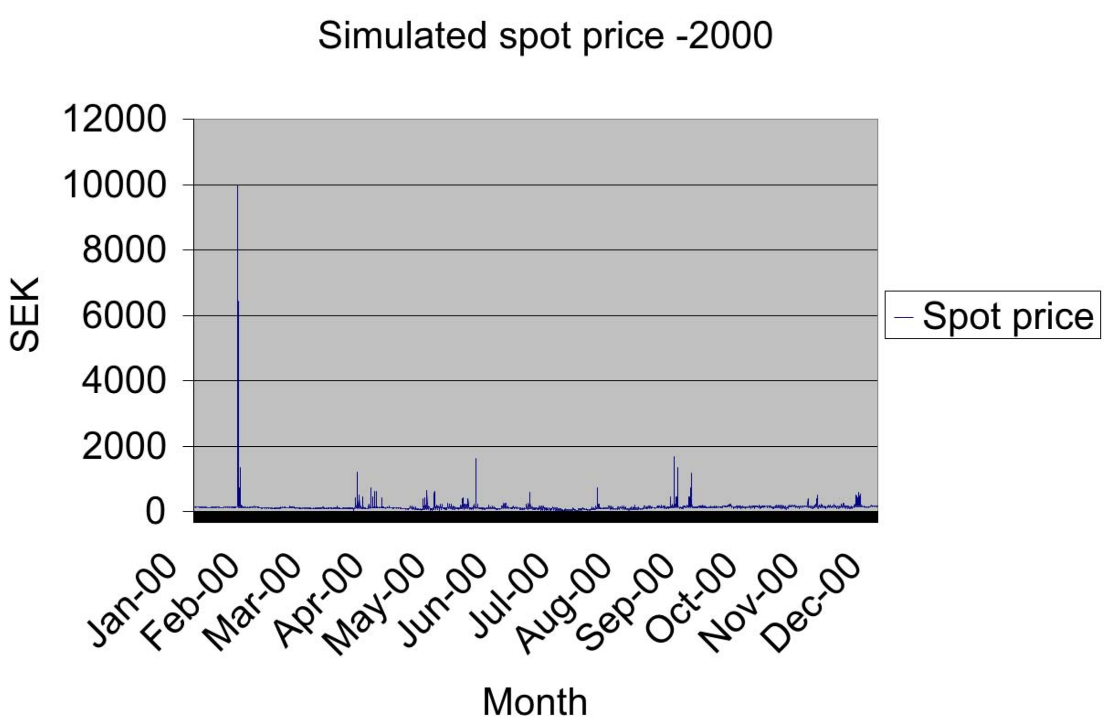
In the first scenario, when having increased the amplitude of the price spike, as explained in our model, the total result of year 2000 was SEK –64,294,198 compared to the total result of SEK –18,710,226, without simulation.

Table 6.3.1: Result simulation Strategy 1 (all figures in SEK).

Simulation 1	Strategy 1
Physical cost (spot)	- 398 198 843
Result hedge	- 71 221 272
Income customer	405 125 917
Results options	
Total result	- 64 294 198
Unhedged result	6 927 074

The cost of buying electricity in the spot market was SEK 398,198,843 and the income received from customer was SEK 405,125,917. One reason, apart from the cost of buying electricity in the spot market, for the negative total result was due to the financial settlement of SEK –71,221,272, which was the consequence of an inaccurate prediction of the average spot price. As can be seen in figure 6.6 below, the amplitude of the price spike is increased and the total result of being hedged during the price spike hours was SEK –17,281,068, while the result of being unhedged was SEK –35,475,772[18]. The underhedged volume during the price spike hours was 1376 MWh, this volume had to be bought to very high spot prices and as a consequence the total result turned out to be negative.

Figure 6.6. Electricity spot price, simulation



The strategy in the second scenario, when we simulated more price spikes in the year 2000 (see figure 6.7), generated a total result of SEK –80,207,078, which can be explained by the extremely high physical cost of buying electricity in the spot market, which turned out to be SEK 547,375,417. This has to do with the increased number of price spikes, which forced the company to buy electricity at

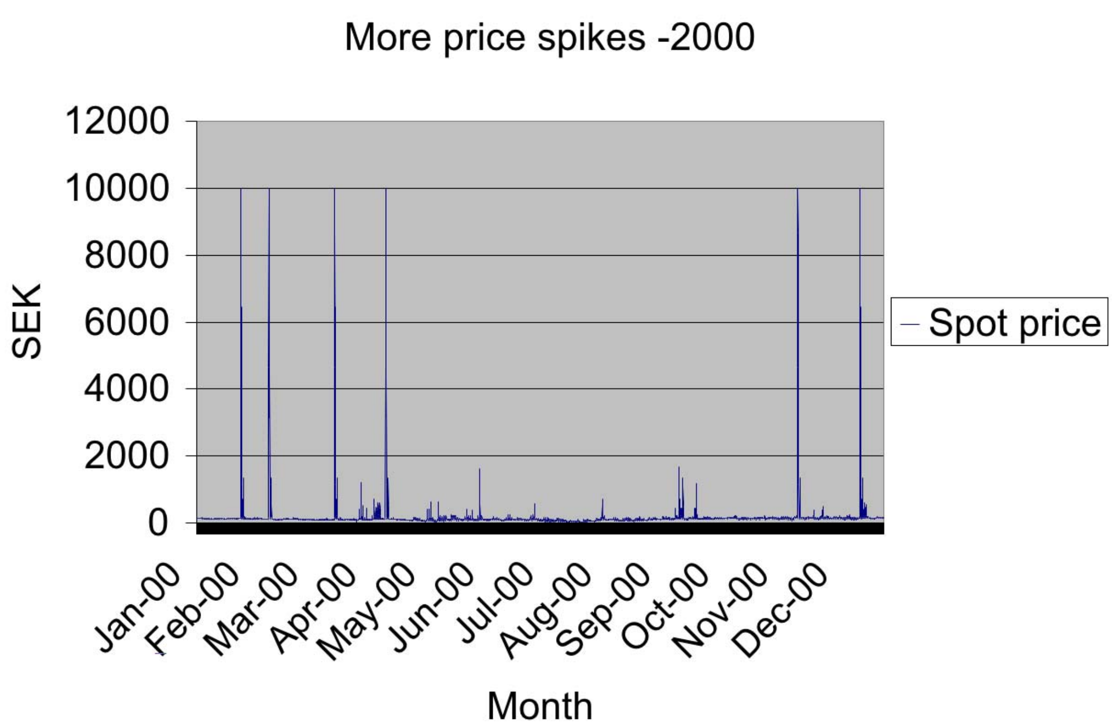
[18] See appendix 9.15

extreme prices at several occasions over the year. The income from customers was, as in the non-simulated year 2000, SEK 405,127,917 and did not reduce the impact of the larger number of price spikes.

Table 6.3.2: Result simulation 2,Strategy 1.

Simulation 2	Strategy 1
Physical cost (spot)	- 547 375 417
Result hedge	62 042 421
Income customer	405 125 917
Results options	
Total result	- 80 207 078
Unhedged result	- 142 249 499

Figure 6.7 Electricity spot price, Simulation 2.



