Assessment of future hydropower plants investments in Switzerland – a Real Options Approach

Master Thesis

for the Degree of

Master of Advanced Studies in Management,

Technology and Economics (MTEC) at ETH Zurich

Author:

Kimon Marketos, MSc Mechanical Engineering ETH

Supervisors:

Prof. Didier Sornette, ETH Zurich - Chair of Entrepreneurial Risks

Supervisor X, PowerProduction Company

Note: This is a modified version of the original Thesis. The names of the company and the power plant as well as the numbers in this version have been changed due to confidentiality obligations.

Abstract

Hydropower accounts for 60% of total Swiss electricity production. Hydropower plant operators are entitled by the local authorities to use of the water. The corresponding contracts, called concessions, have been signed 50-60 years ago. In the following 10-30 years most of the concessions will expire and a call for tenders will be issued. Nevertheless, current operators have legally the solely right to negotiate early concession renewal with the municipalities and cantons before expiration of the respective current concessions. Furthermore, the liberalization of the electricity sector in the near future will increase competition within the existing players and enable new companies to enter the Swiss electricity market. Several hydropower operators are therefore considering early concession renewal with the goal to ensure their production portfolio and secure their positioning in the market.

In this study an assessment of investments in hydropower plants associated to the concession renewal problem is conducted. For this purpose the traditional NPV method is used as well as a more sophisticated model based on real options analysis is developed. The real options model considers the action flexibility of the firm's management, the ambiguity related to the acceptance probability of concession renewal offers by the authorities as well as the uncertainty of future electricity prices. The results of the model comprise the financial valuation of the concessioning options along with the identification of the optimal time for the concession renewal and, thus, highlight the optimal strategy for the company. Moreover, the study identifies the advantages and drawbacks of the real option analysis method compared to the classic NPV methodology that is currently used within the company.

Note: This is a modified Version of the original Thesis. The names of the company and the power plant as well as the numbers in this version have been changed due to confidentiality obligations.

Table of contents

Abbreviations and Notations

CAPM	Capital asset pricing method
CF	Cash flow
DCF	Discounted cash flow
DTA	Decision tree analysis
f_{mb}	Factor for market-entry barriers of competitors
HFVE	Reversion-waiver-compensation (Heimfallverzichtsentschädigung)
IRR	Internal rate of return
MAD	Market asset disclaimer
NPV	Net present value
o&m	Operation and maintenance
PP	Power plant
p_{acc}	Offer acceptance probability
r	Interest rate
RADR	Risk-adjusted discount rate
ROA	Real options analysis
ROR	Run-of-the-river
$sh_{PP,\text{“PowerProduction“}}$	Share of „PowerProduction“ of the „Alpine“ power plant
SH_{tot}	Public authorities total share of the value of „Alpine“ power plants
WACC	Weighted average cost of capital
V_{PP}	Total net present value of a concession of „Alpine“ power plants

1 Introduction

1.1 Hydropower plants in Switzerland

The electricity production in Switzerland is dominated by two main energy conversion technologies: hydro- and nuclear-power plants. Around 60% (in 2011: 30'269 GWh or 51.8%[1]) of the total electricity production in the country is accounted to hydro-power plants. Hydropower plants are divided into run-of-the-rivers and conventional dam plants. Figure 1-1 shows the yearly production of electricity in Switzerland sorted by technology and compared to the total yearly electricity consumption.

