(UR-34) Risk Modeling and Strategic Choices in an Uncertain Environment. Case of a Swiss Power Provider on the eve of Electricity Market Opening

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Abstract

With electricity market liberalisation, the task of decision makers is becoming more and more difficult. In this framework, strategic portfolio choice has become very complex, because of the growing number of uncertain parameters involved, such as energy market prices, water inflow, and demand. The lack of information and the absence of the decision maker's perception are just some of the many elements that must be accounted for. Therefore, the objective of this paper is to propose a methodology based on strategic choices that will enable decision makers to evaluate the performance of both their strategies and portfolios, through the computation of an indicator for different time horizons. This indicator is used to evaluate and select portfolios of customers. With the use of fuzzy numbers theory, this methodology will enable decision makers to incorporate and express uncertainty, in a non probabilistic sense.

With the Swiss electricity market moving towards deregulation, the degree of competition is set to increase. In this context, some energy intensive industries have created their own electricity companies, as one of their divisions, in order to be able to secure the cheapest possible power provision for their processes. The case of this kind of market player is examined.

Keywords: fuzzy set theory, electricity markets, strategic choices.

1. Introduction

The aim of this paper is to evaluate the profit of a power provider on a strategic basis. The objective of such a provider, active in a competitive electricity market, is to maximize its profit. The main contribution of this paper lies in the implementation of a simple methodology based on fuzzy numbers theory, aimed to assist decision makers with their strategic decisions. As a result, a performance indicator will be determined. The necessity of introducing such an approach, stems from many reasons, including (1) the complexity associated with uncertain factors characterizing electricity market parameters (e.g. the risk factors associated with energy market prices, quantity risk; (2) the immaturity of electricity markets characterized by the lack of relevant historical data, which is a major limitation to the evaluation of portfolios; (3) the tools and techniques available to risk practitioners, seem to focus only on the negative side of risk, which is specifically the case of methods using probability theory, like value at risk (Pilipovic, 1997). The approach that we are introducing, extends the scope of the performance/ risk evaluation, to opportunities (Hillson, 2002), and integrates the perception that the decision makers may have for a given outcome. This paper is structured in four parts. The first part aims to justify the use of fuzzy numbers. Part 2 presents the methodology. Part 3 presents an illustration as well as the main results, and finally part 4 presents concluding remarks.

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2. Why use fuzzy numbers?

With competition, it is becoming increasingly difficult for decision makers concerned with power provision in electricity markets, to evaluate the performance of their strategies in a given horizon. Such a challenge is closely connected to the handling of uncertainty, for which several methods have been used. Using these methods to represent uncertainty may lead to some inconsistencies. *The use of probabilities* is possible only if we can assure the availability of information that is precise and dispersed. As soon as this is missing, it is not reasonable to use this theory. The Bayesian approach relies on the idea that a prior probability of an event may be introduced in a given situation, and may be used in the calculation of conditional or joint probabilities. From these theories, parameters like the mean-variance (Markowitz, 1991) or value-at-risk (Szegö, 2005; Pilipovic, 1997), designed for financial markets, are still used in energy markets after attempts to customize them; and their efficiency is yet to prove. Unfortunately, as pointed by Dubois & Prade (1988), the framework of probability theory is too normative to take into account the various aspects of uncertainty, like ignorance or partial knowledge, which characterize some important electricity market parameters like the price, the demand, etc. *Fuzzy numbers* are not a substitute for probability theory, but they are basically a method allowing a gradual representation of the likeness between two objects. One of the interests of introducing fuzzy numbers in electricity markets is that both imprecision and uncertainty can be handled in a unique conceptual framework. Introduced by Lofti Zadeh (1965) as a starting point of his work on uncertainty related to the lack of knowledge, this theory defines the membership of an object set as a degree between 0 and 1 instead of a binary value (0 or 1) (See figure 1a, left). From this starting point, Zadeh aimed to formalize the linguistic reasoning in mathematical form (Zadeh, 1975), which provide a means of approximate characterization of phenomena which are too complex to be amenable to description in conventional quantitative terms. Figure 1b illustrates the concept: “Energy price” is a linguistic variable and its values (the terms) are linguistic – “low”, “moderate” or “high” – rather than numerical – 50, 53, and 59… [CHF/ MWh].

Figure 1a: Graphical representation of a crisp (left) and a fuzzy number (right)

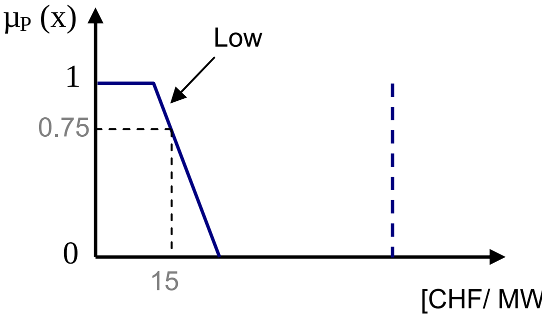
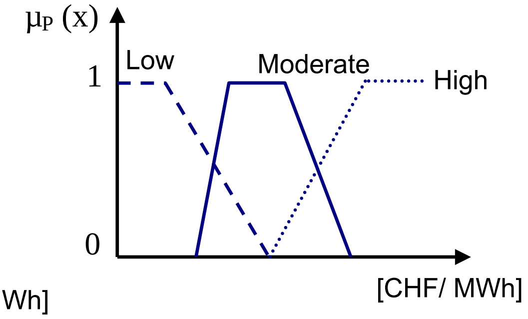


Figure 1b: Graphical representation of the linguistic variable “energy price”.