6.3.2 Strategy 2 – Block Contracts

In the first scenario, the total result for the block strategy using the simulated prices was SEK 1,841,471. The cost of buying the electricity in the spot market was SEK 398,198,843, and the income from customer was SEK 405,125,917. Since the spot prices are higher in this scenario the cost in the spot market is higher and if an electricity trading company decides not to hedge, the company would have a total result of SEK 6,927,074 compared to a total result unhedged in year 2000 of SEK 40,060,446.

Table 6.3.3: Result simulation 1,Strategy 2.

Simulation 1	Strategy 2
Physical cost (spot)	- 398 198 843
Result hedge	- 5 105 603
Income customer	405 125 917
Results options	
Total result	1 821 471
Unhedged result	6 927 074

The total result is still a positive, but the difference between the hedged and unhedged result has decreased. During the price spike (see graph) we can clearly see the importance of being hedged. The financial settlement for these 13 hours generated SEK 23,172,347[19]. The total result of the strategy for the price spike was SEK -12,303,426 compared to SEK -35,475,772, if unhedged. The reason for the large cost for these hours in our strategy is that we are underhedged by 884 MWh, and a regulating cost of SEK 2,532,991. Compared to the year 2000, the results for the price spike differ greatly, but so does the results of the strategy.

In the second scenario, where we added the price spike in scenario 1 at five more dates, the total result of the block strategy was SEK -25,381,152. The cost of acquiring the electricity in the spot market was SEK 547,815,373 and the income generated from sale to customers stayed the same at SEK 405,125,917.

[19] See Appendix 9.16

Table 6.3.4: Result simulation 2, Strategy 2 (All figures in SEK).

Simulation 2	Strategy 2
Physical cost (spot)	- 547 375 417
Result hedge	116 868 347
Income Customer	405 125 917
Results options	
Total result	- 25 381 152
Unhedged result	- 142 249 499

The reason for the decline in the total result for our strategy is that there are price spikes in five more dates compared to scenario 1 and year 2000. The increased cost of buying in the spot market is not offset by the gain of the financial settlement. However if one would have been unhedged at this scenario the loss would have been SEK 142,249,499. This scenario emphasizes the incredible risk an electricity trader is exposed to and the amounts that are at stake even for a small electricity trader in the market today.

6.3.3 Strategy 3 – Block Contracts plus Asian Call Options

In the first scenario when the prices were higher the option part of the strategy generated an income of SEK 4,775,080[20]. The blocks that generated positive financial settlement were: Block 01, Block 04, Block 10, and Block 11. Compared to the result for the year 2000, we can see that the options for this year are more effective, especially the option for Block 01, which generated a positive financial result of SEK 4,215,524 in this year compared to SEK 339,227 in year 2000. This is due to the more severe impact of the price spike since we can see that the average spot price during the period increased from SEK 163,37 (year 2000) to SEK 231,33 (this year). The result for the whole strategy was SEK 6,616,552.

In the second scenario the options part of the strategy generated a financial gain of SEK 25,920,029. All the Blocks generated a positive financial settlement,

[20] See appendix 9.16

compared to the first scenario and year 2000 all blocks except Block 01,Block 10, and Block 11 increase the financial gain from the settlement significantly[21]. The increase, for this extremely simulated year, is due to the fact that there are price spikes in these periods. The total result for the whole strategy was SEK 538,887.

Table 6.3.6 : Result simulation 1 & 2, Strategy 3 (All figures in SEK).

Strategy 3	Simulation 1	Simulation 2
Physical cost (spot)	- 398 198 843	- 547 375 417
Result hedge	- 5 105 603	116 868 347
Income Customer	405 125 917	405 125 917
Results options	4 775 080	25 920 029
Total result	6 616 552	538 877
Unhedged result	6 927 074	- 142 249 499

6.4 Comparison of the Strategies

In order to reach valid conclusions in our thesis we need to compare disadvantages and advantages of our different strategies. Furthermore, we need to analyse the reasons why one strategy is superior to the other and draw conclusions from that.

In 1998, we were only able to compare two strategies since option contracts had not been introduced on Nordpool. Strategy 1, consisting of FWYR, W1, and W2, generated a superior total result compared to strategy 2, consisting of block contracts for the entire year. The difference between the two strategies was SEK 43,250,964. The reason for this difference is that the financial settlement for strategy 1 generated a negative result that was less than the negative financial settlement for strategy 2 (see table 6.4.1). This was due to the fact that the difference between the actual average spot price of SEK 120,51 and the average hedge price of SEK 158,20 for strategy 1 was in fact smaller than the difference between the actual average spot price and the average hedge price of SEK 168,79 for strategy 2.

[21] See appendix 9.17

Table 6.4.1: result comparison of the strategies, Year 1998 (All figures in SEK).

1998	Strategy 1	Strategy 2
Physical cost (spot)	- 356 128 934	- 356 128 934
Result hedge	- 85 597 553	- 128 848 517
Income Customer	524 532 116	524 532 116
Total result	82 805 629	39 554 665
Unhedged result	168 403 183	168 403 183

In 1999, as in 1998 we were only able to compare the first two strategies. The strategy consisting of FWYR, W1, and W2 proved to be the most efficient strategy with a total result of SEK 5,980,201. It was SEK 2,973,170 more profitable than strategy 2, because of a better financial settlement result from the hedge (see table 6.4.2).

Table 6.4.2: result comparison of the Strategies, Year 1999 (All figures in SEK).

1999	Strategy 1	Strategy 2
Physical cost (spot)	- 343 463 226	- 343 463 226
Result hedge	- 101 184 664	- 104 157 834
Income Customer	450 628 091	450 628 091
Total result	5 980 201	3 007 031
Unhedged result	107 164 865	107 164 865

Since there were no major price increases in 1999, the less precise hedge of strategy 1 had a marginally better result. If there would have been some major price increases strategy 2 would have proved to be more efficient. This can be evidenced by the price increase in Dec. 16th, which provided the block strategy with a financial settlement from the hedge in excess of SEK 800,000 compared to only SEK 430,086 for strategy 1.

In 2000, we included our third strategy, which consists of block contracts plus Asian call options. The most successful strategy for this year turned out to be strategy 3, consisting of block contracts plus Asian call options. The total result for this strategy was SEK 13,753,117, compared to SEK 13,510,870 for strategy 2 and SEK –18,710,226 for strategy 1 (see table 6.4.3).

Table 6.4.3. result comparison of the strategies, Year 2000 (All figures in SEK).

2000	Strategy 1	Strategy 2	Strategy 3
Physical cost (spot)	- 365 065 471	- 365 065 471	- 365 065 471
Result hedge	- 58 770 672	- 26 549 576	- 26 549 576
Income Customer	405 125 917	405 125 917	405 125 917
Result options			242 247
Total result	- 18 710 226	13 510 870	13 753 117
Unhedged result	40 060 446	40 060 446	40 060 446

The main reason for the different results is the difference between the average locked in hedge price and the actual average spot price of the year. The average hedge price for strategy 2 and 3 (options serves as an extra insurance, thus the same average hedge) was SEK 134,92 compared to SEK 139,01 for strategy 1. The average annual spot price is SEK 120,11, which means that strategies 2 and 3 will have a better financial settlement over the year compared to strategy 1. The strategy with the smallest deviation from the actual average spot price will most likely have the superior result over the whole year. Having a more precise hedging strategy over the year, i.e. more contracts with better forecasted prices, is especially important in order to reduce the volume difference. This can be evidenced by the result of the volume difference for strategy 2 and 3, which was SEK –8,960,106 compared to SEK –12,180,048 of strategy 1. Another advantage of having a finer hedge is that it reduces the negative impact of price spikes, which in strategy 1 had a total result of SEK –5,708,967 compared to SEK –4,120,442 for strategy 2. From Table 6.4.3, we can see that the option contract contributed with SEK 242,247 in addition to the total result for strategy 2. Even though the premium of the options were set to a very high price we can see that they contribute positively to the total result and that this strategy provides an extra insurance, since it deals in rights and not obligations, for more price spikes.