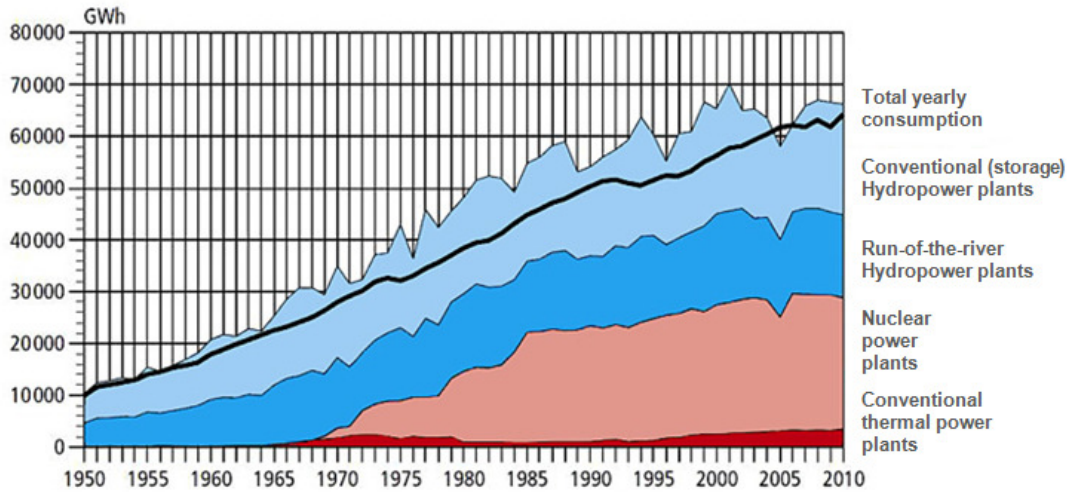

Figure 1-1: Yearly electricity consumption and production in Switzerland [Source: BFE, Swiss Federal Office of Energy]

The conventional hydropower plants are using the water of natural or artificial water storages (lakes or dams). The water is delivered to the turbines in the turbine house that is located at a lower level. In this way the potential energy of the water in the dam is converted into electricity. In such power plants electricity output is completely controlled by the operators and can used as peak or base load energy. A more specific case of dam hydropower plants are the pump-storage plants. There water is pumped with electrical pumps to the storage reservoir in times of low electricity price and is then released back through the turbines at times of high demand.

As their name suggest run-of-the-river (ROR) hydropower plants are situated on rivers and are using the running power of water to produce electricity. Upstream of such plants a relative small storage reservoir may be placed (referred to as pondage) in order to ensure a minimum flow to the turbines in times of low natural flow. ROR plants have a very limited ability of output control and are therefore mainly used for baseload electricity production.

[1] This number accounts for the total electricity produced in running and storage hydropower plants in Switzerland. The electrical energy of the pumps has been deducted.

In Switzerland there are 447 hydropower plants with a total installed capacity of more than 13'000 MW. Most of the plants are located in the mountainous southwestern and south eastern Swiss cantons of Valais, Ticino and Graubünden. On the map of Figure 1-2 the locations of all hydropower plants with an installed capacity of 20 MW or more is depicted.