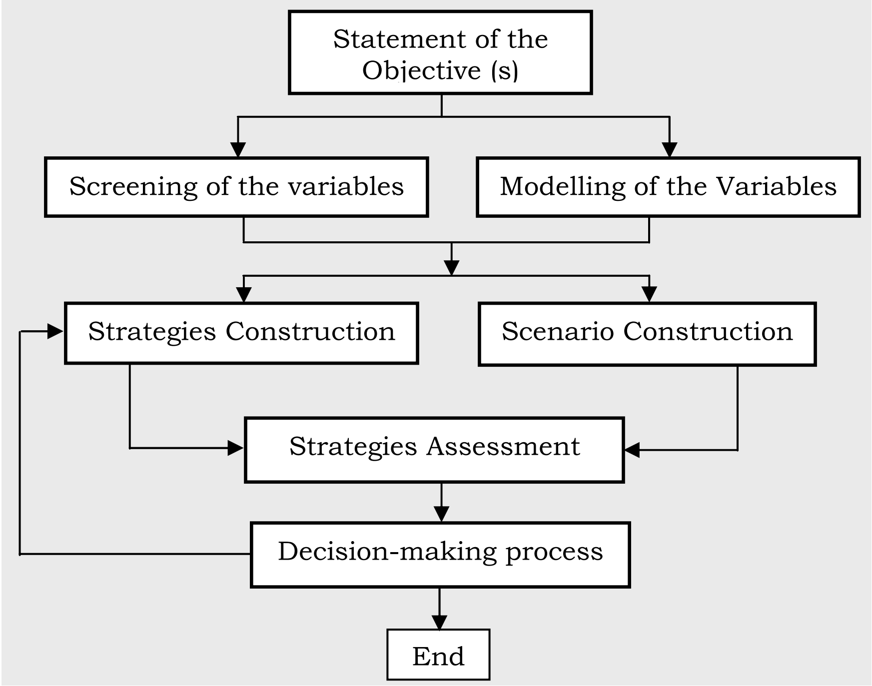
A proposition such as "the energy price is *low*” may be modeled by the fuzzy number which is entirely defined by the membership function μ_P (x) of Figure 1a. If the price is 15 [CHF/ MWh], the price’s degree of membership to the fuzzy set of “low” is μ_P (20) = 0.8. Finally, with the possibility theory developed by Zadeh (1978), sets as a postulate that 0.8 may be considered as the possibility that the energy price is 15 [CHF/ MWh], given the fact that "the price is low".

The complexity of the task, related to evaluating the performance of the strategies, is mainly due to both imprecision and to the uncertainty related to the lack of knowledge (immaturity of energy markets). This lack of knowledge increases the power providers’ exposure to risk factors. In a hydro-thermal energy system, the price risk, the quantity risk and many other risk factors, are due to an array of factors that are hard or almost impossible to express. Therefore, the use of fuzzy numbers is justified.

3. Methodology

The methodology comprises 5 main steps listed below and illustrated in figure 3.

Figure 2: Outline of the methodology



(1) _Screening of the variables_ is about gathering the largest spectrum of variables that concern the problem. From this, explanatory variables are identified.

(1') _The Modelling of the explanatory variables_ is about saying if they are crisp, random or fuzzy, according to the nature of uncertainty governing their variation.

(2)*_Strategies_* are constructed, based on the definition that they are long term plans designed to define a set of future actions or orientations (Godet, 1997). The strategies are constructed on the basis of a function F depending on a coherent combination of selected attributes – $a_1, a_2, \ldots, a_n$ – over which the decision maker has control.

*(3)_Scenarios_* are constructed on the basis of a definition given by Godet (2000) who considers a scenario as the set formed by the description of a future situation and the course of events that enables one to progress from the original situation to the future situation. This is translated into a coherent combination of hypotheses about the evolution of the explanatory variables.

*(4) _The strategies are assessed and evaluated_* through the computation of the profit, which, for a pair strategy/ scenario is the difference between receipts (R) and costs (C) (See equation E.1). In order to have a more sound comparison basis in accordance with different time periods, the profits are levelized for these time periods (See equation E.2). For example, if we are interested to evaluate a given strategy for a period $T = T_{fin} - T_{in}$ *[years]*, the levelized profit for that period is computed as follows:

$$\text{(E.1)} \quad \begin{cases} Profit = Receipts - Costs = f(x_1, x_2, \ldots, x_k) \\ \mu_{Profit} = \sup\limits_{\substack{x_1, x_2, \ldots, x_k \\ Profit = f(x_1, x_2, \ldots, x_k)}} \left\{ \min\left\{ \mu_{x_1}, \mu_{x_2}, \ldots, \mu_{x_k} \right\} \right\} \end{cases} \qquad \text{(E.2)} \quad Profit_{T_{in}}^{T_{fin}} = \left[\sum_{t=T_{in}}^{T_{fin}} \frac{Profit_t}{(1+rate_t)^t} \Bigg/ \sum_{t=T_{in}}^{T_{fin}} \frac{1}{(1+rate_t)^t} \right]$$

The set $x_1, x_2, \ldots, x_k$, represents the variables used for the computation of the profit. As shown in (E.1), the presumption level of the profit μ_{Profit} is computed with the use of the Zadeh's extension principle.