In 2001, strategy 3 proved to be the superior strategy with a total result of SEK 8,229,230, compared to a negative result for strategy 1 of SEK –2,187,120 and SEK –4,798,868 for strategy 2. The better total result of strategy 3 is due to the large positive contribution of the option contracts, which generated an additional positive cash flow of SEK 13,028,098 (see Table 6.4.4). The reason for the positive result of the options was that the locked in exercise prices were lower than the actual average spot price for that period. In fact the average predicted spot price by the market was SEK 137,85 when the actual average spot price turned out to be SEK 215,53. This produced a significant positive financial settlement for the other two strategies as well, but the most effective strategy was the block plus Asian call option strategy since it proved to be very effective when there were price spikes.

Table 6.4.4. Result comparison of the strategies, Year 2001 (All figures in SEK)

2001	Strategy 1	Strategy 2	Strategy 3
Physical cost (spot)	- 424 187 312	- 424 187 312	- 424 187 312
Result hedge	143 555 767	140 944 019	140 944 019
Income Customer	278 444 425	278 444 425	278 444 425
Results options			13 028 098
Total result	- 2 187 120	- 4 798 868	8 229 230
Unhedged result	- 145 742 887	- 145 742 887	- 145 742 887

6.4.1 Simulation

In scenario 1, with a more amplified price spike, the best result was generated by strategy 3, which had a total result of SEK 6,616,552. The option part of the strategy contributed with a financial settlement of SEK 4,775,080. As evidenced by the figures in the table 6.4.5 we can see the need for being hedged with more precise and finer instruments, since strategy 1 shows a significantly negative total result of SEK 64,294,198 compared to strategy 2 and 3. Examining the amplified price spike can further enhance the need for more precise strategies. The total result for strategy 1 was during the price spike a considerable loss of SEK

17,281,068 compared to a negative total result for strategy 2 of SEK 12,303,426. In strategy 3, the negative result during the price spike is reduced by a positive SEK 4,214,524 from the Block 01 Asian call financial settlement.

Table 6.4.5 Result comparison of the strategies, simulation (All figures in SEK).

Simulation 1	Strategy 1	Strategy 2	Strategy 3
Physical cost (spot)	- 398 198 843	- 398 198 843	- 398 198 843
Result hedge	- 71 221 272	- 5 105 603	- 5 105 603
Income Customer	405 125 917	405 125 917	405 125 917
Results options			4 775 080
Total result	- 64 294 198	1 821 471	6 616 552
Unhedged result	6 927 074	6 927 074	6 927 074
Simulation 2			
Physical cost (spot)	- 547 375 417	- 547 375 417	- 547 375 417
Result hedge	62 042 421	116 868 347	116 868 347
Income Customer	405 125 917	405 125 917	405 125 917
Results options			25 920 029
Total result	- 80 207 078	- 25 381 152	538 877
Unhedged result	- 142 249 499	- 142 249 499	- 142 249 499

In scenario 2, with five more amplified price spikes, the need for a more precise and finely tuned hedging strategy is apparent. The strategy that was most successful was again strategy 3, which had a total result of SEK 538,887 (see table 6.4.5). This can be compared with the total result for strategy 1 of SEK – 80,207,078 or even worse an unhedged position, which generated a loss of SEK 142,249,499. The options contributed with a financial settlement of SEK 25,920,029 and even though this is an extreme scenario it shows the importance of considering options as part of a successful hedging strategy. Indeed this is an extreme scenario but it shows, as stressed before, the need of a precise hedging strategy with fine contracts.

In evaluating the hedging strategies it is important to not only emphasise the total result of the strategies from year to year. One very important factor when analysing and comparing the strategies in order to give recommendations for the best strategy is the volatility of the total result. The total result and the volatility will be the base of our final recommendation of the strategies, which we will present in the next chapter.

7. CONCLUSIONS

This chapter presents our conclusion regarding which strategy we found to be the most advantageous to use in terms of reducing the risk associated with price spikes and at the same time produce the best total result over the year. Furthermore, we determine the most critical issues that can improve the performance of a small electricity trading company's hedging strategy.

With the assumptions we have made and with the outcome of our research, we have come to the conclusion that the strategy with a combination of highest total result, least amount of volatility of the result, and the best protection against losses due to sudden large increases in the spot price of electricity, is the most advantageous hedging strategy. We identified strategy 3, i.e. block contract plus Asian call options for the winter seasons, to fulfil all these criteria's. Our conclusion is based on the yearly total results, generated from hourly calculations, obtained from our quantitative model and in-depth analysis of the price spike on an hourly basis. The problem is that it is virtually impossible to know exactly when a price spike will occur, and there is a delicate balance between being hedged to reduce the impacts of the price spike and the possibility that no price spike will occur, thus generating large negative financial settlements from being overhedged. We can conclude from our study that the risk will be minimised if the electricity trading company is finer hedged, i.e. using contracts with shorter time periods and includes options as an extra insurance during the critical winter seasons when the price spike is more likely to occur.

During the course of our thesis we have come across issues that could improve the performance of a smaller electricity trading company's hedging strategy.
First of all more emphasis should be put on implementing a broader risk management strategy, especially for the smaller electricity trading companies. This is based on the trend that today's situation with a rising demand and a decreasing production will lead to significantly more risks on the Nordic electricity market

(Hammarstedt et al, 2001). Secondly, we have observed a need of more precise hedging instruments, such as standardized daily and hourly contracts tailored for the use in times of peak load capacity. We recommend that these contracts should be introduced on Nordpool. In order for these types of contracts to function properly in the market, there must be a common attempt to increase the liquidity on Nordpool. Thirdly, through our work we could see that the use of option contracts was successful, however the option market is illiquid and hardly any trading activity takes place. Even though the poor liquidity and the fact that the premiums are high, we recommend that electricity traders consider options as a tool in their hedging strategy. Fourth, it is extremely difficult to predict how the electricity price will move in the future, which requires that the electricity trader will have to put more time and effort in analyzing and then actively manage this price risk. We recommend the electricity traders to make risk measures each day. Fifth, implementing a well functioning risk management strategy requires capacity and resources and certain smaller electricity companies may not be capable of this. Hence, our recommendation for these companies is to outsource their risk management operations externally since, as proved in our thesis, the risks of not having a well functioning hedging strategy are significant. Finally, based on our work and what we have learnt during the course of our thesis, it is our belief that only the most intense and analytical companies will survive in the future electricity trading industry.