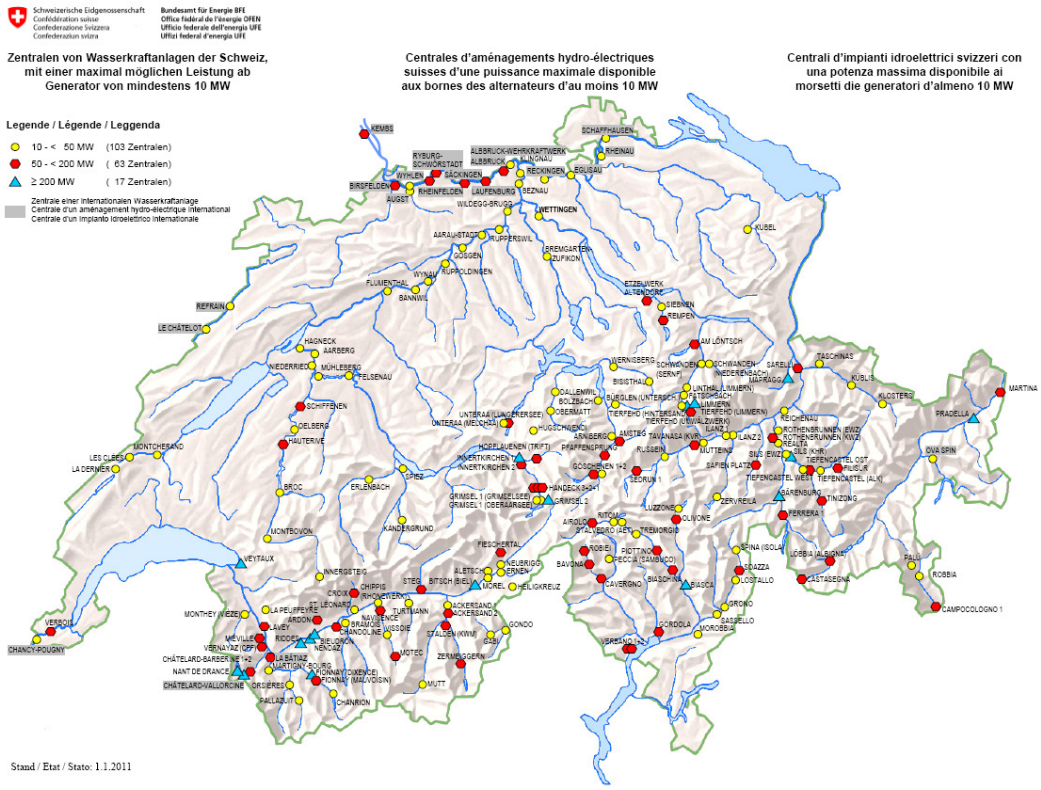

Figure 1-2: Map of Switzerland with all hydropower plants with a capacity of >10MW [Source: BFE, Federal Office of Energy]

1.2 Legal and political framework

All hydropower plants in Switzerland are obliged to obey to the technical, economical and legal rules defined in the Swiss federal legislation. The Federal law 721.80 called "Water-rights law" is the main relevant legal document. In this section the main obligations and rights for the owners and operators as defined in the mentioned document are highlighted and explained.

1.2.1 Water-usage concessions

The use of the water resources in Switzerland demands for a concession by the local authorities. The municipality has the right to grant the usage-right of the waters in its area and its decision has to be approved by the government of the corresponding canton. The decision of the municipality regarding the assignment of the water-usage rights should be taken "in favor of the applicant that ensures the public interest the most and presents the most appropriate usage of the waters" (WRG, 2012).

Each hydropower plant has to ensure a minimum remaining water flow (defined by law) in order to comply with environmental requirements. This minimum flow cannot be used in power production and, thus, limits the maximum output of the power plants.

The duration of the concession is regulated by laws of the Swiss Federation as well as of the cantons. Federal law allows a maximum usage right time of 80 years, while some cantons limit the maximum concession duration (WRG, 2012). The canton of Graubünden defines the maximum concession duration to 60 years (WRG Kanton GR, 2012).

After the period defined by the concession has lapsed out the right of the concessionaire on the usage of the waters expires. The concessionaire is allowed to apply for a renewal of the concession ("early reconcessioning") before the expiration of the valid concession. The responsible authorities are only allowed to negotiate with the current concessionaire during a valid concession. At expiration of the concession an official call for tenders may be launched by the authorities for appointing the new concessionaire.

The federal law prescribes that at expiration of a water-usage concession all parts of the hydropower plant that are necessary for the operation of the plant (dams, intake constructions, pipes, water turbines, buildings etc.) have to be rendered to the municipality. This is called reversion obligation of the "wet parts". On the other hand, the "dry parts" (referring to the equipment and buildings that are used to electricity conversion) belong to the plant owner and a financial compensation is due by the municipality.

In case of an early concession renewal the concessionaire looses the remaining time and income of the old concession until its theoretical expiration. Furthermore, a financial compensation has to be paid by the concessionaire to the corresponding authorities (canton, municipalities) for their waiver of the reversion right. The form and the amount of the compensation is defined in negotiations between the involved parties (participation in a shareholder firm, direct payment etc.). In case of compensation in form of a direct payment by the concessionaire the term "Reversion-waiver-compensation" (Heimfallverzichtsentschädigung, HFVE) is used.