(5) _In the decision making process,_ a performance/ vulnerability indicator is determined, for different time horizons. This indicator is used to evaluate and select strategies and possibly portfolios of customers, considering the perception of the decision maker.

4. Illustration

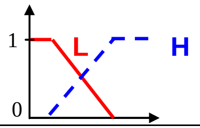
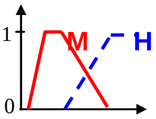
We consider the case of a Swiss regional electricity company called Company X (CX), with a given portfolio of assets and a portfolio of customers. The aim of this company, owned by

two energy-intensive industries - CHEM SA[2] and ALU[3] SA – is to provide electric energy at very competitive prices for the different processes. CX's portfolio of supply is composed of its own power plants[4] as well as partnership agreements with two power generators[5], a distribution network, and finally spot power purchases. Candidates for the portfolios of customers are composed of industries of various sizes – the owners of CX and a number of SME – and municipalities (Mun1, Mun2, Mun3) (See details in appendix A1). Given the competitive environment, the company's ultimate goal is to assess its competitiveness and vulnerability for the coming years. This vulnerability could originate either from the intense competition among suppliers – bigger and more powerful suppliers have the appropriate means and the required size to propose lower prices – or from customers' changing suppliers.
Three time horizons have been chosen, and the profit levelised over each period. A discount rate of 7% is used, but inflation is not taken into account.

4.1. Modelling of the main variables

The identification of the variables is made through a screening of the variables, as outlined in the first table of appendix A2. From this table, a selection among the explanatory variables is made, that result, as presented in table 1 in a set of variables that are assumed independent. This independence is a function of the relationship among variables, as well as being dependent on the context.

Table 1. Explanatory variables and their linguistic variables

Explanatory variables	*Linguistic variables*	*Linguistic terms and membership functions*	
Water inflows (w.i) & Electricity spot prices (els)	Low (L)		$\mu_{w.i}^{L}(x)$, $\mu_{els}^{L}(y)$
	High (H)		$\mu_{w.i}^{H}(x)$, $\mu_{els}^{H}(y)$
Natural gas price (n.g) & Electricity demand (d)	Moderate (M)		μ_{ng}^{M},(x'), $\mu_{d}^{M}(y')$
	High (H)		$\mu_{ng}^{H}(x')$, $\mu_{d}^{H}(y')$
Note: x [m^3] ; y [CHF/ MWh]; x' [CHF/ MWh]; y' [MWh]			

The electricity market in Switzerland is dominated by nuclear power (60%), followed by hydro power (40%). Therefore, it is reasonable to assume that electric energy market prices and natural gas prices are independent in this context.
Three different market prices are considered: the electricity spot price, the natural gas market price. The long-term contracts (OTC) are characterized by two parameters, a volume [MWh] and a price [CHF/ MWh]. These parameters are known with certainty because forward OTC contracts are negotiated contracts, between the buyer and the seller. Therefore the volume and the contract price are crisp numbers. Generally, market prices of energy are strongly dependent on factors like temperature, inflows in reservoirs. If the factor in case has a random behaviour, as the case is for temperature, the probability density function is transformed into a membership function in accordance with a procedure described by Kaufmann and Gupta (1991).

Power generation and network charges: The average seasonal output [MWh] from each hydro plant is considered, instead of a function, depending on water inflows. The output from the hydro plants is therefore represented by a fuzzy number, and follows the scenarios of water inflows. The output [MWh] from the gas turbine (GT) is a fuzzy number. The

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[2] A chemical processing company

[3] An aluminum processing company

[4] Two run-of-the-river plants, 1 dam, and one gas turbine.

[5] Long term contacts for energy procurement (OTC – Over-the-Counter contracts)

justification for this comes from the dependency on a conjunction of uncertain factors - e.g. the electricity spot price, the natural gas price, the demand, the season, etc. The gas turbine output is negatively correlated to the spread between natural gas prices and electricity prices.

Elements of the contracts: For all the *customers*, the contracts are of two types: a contract for electric energy, a capacity contract. The *energy sale prices* (summer/ winter), the network charges are all crisp numbers because the first is negotiated; the second is either negotiated or published. All the customers connected to the CX's network are charged a "Network Use of System Price" [CHF/ MWh], as well as, a fixed charge [CHF/ MW], and depending on the rate demand [MW]. These values, which are known with certainty, are therefore crisp numbers.