7.1 Suggestions for Further Research

During the course of our thesis we have gained the insight that the electricity trading business is a highly complex industry and that there is a lot of work to be done in order to come to terms with the significant risks that are associated with electricity trading. It would be interesting to investigate further what type of combination of financial instruments will be the most favourable protection against the negative economic effects of price spikes. Our thesis can be used as a starting point and then additional strategies can be implemented in order to reach a statistically significant conclusion.

We also believe it would be interesting to investigate how new contracts between the electricity trading company and the customer could be developed. The situation today is that the electricity trading companies take on too many of the risks and are exposed to the large fluctuations in the spot price of electricity. One type of contract that is worth considering is some kind of standardised contract where the customer and the electricity trading company shares the risk i.e. the customer takes on some parts of the risk in exchange for a lower electricity price. Some of these contracts exist today, but the need for a permanent solution is needed.

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.

APPENDICES

9.1 Appendix I

Questionnaire

1. Do you use hedging in your risk management strategy?
2. If yes, what type of contracts are used?
3. How often do you hedge?
4. How far ahead in the future do you hedge?
5. What time periods of the year do you hedge?
6. Is there any specific time period you consider to be more important to hedge?
7. Do you use any combinations of contracts in your hedging strategy?
8. Why are price spikes a tremendous problem?
9. How do you protect yourself against price spikes?
10. What type of contract do you consider being the most effective protection against price spikes?
11. What is your idea of a well functioning hedging strategy in order to minimise the negative economic effects of price spikes and at the same time generate a good yearly result?
12. How do you perceive risk in your company?
13. What risks do you consider to be the greatest?
14. What risk policy do you have?

9.2 Appendix II

Table 9.2: Price spike December 8, 1998, Strategy 1.

Hour	Actual Spot price	Actual (2%) Volume (MWH)	Forecasted Volume	Hedge Price	Hedge Year Volume (MWH)	Winter2 Price	Volume MWh	Volume Difference	Result hedge	Tot. Cost. Phys.	Total cost
8	293,6	464,1	389,7	152,2	255,2	196,9	90,0	-118,9	20729,1	136224,8	115495,7
9	748,8	469,0	417,6	152,2	255,2	196,9	90,0	-123,8	79872,6	351157,2	271284,6
10	511,0	463,3	422,1	152,2	255,2	196,9	90,0	-118,2	50617,5	236731,4	186113,9
11	409,3	462,2	423,7	152,2	255,2	196,9	90,0	-117,1	36959,7	189179,5	152219,8
12	311,8	457,8	423,1	152,2	255,2	196,9	90,0	-112,7	24149,9	142754,1	118604,2
13	245,2	451,4	418,3	152,2	255,2	196,9	90,0	-106,3	15175,1	110678,4	95503,3
14	243,1	447,5	417,9	152,2	255,2	196,9	90,0	-102,4	15162,2	108783,5	93621,4
15	270,6	450,7	425,4	152,2	255,2	196,9	90,0	-105,6	19022,9	121951,3	102928,4
16	296,6	464,8	441,5	152,2	255,2	196,9	90,0	-119,7	21054,4	137872,3	116817,9
17	402,1	472,3	464,4	152,2	255,2	196,9	90,0	-127,2	33536,8	189909,0	156372,2
18	803,9	468,9	467,1	152,2	255,2	196,9	90,0	-123,8	87125,9	376999,6	289873,8
19	245,4	458,3	456,2	152,2	255,2	196,9	90,0	-113,2	14641,4	112490,4	97849,0
20	222,4	446,8	441,3	152,2	255,2	196,9	90,0	-101,7	12038,6	99354,9	87316,3
		5977,1			**3317,1**		**1169,4**	**-1490,7**	**430086,1**	**2314086,6**	**1884000,5**

Customer Price	**Tot. Cost Physical**	**Result hedge**	**Total Cost**	**Income from customer**
188,9	**2314086,6**	**430086,1**	**1884000,5**	**1128804,2**
Actual Consumption	**Regulating cost**	**Hedged**	**Unhedged**	**MWh underhedged**
5977,1	**0,0**	**-755196,3**	**-1185282,5**	**-1490,7**
	Gain from Strategy VS Unhedged			
	430086,1			

9.3 Appendix III

Table 9.3: Price spike December 16, 1999, Strategy 1.

Hour	Actual Spot price	Actual (2%) Volume (MWH)	Forecasted Volume	Hedge Price	Hedge Year Volume (MWH)	Winter2 Price	Volume MWh	Volume Difference	Result hedge	Tot. Cost. Phys.	Total cost
8	286,1	471,7	388,9	154,7	253,2	174,3	89,3	-129,3	17024,9	189946,6	172921,7
9	768,0	481,6	415,1	154,7	253,2	174,3	89,3	-139,2	70727,3	381980,2	311253,0
10	488,9	477,8	415,8	154,7	253,2	174,3	89,3	-135,3	40170,8	233601,0	193430,2
11	240,2	476,0	419,4	154,7	253,2	174,3	89,3	-133,5	10992,5	115164,7	104172,2
12	227,5	474,1	424,7	154,7	253,2	174,3	89,3	-131,7	9601,3	108970,6	99369,4
13	206,8	473,9	425,2	154,7	253,2	174,3	89,3	-131,4	7102,9	100117,5	93014,6
14	205,8	472,1	424,0	154,7	253,2	174,3	89,3	-129,7	7057,4	97171,1	90113,7
15	207,8	474,6	430,1	154,7	253,2	174,3	89,3	-132,2	7187,9	98640,3	91452,4
16	314,6	481,5	443,5	154,7	253,2	174,3	89,3	-139,0	19047,7	154692,4	135644,7
17	556,1	483,8	466,6	154,7	253,2	174,3	89,3	-141,3	45714,3	275817,1	230102,8
18	350,9	482,0	465,2	154,7	253,2	174,3	89,3	-139,5	23103,1	169277,1	146174,0
19	246,9	473,2	450,7	154,7	253,2	174,3	89,3	-130,8	12039,3	116852,4	104813,1
20	227,4	463,3	435,2	154,7	253,2	174,3	89,3	-120,8	10327,9	105359,2	95031,3
		6185,6			**3291,6**		**1160,4**	**-1733,6**	**280097,2**	**2147590,3**	**1867493,2**

Customer Price	**Tot. Cost Physical**	**Result hedge**	**Total Cost**	**Income from customer**
163,5	**2 147 590,3**	**280 097,2**	**1 867 493,2**	**1 011 360,1**
Actual Consumption	**Regulating cost**	**Result Strategy**	**Unhedged Res.**	**MWh underhedged**
6 185,6	**81 314,0**	**- 856 133,1**	**- 1 136 230,3**	**- 1 733,6**
	Gain from Strategy VS Unhedged			
	280 097,2			

9.4 Appendix IV

Table 9.4: Price spike January 24, 2000, Strategy 1.