1.2.2 The „water tax"

During the operation of the hydropower plants the concessionaire is obliged to pay to the municipality and/or the canton certain operation fees. These fees are either in the form of a "power plant tax" or an electricity-production-dependent "water tax". By federal law the sum of the imposed tax and "water tax" is limited to a maximum of 100 CHF per kW of gross installed power. This limit is valid until the end of year 2014; thereafter a limit of 110 CHF per kW will apply (WRG, 2012). In the canton of Graubünden the relevant fees are raised to 50% as "power plant tax" (by the canton) and to 50% as "water tax" by the corresponding municipalities (WRG Kanton GR, 2012).

1.3 „Alpine“ hydropower plants[2]

In the canton of Graubünden „PowerProduction“ owns and operates the „Alpine“ hydropower plants. This group of power plants consists of five plants: Plant 1, Plant 2, Plant 3, Plant 4 and Plant 5. Its total installed producing capacity is 750 MW and its average yearly production is 2’450 GWh. Figure 1-3 shows the arrangement of the five plants in „Alpine“. The water accumulated in the Albigna storage is used to produce electricity (together with the water coming from the Plant 1 intake) at the Plant 3 power plant (3 turbine groups with a total of 95 MW). Plant 1 is a small-scale hydropower plant close to the Plant 1 intake with a capacity of 2.5MW. Plant 2 is a ROR-plant with 33 MW capacity. Another ROR plant is located in Plant 5 (34.5 MW). The water from the storage dam in Plant 3 is delivered to the power plant in Plant 4 (500MW). Between Plant 3 and Albigna-storage two pumps can be used for directing the water up to the Albigna-storage (mainly in the summer months).

Figure 1-3: Map of the canton Graubünden with the location of the „Alpine“ power plants

Start of the constructions works in „Alpine“ power plants was in XXXX and the commissioning was successfully completed in XXXX. The concession of all four „Alpine“ hydropower plants took effect as of XXXX and allowed the use of the water in the region for 80 years. Thus, at the end of 2039 the concession will fall due.

„Alpine“ hydropower plants have the highest installed capacity of all other hydropower plants of „PowerProduction“ (taking into account the shares at partnership-plants) producing almost 30% of the total yearly production of „PowerProduction“ hydropower. Thus, it is of high importance for „PowerProduction“, in order to be able to retain its positioning in the market as a reliable power producer and distributor. Therefore, „PowerProduction“-Management has launched working groups to study the best possible way of assuring a concession renewal of this group of hydropower plants

[2] Note: This is a modified Version of the original Thesis. The names of the company and the power plant as well as the numbers in this version have been changed due to confidentiality obligations.

either through an early concession renewal process or an renewal over the bidding process (under competition) at the expiration of the concession in 2040.

In the following sections the business case of the „Alpine“ hydropower plants is going to be assessed and the results are going to be discussed. The goal is to present an assessment model that incorporates the complex situation of the concession renewal process for hydropower plants in Switzerland. This model is aspired to serve as a decision tool by the management and should therefore be able to present to the decision makers the flexibility and decision options that they have, in a comprehensive and informative manner.

1.4 Swiss electricity market

The Swiss electricity market is going through major restructurings in the recent years. In 2008, the new electricity bill came into effect as a first step towards a more liberal market structure. With this bill, consumers with a yearly consumption of 100’000 kWh are allowed to choose their electricity distributor freely. This is a big leap change in Switzerland, where up to then municipal and cantonal utility companies where granted the exclusive right of electricity distribution in their geographical region. It is expected that until 2015 all consumers will be able to choose their provider by their own ("PowerProduction", 2012).