4.2. Strategies construction: examples

As described in the previous section, a strategy is characterized by a function depending on a set of combined attributes (a_1, a_2, …,a_n). These attributes generally are factors over which the decision maker can have a certain control, including the *sub strategies* (market orientation, company policy towards customers, reputation enhancement), the *assets opetated* (energy produced, production costs), the *type of long term contracts* (quantities and unit price of energy), and finally the *portfolios of customers*.

Of course, the time-frame (table 2) is an important element to take into account, especially for the different adjustments, within the different strategies. Attention is paid to always have over time, a balance between supply and demand by either purchasing the missing electric energy or selling the excess in the spot market.

Periods	*Period 1*	*Period 2*	*Period 3*
Features	Market opening imminent. No specificity on prices	Market opened. Strong pressure on retail prices (increased competition)	Market maturity. Slight increase in retail prices.
Years	1 to 3	4 to 7	8 to 10
Time horizon: 10 years. Reference year is labelled year 0 (before the evaluation). *Target years*: year 3, year 7, and year 10.			

Table 2: Definition and significance of the different time-frames

Sub strategies: *Sub-Strategy St1* is labeled "Business as usual - Strengthening of the current position". It is oriented towards the development of consumer loyalty, prior to liberalization – exception made for the owners (CHEM SA and ALU SA)

Sub-Strategy St2 is labelled "Downside Protection and self-image enhancement". It aims to positively influence consumers' perception of the company through the development of personalized services, in terms of prices and quality of service, in order to remain competitive.

Three strategies have been considered, each with two variants as outlined in the tables below.

Strategies "Status quo" (SQ) are the reference strategies. Their attributes remain unchanged through from year 0 to year 10.

Strategies "Large scale offensive" (LSO) are strategies in which portfolios of customers are gradually adjusted, for matter adaptation to the new competitive environment. These strategies are only the expression of CX leaving strategy SQ2, at the beginning of the second time period or at the end of the first time period, and adopting for the rest of the time, a more aggressive strategy to attract new customers. The portfolio of supply is

adjusted by changing the terms of the older forward contracts in SQ2 in favour of new contracts, characterized by different annual volumes [MWh] and cheaper purchase prices.
Strategies "Strategic withdrawal" (SW) are characterized by a decrease of the portfolios of customers, as a result of tougher degree of competition. Cheaper long-term contracts are entered into for periods 2 and 3.
In table 3, an example using SQ strategies illustrates the way strategies are constructed. The remaining strategies are described in appendix A3.

Table 3: Attributes of Strategies ***SQ*** *(Reference strategies)*

Time frame	*Sub strat.*	*Assets*	*LT contracts*	*Portfolio cust.* ***SQ1***	*Portfolio cust.* ***SQ2***
Period 1	St1	All operated	F1, F2	Portfolio 3	Portfolio 4
Period 2	St2				
Period 3					

<u>Scenarios</u>: The variables in the scenario are each represented by their membership function. Every scenario (see the example below) or state of the nature is characterized by the simultaneous occurrence of the set of events, which in other words means the intersection of the respective membership functions of the explanatory variables.
For example, Sc 1 which is the reference scenario is expressed as the intersection of a "*moderate* energy demand", a "*low* electricity market price", a "*moderate* natural gas price" and a "*high* water inflow", i.e. $[d, \mu_d^M (y')] \cap [els, \mu_{els}^L(y)] \cap [ng, \mu_{ng}^M,(x')] \cap [w.i, \mu_{w.i}^H(x)]$.

Strategies assessment

The <u>receipts and costs</u> are respectively presented below:

$$Receipts = Receipts^{Energy} + Receipts^{Distribution} \qquad Costs = Costs^{Gen} + Costs^{For} + Costs^{Mark}$$

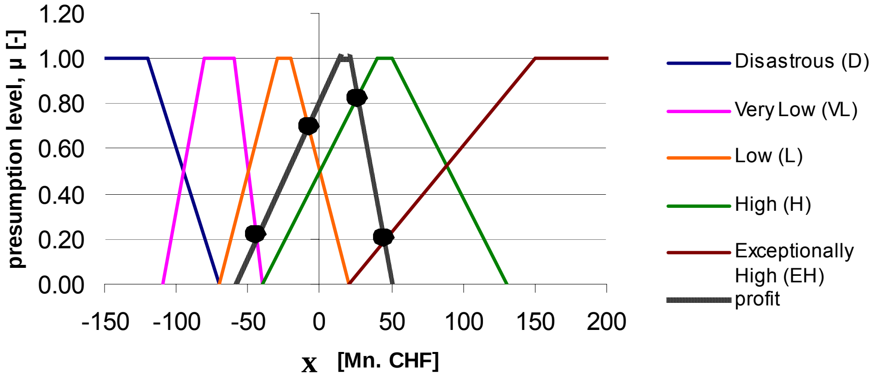
The receipts are composed of the electric energy sales, the distribution charges and the potential profit from the activity on the market. Whereas the costs are composed of generation costs, energy purchased through the forward/ bilateral contracts and finally the potential losses/ costs from market activity.