	Actual volume		Forecast	Hedge year		W1		Volume difference	Result hedge	Tot. cost. Phys.	Total Cost
Hour	**spot**	**volume (MWH)**		**Price**	**volume**	**Price**	**volume**				
8	1548,1	505,3	534,8	136,6	262,3	145,7	121,0	-122,0	367991,4	821699,3	453707,9
9	4083,6	507,6	550,9	136,6	262,3	145,7	121,0	-124,3	1021293,5	2225848,8	1204555,2
10	2889,8	503,2	551,5	136,6	262,3	145,7	121,0	-119,9	724386,7	1561113,2	836726,5
11	2888,8	501,0	547,2	136,6	262,3	145,7	121,0	-117,7	730234,7	1553350,6	823115,8
12	1476,7	495,8	543,5	136,6	262,3	145,7	121,0	-112,5	362117,0	783800,8	421683,8
13	1444,5	487,5	536,7	136,6	262,3	145,7	121,0	-104,2	364239,8	754425,6	390185,7
14	1358,6	480,4	530,9	136,6	262,3	145,7	121,0	-97,1	348920,8	699166,8	350246,0
15	1042,8	480,1	531,2	136,6	262,3	145,7	121,0	-96,8	258781,3	535497,0	276715,7
16	1444,6	481,5	536,7	136,6	262,3	145,7	121,0	-98,2	372008,8	745460,7	373451,9
17	1445,4	485,5	556,3	136,6	262,3	145,7	121,0	-102,3	367004,0	753534,6	386530,6
18	2147,4	489,2	573,1	136,6	262,3	145,7	121,0	-105,9	556996,7	1131849,9	574853,3
19	1445,0	478,6	558,8	136,6	262,3	145,7	121,0	-95,3	376007,3	743480,9	367473,6
20	574,6	463,3	538,8	136,6	262,3	145,7	121,0	-80,1	131955,9	283929,3	151973,4
		6358,9			**3409,8**		**1572,9**	**-1376,2**	**5981938,0**	**12593157,4**	**6611219,4**

Customer Price	**Tot. Cost Physical**	**Result hedge**	**Total Cost**	**Income from customer**
142,0	**12593157,4**	**5981938,0**	**6611219,4**	**902971,1**
Actual Consumption	**Regulating cost**	**Hedged**	**Unhedged**	**MWh underhedged**
6358,9	**841663,9**	**-5708248,3**	**-11690186,3**	**-1376,2**
	Gain from Strategy VS Unhedged			
	5 981 938,01			

9.5 Appendix V

Table 9.5: Price spike February 5 and 6, 2001, Strategy 1.

Hour	Actual Spot price	Actual volume (MWH)	Forecast MWh	Hedge W1 Price	Hedge W1 volume (MWH)	Vol. difference	Result hedge	Tot. Cost. Phys.	Total Cost
7	379,2	487,6	534,0	147,1	418,9	-68,6	81299,9	187305,7	106005,8
8	1194,1	521,0	588,4	147,1	418,9	-102,0	331805,0	633953,1	302148,1
9	2121,3	520,2	595,2	147,1	418,9	-101,3	627162,4	1126700,6	499538,2
10	1507,9	521,7	609,7	147,1	418,9	-102,8	430242,5	802918,4	372675,9
11	1194,4	522,0	616,2	147,1	418,9	-103,1	330835,0	623482,0	292647,0
12	1018,7	521,2	614,9	147,1	418,9	-102,3	276015,6	541116,4	265100,8
13	542,8	515,6	608,9	147,1	418,9	-96,7	127525,0	284439,6	156914,6
14	498,4	514,2	602,2	147,1	418,9	-95,3	113689,9	259749,4	146059,5
15	450,1	512,7	603,4	147,1	418,9	-93,8	98531,4	230775,3	132243,9
16	480,7	514,0	610,0	147,1	418,9	-95,1	108054,4	247079,8	139025,4
17	1079,4	514,3	626,1	147,1	418,9	-95,4	301684,0	555135,4	253451,4
18	1691,4	526,2	672,0	147,1	418,9	-107,2	481364,7	889970,3	408605,7
19	1194,0	517,7	669,1	147,1	418,9	-98,8	335174,9	618197,1	283022,1
20	982,8	505,1	654,5	147,1	418,9	-86,2	278101,1	496392,1	218290,9
21	357,6	490,7	624,6	147,1	418,9	-71,8	73079,0	177203,1	104124,2
22	268,3	472,9	585,5	147,1	418,9	-53,9	44249,7	126878,4	82628,8
23	206,3	456,0	541,1	147,1	418,9	-37,0	22610,1	94055,4	71445,3
24	186,3	437,5	491,1	147,1	418,9	-18,6	15681,7	81491,8	65810,1
1	195,5	420,6	458,1	147,1	418,9	-1,7	20186,5	82218,3	62031,8
2	191,9	415,8	445,7	147,1	418,9	3,1	18933,2	79816,3	60883,2
3	187,4	413,0	439,0	147,1	418,9	5,9	17140,1	77404,5	60264,4
4	188,1	413,6	440,3	147,1	418,9	5,3	17395,1	77793,6	60398,6
5	193,5	417,7	443,6	147,1	418,9	1,2	19483,3	80807,9	61324,7
6	200,3	434,1	463,6	147,1	418,9	-15,1	21491,8	86942,2	65450,4
7	270,8	468,6	512,1	147,1	418,9	-49,6	45707,8	126904,8	81197,0
8	976,6	496,9	565,4	147,1	418,9	-78,0	282829,8	485282,1	202452,3

9	1666,5	496,3	570,9	147,1	418,9	-77,4	518938,7	827135,7	308197,0
10	1046,2	496,8	579,5	147,1	418,9	-77,9	306661,1	519778,1	213117,0
11	785,6	497,6	588,1	147,1	418,9	-78,6	217287,7	390893,9	173606,2
12	343,6	495,7	587,2	147,1	418,9	-76,8	67238,4	170336,3	103097,9
13	272,9	492,1	584,3	147,1	418,9	-73,2	43493,9	134284,8	90790,9
14	252,3	487,9	577,8	147,1	418,9	-69,0	36812,9	123087,6	86274,6
15	232,8	485,7	578,9	147,1	418,9	-66,8	30201,8	113095,0	82893,2
16	227,3	489,1	578,5	147,1	418,9	-70,2	27969,2	111157,8	83188,5
17	279,2	489,0	580,7	147,1	418,9	-70,1	46106,1	136553,9	90447,9
18	344,6	494,7	608,7	147,1	418,9	-75,7	67776,7	170435,1	102658,4
19	655,0	485,7	604,9	147,1	418,9	-66,7	178912,4	318121,9	139209,5
		17961,7		**5441,9**	**15500,9**	**-2460,8**	**6061672,8**	**12088893,8**	**6027221,0**

Customer Price	**Tot. Cost Physical**	**Result hedge**	**Total Cost**	**Income from customer**
145,9	**12088893,8**	**6061672,8**	**6027221,0**	**2621106,0**
Actual Consumption	**Regulating cost**	**Hedged**	**Unhedged**	**MWh underhedged**
17961,7	**73688,3**	**-3406115,1**	**-9467787,8**	**-2460,8**
	Gain from Strategy VS Unhedged			
	6061672,8			

9.6 Appendix VI

Table 9.6: Price spike March 1, 2001, Strategy 1.