The liberalization of the Swiss electricity market calls for adaptation to the new situation by the existing players in the electricity market. New entrants of abroad as well as geographical expansion of the Swiss utility companies are almost certain in near future. Competition is expected to grow in all steps of the electricity sector value chain; from production over to distribution. Investments in production sites (Wind farms, Hydropower plants etc.) are expected to get more under pressure, in order to ensure competitive profitability levels. In general, the financial performance indexes of electricity production projects, especially in big centralized projects such as big hydropower plants, are highly possible to decrease compared to the prosperous years of the last decades as a results of the enhanced competition in the market.

1.5 Goal of the study

It is, therefore, of major importance for „PowerProduction“ to thoroughly assess its investment projects. The present study aims to aid the investment assessment of concession renewals that are related to the operation of „PowerProduction“ hydropower plants throughout Switzerland. „Alpine“ hydropower plants were selected as the business case for this study. The goal of the study is to develop a model that enables the financial assessment of the different action possibilities that „PowerProduction“ has with the aforementioned power plant. Firstly, the assessment is conducted with the traditional net present value method. In advance, a more profound real options based model is elaborated. The intention is to gain experience with the real options analysis method and to investigate its use and benefits for similar investment projects. The real options model illustrates the optimal path that „PowerProduction“ should follow in the concession renewal problem. Moreover, the results of the real options model are

compared to the ones attained by NPV analysis and the advantages as well as drawbacks of real options are determined. Therewith, capabilities of real options for „PowerProduction“ are addressed.

In the following section of the thesis, the capital budgeting methods are presented to the reader. The theoretical background of real options is highlighted and the necessary basics of this method are introduced. In section 3 the assessment of the „Alpine“ hydropower plants is presented. The results of the NPV analysis are presented first. In the second part of section 3 the development of the real options model of the present study is explained. Thereafter, the base case scenario and the sensitivity analyses are presented. In the last section, conclusions are drawn with respect to the specific business case studied as well as to the possible benefits of real options implementation within „PowerProduction“.

2 Capital budgeting methods

The main goal of a company is to serve the interests of its shareholders. This goal is identical with the goal of increasing the company's economic value (Trigeorgis, 1996). In order to achieve value maximization it is therefore of high importance to define economical indexes that allow for forecasting, planning and, last but not least, for monitoring of this goal.

Each company can act within boundaries defined by the markets it is operating in, their legal and political frameworks and the financial resources it has available. Allocation of the latter is the main control element that the management of the company is able to influence. Thus, management practitioners, scholars and researchers have been studying for a long time the best methods of resource allocation within a company, aiming at the continuous value increase of the company and, hence, the satisfaction of its shareholders. This field of study and its practical implementation is known as capital budgeting.

Over the second half of the last century quantitative methods of capital budgeting have made the breakthrough and are currently applied in almost every company. In the first part of this section the most widely spread capital budgeting methods are presented along with their advantages, shortfalls and drawbacks. After that, a more detailed insight into the theory of the real options analysis is provided to the reader.

2.1 Traditional capital budgeting methods

Net Present Value (NPV)

The method of net present value refers to the calculation of the total value of a project, or more generally an asset, throughout its complete service life. In order to calculate the net present value the concept of discounted cash flow (DCF) is used. DCF is the process of mathematically expressing the value of future expenditure or income flows that are related to the project or asset of study (e.g. rent income of a building, R&D expenditure of a project etc.). The relevant money-flows for the calculations are called cash flows (CF), referring to transactions of direct exchange of money between the main party involved in the project and its business partners[3]. As its name tells, DCF is based on the discounting method that is explained in Section 2.3. The main equation of the net present value concept is the following

$$NPV = \sum_{0}^{T} \frac{CF_t}{(1+r)^t} - I$$

where r is the discount rate (see section 2.3), CF_t is the net cash flow in year t, I is the initial investment expenditure (at year t=0), and T is the total years of the project's life.

[3] *„It is cash flows, and not accounting profits, that the firm owners can withdraw for consumption or reinvest to generate future cash flows"* (Trigeorgis, 1996).

According to the NPV criterion, projects that have a positive NPV will increase the value of a company and, thus, the shareholder's wealth (Trigeorgis, 1996). If more than one of the planned projects have a positive NPV, the ones with the most positive NPVs should be chosen.