<u>The perception of the profit that the decision makers of CX</u> have is a way to express the vagueness on how a given profit can be sensed by these decision makers. This vagueness is modelled through the construction of the terms of the linguistic variable "levelised profit" as shown in figure 3. This perception can be expressed through words like for example "Disastrous" or D, "Very low" or VL, "Low" or L, "High" or H, and "Extremely high" or EH.
<u>The performance/ vulnerability index</u>: Figure 3 below shows how the performance/ vulnerability indicator is obtained. It is simply the result of the intersection of the decision maker's perception and the levelized profit (dashed).

$$Performance = \underset{x}{Max}\left[\underset{x}{Min}\left(\mu_{profit}(x), \mu_{perception}(x)\right)\right]$$

This graph shows that risk cannot be considered only in monetary terms, because, a given amount of money – a loss or a gain – does not have the same meaning across individuals. The bullets in the above mentioned figure show that as in any natural event, even a very precise approach that we use to decide and, that we believe accurate, include a certain amount of ambiguity and vagueness. The vagueness comes from the fact that, the answer is not unique as shown in the figure above. The ambiguity stems from the fact that we don't know which one to choose.

Figure 3: Decision maker's perception & performance of a strategy



Therefore, risk can be better characterized by considering the following: *(1)* every level of presumption may be considered as an interval with a given level of confidence, as shown below. The level of presumption, which is similar to the confidence level in statistics, is related to the degree of uncertainty exhibited by the length of the associated interval. The higher this length, the greater the uncertainty. (e.g., $\mu_{profit}[-60, 50] = 0$; $\mu_{profit}[-26, 33] = 0.5$; $\mu_{profit}[0, 28.5] = 0.8$; $\mu_{profit}[5, 25] = 1$);

(2) the fuzzy number, representing the simulated profit, may be considered as made of stacked levels of confidence, which adds another dimension to the characterization of risk;

(3) the risk can finally be characterized by the confrontation of the decision maker's perception with the simulated profit. The intersection of the simulated profit with each term of the decision maker's perception, leads to a performance indicator, which can be defined as a measure of exposure to risk. It is then possible to characterize downside and upside risks.

The different *performances* on the figure above are as follows: Perf (VL)= 0.22; Perf (L)= 0.75; Perf (H)= 0.83; Perf (EH)= 0.18. In the light of these result we notice that: *(a)* the exposure to VL profit is low, as the case is for EH profit; *(b)* the exposure to L and H profits is quite important. In this case, the choice of either option (L or H) depends on the decision maker's objective. If that objective is to avoid bad outcomes, e.g. a VL profit, then the result is more than satisfactory, since the exposition to VL profits is quite low.

4.5. Results

The results are presented on the basis of 3 time horizons, as shown in table 4. First, the performances of the different strategies are exposed and briefly commented. Second, the strategies are compared by pairs. Finally portfolios of customers are compared. The objectives of the decision maker in terms of performances are as follows:

Perf (D) and Perf (VL) < 0.3; Perf (L) and Perf (H)> 0.5; Perf (EH) < 0.3

Analysing the performances of the strategies

The results of the Strategies "Status Quo" (SQ1 and SQ2) show that CX is neither exposed to "disastrous profit" nor "very high profit". For the term "Low", SQ2 generally performs better than SQ1, whereas for the term "High", the opposite happens. The exposition to "High" profit is good.

Table 4: Economic performances of strategies SQ1 and SQ2

Perf (SQ1)/ Perf (SQ2)	D, VL	L	H	EH
Yr1-yr3	0 – 0	0 – 0.45/ 0 – 0.70	0.50 – 1.0/ 1.0 – 1.0	0.51 – 0.9/ 0.42 – 0.65
Yr1-yr7	0 – 0	0 – 0.40/ 0 – 0.63	0.33 – 1.0/ 0.05 – 1.0	0.60 – 1.0/ 0.40 – 0.75
Yr1-yr10	0 – 0	0 – 0.45/ 0 – 0.63	0.68 – 1.0/ 0.97 – 1.0	0.70 – 1.0/ 0.42 – 0.80
Note: the numerical results of the other two strategies can be found in appendix A4.				

With the Large Scale Offensive” (LSO and LSO2) strategies, there is no exposition neither to “Disastrous” nor “Very low” profit. The exposition to positive outcomes is higher than for negative ones. Therefore, the exposition to “Low”, “High” and “E. high” profit is satisfactory.
The Strategies “Strategic Withdrawal” (SW) may be translated by a withdrawal of CX from the market, in order for the owners to return to their core businesses. This is achieved by a gradual reduction of the size of its portfolio of customers, to leave only ALU SA, CHEM SA and Mun1. This is a situation in which the decision makers of CX may believe in advance that they cannot sustain the developing competition, and that the solution to remain in the market would be to refocus its efforts towards its basic customers. The performance for “Low” profit is almost stable for SW1 and SW2. But the slight difference lies in the fact that SW1 is more exposed to negative outcomes than SW2. But on the other hand, both strategies have performances greater than the reference SQ, for “High” profit and “E. high” profit.

Comparing portfolios of customers

In this paragraph, portfolios of customers are compared, ceteris paribus. This comparison is based on the performances of specific strategies, for specific time-horizons. The second time period is chosen as a comparison basis, because it corresponds in our strategies with the time period during which portfolios of customers are adjusted due to deregulation. The average performance of each strategy in that time period is computed and attributed to the portfolio.