Hour	Actual Spot price	Actual volume (MWH)	Forecast MWh	Hedge W1 Price	Hedge W1 volume (MWH)	Vol. difference	Result hedge	Tot. Cost. Phys.	Total Cost
8	479,7	474,6	510,8	147,1	418,9	-55,7	120836,4	227684,7	106848,3
9	1354,6	482,4	532,1	147,1	418,9	-63,5	429233,6	653491,0	224257,3
10	1152,1	482,0	538,5	147,1	418,9	-63,1	357664,9	555354,5	197689,6
11	914,5	480,0	537,6	147,1	418,9	-61,0	274677,2	438960,9	164283,7
12	431,6	475,8	535,2	147,1	418,9	-56,9	103016,2	205382,1	102365,8
		2394,9	**2654,2**		**2094,7**	**-300,2**	**1285428,3**	**2080873,2**	**795444,8**

Customer Price	Tot. Cost Physical	Result hedge	Total Cost	Income from customer
145,9	**2080873,2**	**1285428,3**	**795444,8**	**349478,9**
Actual Consumption	**Regulating cost**	**Hedged**	**Unhedged**	**MWh underhedged**
2394,9	**0,0**	**-445966,0**	**-1731394,3**	**-300,2**
	Gain from Strategy VS Unhedged			
	1285428,3			

9.7 Appendix VII

Table 9.7: Price spike December 8, 1998, Strategy 2.

Hour	Actual volume Price	Actual cons.(2%) Volume	Forecast	Hedge B-01 Price	volume	Vol. Difference	Result hedge	Tot. Cost. Phys.	Total Cost
8	293,6	464,1	389,7	188,1	392,8	-71,3	33899,6	136224,8	102325,3
9	748,8	469,0	417,6	188,1	392,8	-76,2	177538,5	351157,2	173618,7
10	511,0	463,3	422,1	188,1	392,8	-70,5	104069,5	236731,4	132661,9
11	409,3	462,2	423,7	188,1	392,8	-69,4	71541,4	189179,5	117638,1
12	311,8	457,8	423,1	188,1	392,8	-65,0	40557,7	142754,1	102196,4
13	245,2	451,4	418,3	188,1	392,8	-58,6	19076,3	110678,4	91602,1
14	243,1	447,5	417,9	188,1	392,8	-54,7	18575,3	108783,5	90208,2
15	270,6	450,7	425,4	188,1	392,8	-57,9	27610,1	121951,3	94341,2
16	296,6	464,8	441,5	188,1	392,8	-72,0	34815,0	137872,3	103057,3
17	402,1	472,3	464,4	188,1	392,8	-79,5	67019,7	189909,0	122889,3
18	803,9	468,9	467,1	188,1	392,8	-76,1	195011,0	376999,6	181988,6
19	245,4	458,3	456,2	188,1	392,8	-65,5	18754,3	112490,4	93736,1
20	222,4	446,8	441,3	188,1	392,8	-54,0	11594,5	99354,9	87760,4
		5977,1			**5106,5**		**820063,0**	**2314086,6**	**1494023,7**

Actual volume	**Customer price**	**Total Phys. Cost**	**Res.hedge**	**Income Customer**	**Total cost strategy**
5977,1	**188,9**	**2314086,6**	**820063,0**	**1128804,2**	**1494023,7**
Reg.cost		**Res. Strategy**	**res. Un hedged**		**MWh underhedged**
0,0		**-365219,5**	**-1185282,5**		**870,7**
		Gain from strategy vs. Unhedged			
		820063,0			

9.8 Appendix VIII

Table 9.8: Price spike December 16, 1999, Strategy 2.

Hour	Price	Actual volume Actual cons. (2%) Volume	Forecast	Hedge B-01 Price	volume	Vol. Difference	Result hedge	Tot. Cost. Phys.	Total Cost
8	286,1	471,7	388,9	152,7	389,0	-82,8	40855,6	189946,6	149091,0
9	768,0	481,6	415,1	152,7	389,0	-92,7	182314,2	381980,2	199666,0
10	488,9	477,8	415,8	152,7	389,0	-88,8	100926,6	233601,0	132674,4
11	240,2	476,0	419,4	152,7	389,0	-87,0	26423,1	115164,7	88741,7
12	227,5	474,1	424,7	152,7	389,0	-85,2	22732,4	108970,6	86238,2
13	206,8	473,9	425,2	152,7	389,0	-84,9	16472,0	100117,5	83645,5
14	205,8	472,1	424,0	152,7	389,0	-83,2	16251,3	97171,1	80919,8
15	207,8	474,6	430,1	152,7	389,0	-85,7	16732,2	98640,3	81908,1
16	314,6	481,5	443,5	152,7	389,0	-92,5	47995,8	154692,4	106696,7
17	556,1	483,8	466,6	152,7	389,0	-94,8	118675,0	275817,1	157142,1
18	350,9	482,0	465,2	152,7	389,0	-93,0	58672,9	169277,1	110604,3
19	246,9	473,2	450,7	152,7	389,0	-84,3	28718,2	116852,4	88134,3
20	227,4	463,3	435,2	152,7	389,0	-74,3	23526,2	105359,2	81833,1
		6185,6			**5056,5**		**700295,3**	**2147590,3**	**1447295,0**

Actual volume	Customer price	Total Phys. Cost	Res.hedge	Income Customer	Total cost strategy
6185,6	**163,5**	**2147590,3**	**700295,3**	**1011360,1**	**1447295,0**
Reg.cost		**Res. Strategy**	**res. Un hedged**		**MWh underhedged**
81314,0		**-435935,0**	**-1136230,3**		**1129,1**
		Gain from strategy vs. Unhedged			
		700295,3			

9.9 Appendix VIV

Table 9.9: Price spike: January 24, 2000, Strategy 2.

Hour	Actual Price	Actual volume	Forecast	Hedge B-01 Price	volume	Vol. Difference	Result hedge	Tot. Cost. Phys.	Total Cost
8	1548,1	505,3	534,8	156,2	421,2	-84,2	469048,4	821699,3	352650,9
9	4083,6	507,6	550,9	156,2	421,2	-86,5	1314433,5	2225848,8	911415,2
10	2889,8	503,2	551,5	156,2	421,2	-82,0	927032,5	1561113,2	634080,7
11	2888,8	501,0	547,2	156,2	421,2	-79,8	932770,0	1553350,6	620580,6
12	1476,7	495,8	543,5	156,2	421,2	-74,6	457604,6	783800,8	326196,2
13	1444,5	487,5	536,7	156,2	421,2	-66,3	457152,6	754425,6	297272,9
14	1358,6	480,4	530,9	156,2	421,2	-59,2	435208,5	699166,8	263958,3
15	1042,8	480,1	531,2	156,2	421,2	-58,9	321147,3	535497,0	214349,7
16	1444,6	481,5	536,7	156,2	421,2	-60,4	464826,9	745460,7	280633,9
17	1445,4	485,5	556,3	156,2	421,2	-64,4	459954,4	753534,6	293580,2
18	2147,4	489,2	573,1	156,2	421,2	-68,0	703174,8	1131849,9	428675,2
19	1445,0	478,6	558,8	156,2	421,2	-57,4	468811,4	743480,9	274669,5
20	574,6	463,3	538,8	156,2	421,2	-42,2	158579,3	283929,3	125350,0
		6358,9		**2030,4**	**5475,0**	**-883,9**	**7569744,1**	**12593157,4**	**5023413,3**

Actual volume	Customer price	Total Phys. Cost	Res.hedge	Income Customer	Total cost strategy
6358,9	**142,0**	**12593157,4**	**7569744,1**	**902971,0**	**5023413,3**
Reg.cost		**Res. Strategy**	**res. Un hedged**		**MWh underhedged**
841663,9		**-4120442,3**	**-11690186,4**		**883,9**
		Gain from strategy vs. Unhedged			
		7569744,1			

9.10 Appendix X

Table 9.10: Price spike February 5 and 6, 2001, Strategy 2.