NPV is the most wide-spread method of capital budgeting within companies nowadays. Nevertheless, it has been realized by many practitioners that NPV comes to its limits when complex projects that include managerial flexibility coupled to decision making are present. Furthermore, the higher the uncertainty of crucial parameters that influence the cash flows of a project is, the less is the NPV method able to provide correct measures that managerial decisions can rely on.

Internal Rate of Return (IRR)

The internal rate of return method is similar to the NPV method, using again the concept of discounted cash flows. Nevertheless, the dependent variable in IRR is the discount rate. The NPV equation, presented in the previous paragraph, is rewritten as follows

$$0 = \sum_{0}^{T} \frac{CF_t}{(1 + IRR)^t} - I$$

Thus, IRR is the rate of return for which the project under consideration will have a net present value of zero. The higher the IRR is, the more favorable a project is. In case of several, mutually exclusive, projects the one with the highest IRR is preferred. When a single project is being evaluated, the IRR method says that if the resulting IRR of the project is higher than the market interest rate, the project should be realized. In other case, if the projects considered results in IRRs lower than the potential returns from other investment activities in the financial markets, it would be more favorable for the company to invest its financial resources into these markets.

Although IRR method is straightforward and easy to use for the management, pitfalls are lurking in its use and have been pointed out by finance experts (Brealy & Myers, 2000 and Trigeorgis, 1996). In case of alternating positive and negative cash flows during the project life, more than one IRR may result from the equation above. Moreover, the use of one rate of return (IRR) in such cases, of alternating lending and borrowing, results in misleading conclusions about the attractiveness of a project. Generally in cases of a non-constant cost of capital for the company over the years of the project, the IRR rule cannot be applied on ist own. Nevertheless, the most common and wide spread pitfall is that using the IRR rule to decide over mutually exclusive projects, may result in choosing the project with the lower NPV. The internal rate of return method should, therefore, be used only in combination with and in support of the NPV decision rule; in cases where the NPV method does not give a clear answer which of the competing project is best.

Payback Period

Payback Period in capital budgeting refers to the concept of calculating the number of years that are necessary until a company recovers a specific project's initial investment. The cash flows of the project are accumulated year by year until the point where their sum equals the outlays at year zero. In its original version, payback period does not

account for the time value of money. In the discounted payback period method, cash flows are first discounted with the appropriate discount rate and then summed to give the accumulated net cash flows.

The payback period rule is still used in some (mainly small) companies, even though it can be misleading and wrong as a decision rule. A first shortfall is that the cash flows after the cutoff date (point of time at which the initial investment is equalized by the project incomes) are not taken into consideration. Secondly, if the relative cash flows are not discounted, the payback rule may lead to acceptance of projects with negative NPV (Brealy & Myers, 2000).

2.2 Real Options Analysis Method

In 1977 Steward Meyers used for the first time the term “real options” to refer to the application of financial option pricing theory to “real” investments. The relevant investment projects were multi-stage R&D or modular manufacturing plant expansion (Borison, 2005). Thus, projects that included flexibility, learning and uncertainties. In the 1990’s research on real options advanced rapidly and was introduced to a broader public through the work of Trigeorgis (Trigeorgis, 1996). Industries got attracted by the possibilities of the new capital budgeting method and airplane companies were the first to widely apply this new technique (Copeland & Antikarov, 2003). In the following years real option analysis diffused in several industries like real estate, IT management, gas and oil sector or electricity production (Nembhardt & Aktan, 2010).