Figure 4: Comparison of portfolios of customers

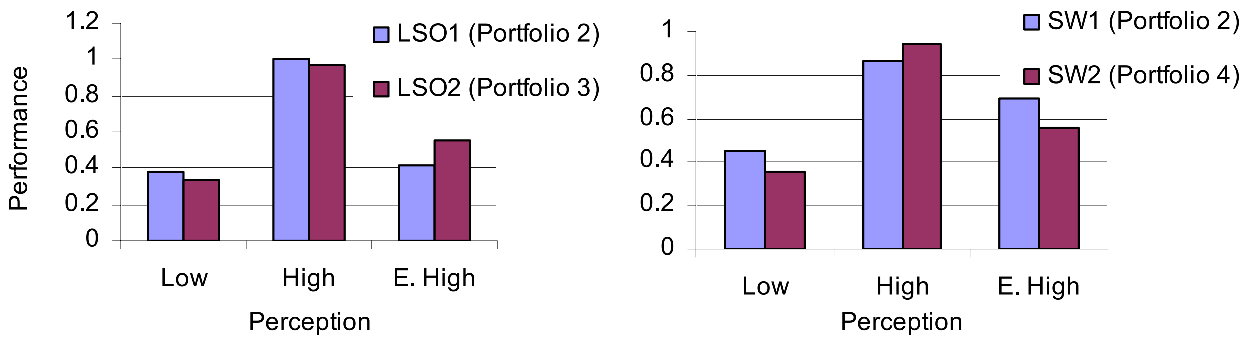


Figure 4 shows that for the set “Low” and “High”, portfolio 2 and 3 have more or less the same performance, except for the set “E. High”, in which portfolio 3 dominates. Portfolio 4 clearly has dominance over portfolio 2 as far as the sets “low” and “high” are concerned, indicating and giving the confirmation that that the number of customers does not guarantee a better performance.

5. Concluding remarks

The goal of this case study, which was to evaluate the profit of a distribution company in an uncertain environment, has been reached. An approach based on the measure of potential losses, as well as a measure of potential gains, through the measure of an economic performance indicator has been proposed. Through the use of fuzzy numbers and the concept of linguistic variable, we have been able to model uncertainty and economic risk in the framework of an opened electricity market. Imprecision has been modelled through fuzzy numbers, whereas vagueness has been modelled with the expression of the decision maker’s perception through a linguistic variable “profit”, introducing the “a human dimension”. The results show that the outcome depends not only on the perception of the market player, but also on the strategy, as well as on the imprecision of the variables

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Appendix

Appendix A1

Table 1: CX's Installed capacity and portfolio of customers

Plants	*Type*	*[MW]*	*Potential Customers*[a]
GT	Gas turbine	25	CHEM SA[b]
Hydro 1	Run-of-river	25	ALU SA[b]
Hydro 2	Run-of-river	10	Mun 1, 2, 3[c]
Hydro 3	Dam	200	INDs[d]

Notes

[a] All the customers are connected to the medium voltage network, except Mun 3 and INDs

[b] ALU SA and CHEM SA: respectively an aluminium melting and chemical industries

[c] Mun 1, 2, 3 are municipalities.

[d] INDs is a set of small to medium industries

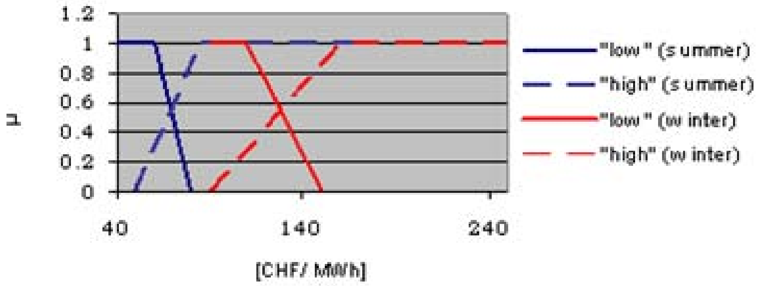
Appendix A2

Table 1: Screening of the variables

Explained Variables	*Explanatory Variables*
Electric energy generated	
2 run-of-river plants and 1 dam	Water Inflows[6] (S)
1 gas turbine (GT)	Natural Gas Prices (F), Demand (F)
Volumes of the long-term contracts	Ownership of the plants (C)
Hydro generation costs	Operation costs & Taxes (C)
GT generation costs	Natural gas and electricity spot prices (F)
Sale prices	Energy costs (F), Other charges (C)
Price long-term contracts	Electric energy spot price[7] (F)
Price futures contracts	Electric energy market price[8] (F)-→ (C)

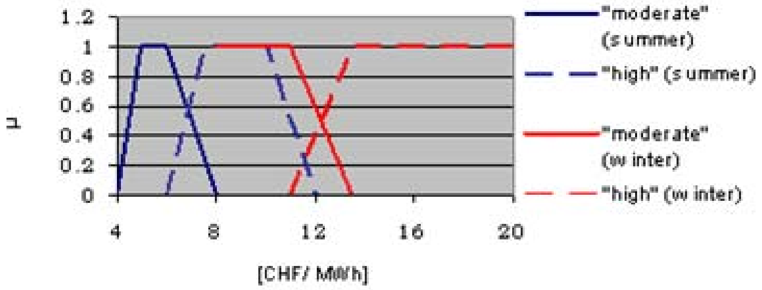
Notations: C: crisp/ deterministic S: stochastic F: fuzzy

- *Water Inflows*, *Natural gas prices*, the *electricity spot price* as well as the *electric energy demand* are used for scenarios construction.