Hour	Spot price	Actual volume MWh	Forecast MWh	Hedge B-03 Price	volume	Vol. Difference	Result hedge	Tot. Cost. Phys.	Total Cost
7	379,2	487,6	534,0	159,8	454,2	-33,4	92319,5	187305,7	94986,1
8	1194,1	521,0	588,4	159,8	454,2	-66,8	400676,9	633953,1	233276,1
9	2121,3	520,2	595,2	159,8	454,2	-66,0	761359,7	1126700,6	365340,9
10	1507,9	521,7	609,7	159,8	454,2	-67,5	521236,9	802918,4	281681,5
11	1194,4	522,0	616,2	159,8	454,2	-67,8	399741,7	623482,0	223740,4
12	1018,7	521,2	614,9	159,8	454,2	-67,0	332527,3	541116,4	208589,1
13	542,8	515,6	608,9	159,8	454,2	-61,5	150434,3	284439,6	134005,3
14	498,4	514,2	602,2	159,8	454,2	-60,1	133448,3	259749,4	126301,1
15	450,1	512,7	603,4	159,8	454,2	-58,5	114869,7	230775,3	115905,5
16	480,7	514,0	610,0	159,8	454,2	-59,8	126565,3	247079,8	120514,5
17	1079,4	514,3	626,1	159,8	454,2	-60,1	362388,5	555135,4	192746,9
18	1691,4	526,2	672,0	159,8	454,2	-72,0	585345,3	889970,3	304625,1
19	1194,0	517,7	669,1	159,8	454,2	-63,6	404000,9	618197,1	214196,2
20	982,8	505,1	654,5	159,8	454,2	-50,9	331878,8	496392,1	164513,2
21	357,6	490,7	624,6	159,8	454,2	-36,5	82617,7	177203,1	94585,5
22	268,3	472,9	585,5	159,8	454,2	-18,7	47272,4	126878,4	79606,0
23	206,3	456,0	541,1	159,8	454,2	-1,8	21047,2	94055,4	73008,2
24	186,3	437,5	491,1	159,8	454,2	16,6	12473,8	81491,8	69018,0
1	195,5	420,6	458,1	159,8	454,2	33,5	17413,4	82218,3	64804,9
2	191,9	415,8	445,7	159,8	454,2	38,3	15851,2	79816,3	63965,2
3	187,4	413,0	439,0	159,8	454,2	41,2	13703,6	77404,5	63700,9
4	188,1	413,6	440,3	159,8	454,2	40,6	14012,9	77793,6	63780,7
5	193,5	417,7	443,6	159,8	454,2	36,5	16531,5	80807,9	64276,4
6	200,3	434,1	463,6	159,8	454,2	20,1	19229,9	86942,2	67712,4
7	270,8	468,6	512,1	159,8	454,2	-14,4	48854,1	126904,8	78050,7
8	976,6	496,9	565,4	159,8	454,2	-42,7	336068,4	485282,1	149213,8

9	1666,5	496,3	570,9	159,8	454,2	-42,2	620785,7	827135,7	206350,0
10	1046,2	496,8	579,5	159,8	454,2	-42,6	364805,1	519778,1	154973,0
11	785,6	497,6	588,1	159,8	454,2	-43,4	257075,7	390893,9	133818,1
12	343,6	495,7	587,2	159,8	454,2	-41,6	75856,5	170336,3	94479,8
13	272,9	492,1	584,3	159,8	454,2	-37,9	47081,9	134284,8	87202,9
14	252,3	487,9	577,8	159,8	454,2	-33,7	38896,0	123087,6	84191,5
15	232,8	485,7	578,9	159,8	454,2	-31,5	30887,8	113095,0	82207,2
16	227,3	489,1	578,5	159,8	454,2	-34,9	28305,5	111157,8	82852,2
17	279,2	489,0	580,7	159,8	454,2	-34,8	50103,7	136553,9	86450,3
18	344,6	494,7	608,7	159,8	454,2	-40,5	76448,1	170435,1	93987,0
19	655,0	485,7	604,9	159,8	454,2	-31,5	209348,9	318121,9	108773,0
		17961,7	**21054,0**		**16804,5**	**-1157,2**	**7161464,1**	**12088893,8**	**4927429,7**

Actual volume	**Customer price**	**Total Phys. Cost**	**Res.hedge**	**Income Customer**	**Total cost strategy**
17961,7	**145,9**	**12088893,8**	**7161464,1**	**2621105,1**	**4927429,7**
Reg.cost		**Res. Strategy**	**res. Un hedged**		**MWh underhedged**
73688,3		**-2306324,6**	**-9467788,7**		**1157,2**
		Gain from strategy vs. Unhedged			
		7161464,1			

9.11 Appendix XI

Table 9.11: Price spike March 1, 2001, Strategy 2.

Hour	Spot price	Actual volume MWh	Forecast MWh	Hedge B-03 Price	volume	Vol. Difference	Result hedge	Tot. Cost. Phys.	Total Cost
8	479,7	474,6	510,8	144,2	432,5	-42,1	130980,8	227684,7	96703,9
9	1354,6	482,4	532,1	144,2	432,5	-49,9	463088,9	653491,0	190402,0
10	1152,1	482,0	538,5	144,2	432,5	-49,5	386028,9	555354,5	169325,6
11	914,5	480,0	537,6	144,2	432,5	-47,5	296601,7	438960,9	142359,2
12	431,6	475,8	535,2	144,2	432,5	-43,3	111852,3	205382,1	93529,7
	4332,6	**2394,9**			**2162,5**	**-232,4**	**1388552,6**	**2080873,2**	**692320,5**

Actual volume	Customer price	Total Phys. Cost	Res.hedge	Income Customer	Total cost strategy
2394,9	**145,9**	**2080873,2**	**1388552,6**	**349478,7**	**692320,5**
Reg.cost		**Res. Strategy**	**Res. Un hedged**		**MWh underhedged**
0,0		**-342841,8**	**-1731394,4**		**232,4**

Gain from strategy vs. Unhedged
1388552,6

9.12 Appendix XII

Table 9.12: Block strategy –Options 2000.

Year 2000			call options for every block in V1 and V2					
Asian Call Options Strategy	1999-11-24	1999-11-24	1999-11-24	2000-02-17	2000-07-27	2000-07-27	2000-10-09	2000-10-09
% best seller	Block 01-00	Block 02-00	Block 03-00	Block 04-00	Block 10-00	Block 11-00	Block 12-00	Block 13-00
100%	AC150	AC150	AC150	AC100	AC110	AC115	AC145	AC155
Exercise price	150	150	150	100	110	115	145	155
Option price	7,37	7,37	7,37	4,46	10,37	13,45	14,38	17,10
Avg spotprice	163,3676	111,46	97,6228	117,3565	143,1655	140,6074	148,3933	146,7281
Premium per contract	4956	4956	4956	2999	6967	9036	9666	11082
Hours	672	672,00	672	672	672	672	672	648
20% of total volume	56603	55143,75	51995	55144	38663	43423	48863	52062
Number of contracts	84,23	82,06	77,37	82,06	57,53	64,62	72,71	80,34
Total premium	417419	406658	383436	246079	400846	583922	702864	890332
Settlement (no premium)	756646	406658	383436	957103	1282282	1111963	165808	890332
Financial settlement	339 227	- 406 658	- 383 436	711 024	881 436	528 041	- 537 055	- 890 332
Total Result								
242 247								
Sum Total Strategy								
13 753 117								

9.13 Appendix XIII

Table 9.13: Block strategy –Options 2001.