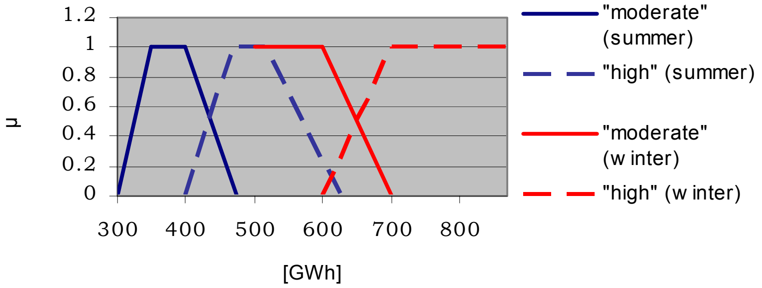


Membership functions of the electric energy spot price

&

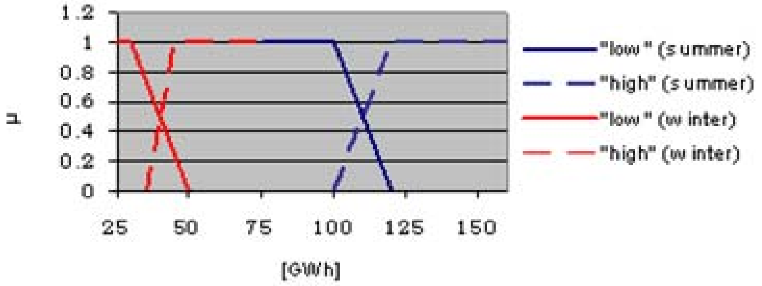


Membership functions of the natural gas market price



Electric energy demand

&



Electric energy output (run-of-river plant, Hydro 1)

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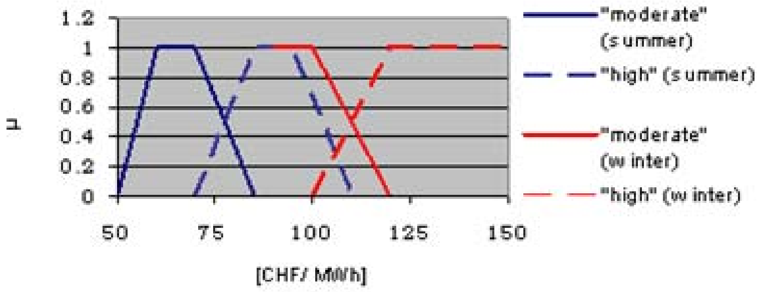
[6] A stochastic variable can be transformed into a fuzzy set

[7] Values of chosen α-cuts

[8] The value of the centre-of-are of the fuzzy number



Gas turbine production costs

Hydro generation costs [CHF/ MWh]		*Network charge [CHF/ MWh]*	
Hydro 1		MV (incl. HV)	45
Hydro 2		LV (incl. HV & MV	70
Hydro 3			

Appendix A3

Candidate portfolios of customers

Portfolio 1	*Portfolio 2*	*Portfolio 3*	*Portfolio 4*
CHEM SA	CHEM SA	CHEM SA	CHEM SA
ALU SA	ALU SA	ALU SA	ALU SA
Mun 1	INDs	Mun 1, 2, 3	Mun 1
Mun 2	Mun 1	INDs	

Characteristics of the potential forward contracts

Denomination[a, b]	*[GWh/ year]*	*[CHF/ MWh]*
F1	180	50
F2	100	80
F3	30	61
F4	70	50
F’1	40	61
F’2	70	50
F’3	60	61
F’4	80	50
Note [a] Long-term contracts for summer: F1, F3, F’1, F’3 [b] Long-term contracts for winter: F2, F4, F’2, F’4		

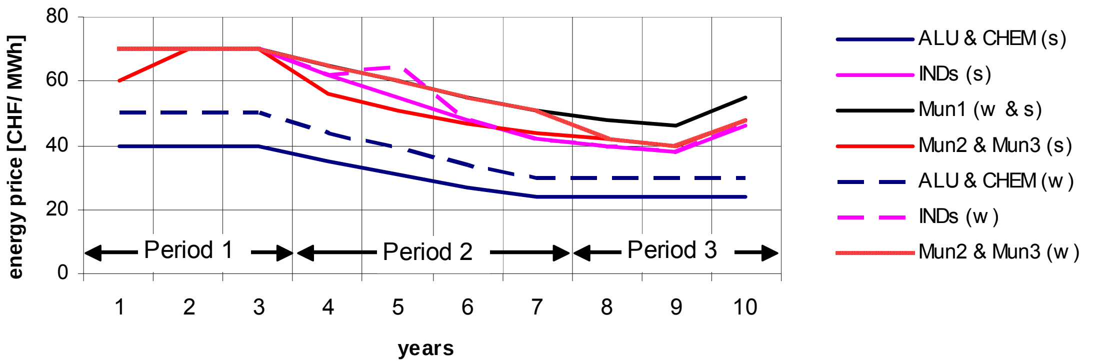
Attributes of Strategies ***LSO***					
Time frame	*Sub strat.*	*Assets*	*LT contracts*	*Portfolio cust.* ***LSO1***	*Portfolio cust.* ***LSO2***
Period 1	St1	All operated	F’1, F’2	Portfolio 4	Portfolio 4
Period 2	St2		F’3, F’4	Portfolio 2	Portfolio 3
Period 3				Portfolio 3	

Attributes of Strategies ***SW***					
Time frame	*Sub strat.*	*Assets*	*LT contracts*	*Portfolio cust.* ***SW1***	*Portfolio cust.* ***SW2***
Period 1	St1	All operated	F1, F2	Portfolio 3	Portfolio 3
Period 2	St2		F3, F4	Portfolio 2	Portfolio 4
Period 3				Portfolio 4	

Scenarios (with scenario Sc2 as the base case scenario)

	Elec. Demand (d)	Elec. Spot Price (els)	Nat. Gas Price (ng)	Water Inflows (w.i)
Sc 1[b]	μ_d^{M} (y’)	μ_{els}^{L}(y)	μ_{ng}^{M},(x’)	$\mu_{w.i}^{H}$(x)
Sc 2	μ_d^{M} (y’)	μ_{els}^{H} (y)	μ_{ng}^{H}(x’)	$\mu_{w.i}^{H}$(x)
Sc 3	μ_d^{H} (y’)	μ_{els}^{L}(y)	μ_{ng}^{M},(x’)	$\mu_{w.i}^{H}$(x)
Sc 4	μ_d^{H} (y’)	μ_{els}^{L}(y)	μ_{ng}^{H}(x’)	$\mu_{w.i}^{H}$(x)
Sc 5	μ_d^{H} (y’)	μ_{els}^{H} (y)	μ_{ng}^{M},(x’)	$\mu_{w.i}^{H}$(x)
Sc 6	μ_d^{H} (y’)	μ_{els}^{H} (y)	μ_{ng}^{H}(x’)	$\mu_{w.i}^{H}$(x)

Sale prices and pricing policy towards customers all through from year 1 to year 10 (Energy contracts)



Capacity contracts

	Distribution Network					Interruptibility		
	P^{inst} [MW][a]	α [-][b]	P^{subs} [MW][a]	c_j^{dist} [CHF/MWh][c]	c_j^{con} [kCHF/MW][c]	Status	Duration [h]	P^{shaved} [MW][d]
ALU SA	56	0.9	50	45	90	Yes	1000	10
CHEM SA	41	0.85	35	45	90	Yes	1000	7
INDs	47	0.75	35	70	105	No	-	-
Mun 1	35	0.57	20	45	105	No	-	-
Mun 2	38	0.7	27	45	90	Yes	2000	7
Mun 3	27	0.75	20	70	90	Yes	2000	5
CX	3	0.67	2	45	90	No	-	-

Note: [a] P^{inst} :and P^{subs} represent respectively the Installed capacity and the highest capacity demand per annum

[b] α is the utilization factor of customer *j*’s installed capacity

[c] c_j^{con} and c_j^{dist} are respectively the monthly demand rate paid by each customer and the peak/ off peak unit rate

[d] Capacity shaved during winter

Appendix A4

Economic performances of strategies LSO1 and LSO2

Perf (LSO1)/ Perf (LSO2)	D, VL	L	H	EH
Yr1-yr3	0 – 0	0 – 0.4/ 0 – 0.33	0.95 – 1.0/ 0.92 – 1	0.2 – 0.38/ 0.2 – 0.42
Yr1-yr7	0 – 0	0 – 0.4/ 0 – 0.35	1.00 – 1.0/ 0.90 – 1	0.3 – 0.52/ 0.41 – 0.70
Yr1-yr10	0 – 0	0 – 0.4/ 0 – 0.40	0.00 – 0.40/ 0.95 – 1	0.4 – 0.63/ 0.46 – 0.78

Table 15: Economic performances of strategies SW

Perf (SW1)/ Perf (SW2)	D, VL	L	H	EH
Yr1-yr3	0 – 0	0.0 – 0.52/ 0 – 0.38	0.75 – 1/ 0 – 0.38	0.58 – 0.95/ 0.52 – 0.92
Yr1-yr7	0 – 0	0.0 – 0.50/ 0 – 0.36	0.80 – 1/ 0 – 0.36	0.56 – 0.68/ 0.42 – 0.73
Yr1-yr10	0 – 0	0.1 – 0.50/ 0 – 0.38	0.85 – 1/ 0 – 0.38	0.5 – 0.8/ 0.40 – 0.68