Year 2001	call options for every block in V1 and V2			
Asian Call Options Strategy	2000-11-24	2000-11-24	2000-12-27	2001-01-29
% best seller	Block 01-00	Block 02-00	Block 03-00	Block 04-00
100%	AC165	AC160	AC130	AC150
Exercise price	165	160	130	150
Price	9,65	12,53	11,13	20,21
Avg. spotprice	179,6336	230,74	242,0037	237,4167
Premium per contract	6486	8417	7479	13578
Hours	672	672,00	672	672
20% of total volume	60222	61041,31	58129	49262
Number of contracts	89,62	90,84	87	73
Total premium	581270	764602	646924	995365
Settlement (no premium)	881272	4317990	6510637	4306359
Financial settlement	300 001	3 553 388	5 863 713	3 310 995
Total Result				
13 028 098				
Sum Total Strategy 2001				
8 229 229				

9.14 Appendix XIV

Table 9.14: Price spike January 24, 2001, Simulation - Strategy 1.

Hour	Actual volume spot	volume (MWH)	Forecast	Hedge year Price	volume	W1 Price	volume	Volume difference	Result hedge	Tot. cost. Phys.	Total Cost
8	4644,2	505,3	534,8	136,6	262,3	145,7	121,0	-122,0	1176841,2	2477472,1	1300630,9
9	10000,0	507,6	550,9	136,6	262,3	145,7	121,0	-124,3	2553316,3	5457305,8	2903989,5
10	8669,3	503,2	551,5	136,6	262,3	145,7	121,0	-119,9	2246624,0	4692372,3	2445748,3
11	8666,4	501,0	547,2	136,6	262,3	145,7	121,0	-117,7	2264787,4	4669014,9	2404227,5
12	4430,0	495,8	543,5	136,6	262,3	145,7	121,0	-112,5	1161884,7	2360305,5	1198420,9
13	4333,5	487,5	536,7	136,6	262,3	145,7	121,0	-104,2	1170568,1	2271241,9	1100673,8
14	4075,8	480,4	530,9	136,6	262,3	145,7	121,0	-97,1	1126591,3	2105378,8	978787,5
15	3128,5	480,1	531,2	136,6	262,3	145,7	121,0	-96,8	856245,6	1614374,0	758128,4
16	4333,7	481,5	536,7	136,6	262,3	145,7	121,0	-98,2	1195532,0	2245173,5	1049641,5
17	4336,3	485,5	556,3	136,6	262,3	145,7	121,0	-102,3	1179396,3	2269715,2	1090318,9
18	6442,1	489,2	573,1	136,6	262,3	145,7	121,0	-105,9	1748364,5	3404936,7	1656572,2
19	4335,1	478,6	558,8	136,6	262,3	145,7	121,0	-95,3	1208353,0	2239595,9	1031243,0
20	1149,3	463,3	538,8	136,6	262,3	145,7	121,0	-80,1	306199,9	571856,6	265656,7
		6358,9			**3409,8**	**1894,6**	**1572,9**	**-1376,2**	**18194704,0**	**36378743,0**	**18184039,0**

Customer Price	**Tot. Cost Physical**	**Result hedge**	**Total Cost**	**Income from customer**
142,0	**36378743,0**	**18194704,0**	**18184039,0**	**902971,1**
Actual Consumption	**Regulating cost**	**Hedged**	**Unhedged**	**MWh underhedged**
6358,9	**2532991,1**	**-17281067,9**	**-35475771,9**	**-1376,2**
	Gain from Strategy VS Unhedged			
	18194704,0			

9.15 Appendix XV

Table 9.15: Simulation 1 – Options.

Simulation 1			call options for every block in V1 and V2					
Asian Call Options Strategy	1999-11-24	1999-11-24	1999-11-24	2000-02-17	2000-07-27	2000-07-27	2000-10-09	2000-10-09
% best seller	Block 01-00	Block 02-00	Block 03-00	Block 04-00	Block 10-00	Block 11-00	Block 12-00	Block 13-00
100%	AC150	AC150	AC150	AC100	AC110	AC115	AC145	AC155
Exercise price	150	150	150	100	110	115	145	155
Price	7,37	7,37	7,37	4,46	10,37	13,45	14,38	17,10
Avg Spot price	231,8322	111,46	97,4910	124,3588	152,1448	140,6074	150,8081	150,5184
Premium per contract	4956	4956	4956	2999	6967	9036	9666	11082
Hours	672	672,00	672	672	672	672	672	648
20% of total volume	56603	56603	51995	45946	38663	43423	48863	52062
Number of contracts	84,23	84,23	77,37	68,37	57,53	64,62	72,71	80,34
Total premium	417419	417419	383436	205035	400846	583922	702864	890332
Settlement	4631943	417419	383436	1119195	1629449	1111963	283803	890332
Financial settlement	4 214 524	- 417 419	- 383 436	914 160	1 228 603	528 041	- 419 061	- 890 332
Total Result		Result strategy 2						
4 775 080		1 841 471						
Sum Total Strategy								
6 616 552								

9.16 Appendix XVI

Table 9.16: Simulation 2 – Options.

Extreme Year - Simulation 2			call options for every block in V1 and V2					
Asian Call Options Strategy	1999-11-24	1999-11-24	1999-11-24	2000-02-17	2000-07-27	2000-07-27	2000-10-09	2000-10-09
% best seller	Block 01-00	Block 02-00	Block 03-00	Block 04-00	Block 10-00	Block 11-00	Block 12-00	Block 13-00
100%	AC150	AC150	AC150	AC100	AC110	AC115	AC145	AC155
Exercise price	150	150	150	100	110	115	145	155
Price	7,37	7,37	7,37	4,46	10,37	13,45	14,38	17,10
Avg spot price	231,6196	216,16	206,3350	225,0796	151,7734	140,4506	253,1904	245,2671
Premium per contract	4956	4956	4956	2999	6967	9036	9666	11082
Hours	672	672,00	672	672	672	672	672	648
20% of total volume	56603	56603	51995	45946	38663	43423	48863	52062
Number of contracts	84,23	84,23	77,37	68,37	57,53	64,62	72,71	80,34
Total premium	417 419	417 419	383 436	205 035	400 846	583 922	702 864	890 332
Settlement	4 619 909	3 744 954	2 929 132	5 746 945	1 615 089	1 105 151	5 286 552	4 873 570
Financial settlement	4 202 491	3 327 535	2 545 695	5 541 910	1 214 243	521 229	4 583 688	3 983 238
Total Result		result more price spikes						
25 920 029		- 25 381 152						
Sum total strategy								
538 877								