Real option analysis (ROA) theory has emerged from the financial options valuation technique and, thus, builds on the seminal work of Black and Scholes (Black & Scholes, 1973). An option is defined as the right to take a decision at one or more point in the future but not the obligation to do it. This decision may be related to investments, production output levels, sell-outs, mergers and acquisitions etc. The main difference between financial options and real options is that financial options are not directly coupled to a firm’s value. Financial options are agreements on financial assets that are met between two outsiders (e.g. stockholders). The financial option does not change the company’s activities at all (Howell, et al., 2001). On the contrary, real options are directly linked to a firm’s value, since a decision taken by the management will have a direct impact on the valuation of the firm (e.g. stock price). They are options linked to “real” changes of the intellectual or physical assets of a company. Moreover, financial options are usually traded in the market, so that their price can be checked relatively easy within the market. In contrast, in most cases the underlying asset of real options, i.e. the asset to which the option is linked, is not traded and, hence, there is no market price against which to assess the option’s value. In general, there are two key business decisions that real options address; first, how much to pay for a given real option and second, what is the optimal timing to exercise the option.

Traditional capital budgeting techniques regard the management companies in a passive manner, assuming that it will comply with the future market situation. This view is not very realistic, since in reality, depending on future developments, a firm’s management is able to adjust its strategy and actions to the overall situation it faces in each point in time. The real options approach accounts for such flexibilities as well as

for the fact that the future is unforecastable and, hence, involves uncertainties. In Table 2-1 an overview of the most common types of real options is presented.

Option to defer	Flexibility of the management is linked to the timing to start a project.
Option to expand /contract	Managerial flexibility to increase or reduce production if conditions turn out favorable or unfavorable respectively
Option to abandon	Flexibility to cease or step out of a project during its execution.
Option to switch	Management has the possibility to switch between two or more project parameters like inputs or outputs (e.g. switch between gas and oil in a dual unit power plant)
Compound options	Option on an option. Case where the outcome of one real option leads to further options.

Table 2-1: Overview of common types of real options

Over the years finance practitioners and scholars have developed several approaches for the calculation of real options (Barton & Lawryshyn, 2010). The main differences of these approaches are related to the classification of the project risk, the existence of a replicating asset in the market and the choice of the appropriate discount rate (Borison, 2005).

Classical Approach

In the classical real options approach it is assumed that the capital markets are complete, thus, for each traded asset there exists a replicating portfolio comprised by risk-free bonds and risky assets. Furthermore, this approach assumes that the real assets related to the option have cash flows that are highly dependent on the market prices and can, therefore, be represented by an equivalent portfolio found in the market. Closed form mathematical equations from the financial options theory (Black-Scholes equations) can be used for the calculation of the option value. By this approach, real options that are closely related to the market can be studied. Nevertheless, for real-world projects it is often impossible to find a highly correlated market portfolio (Copeland & Antikarov, 2003). Moreover, the classical approach fails to account to project risks that are not related to broader market risks.

Subjective Approach

The subjective ROA approach uses available indices or industry standards to estimate the underlying project value and volatility variables. Thereafter, the same equation as in the classical approach is used to determine option value. Although the subjective approach is simple to implement, researchers criticize that there are inconsistencies in the use of subjective information with replicating portfolio techniques and no arbitrage assumptions (Borison, 2005).

Revised Classical Approach

In real options studies, risks are separated into two main categories; public risks and private risks. Public risks refer to risks that are related to exogenous market factors such as market dynamics, regulatory or political uncertainty, and competitive forces. Private risks are endogenous risks, inherent to the firm and the project itself, including organizational capabilities and available resources. The revised classical approach accounts for the aforementioned categorization of risks. Based on the proposal of Dixit and Pindyck (Dixit & Pindyck, 1994), if the relevant project is dominated by market-risks, the classical approach can be used, whereas if it is governed by private risks, a decision tree analysis is recommended. Using subjective probabilities of possible project outcomes, an event tree represents the changing project value over time. At terminal nodes, cash flow statements are constructed and the NPV is calculated. A "roll back" procedure determines the initial expected NPV by using the subjective probabilities.

Integrated Approach

The integrated approach acknowledges that several problems include both types of risks; public as well as private risks. The former are replicated by a replicated portfolio found in the market, whereas subjective probabilities are assigned to the latter. A decision tree, representing the investment alternatives, is built, cash-flow modes are applied to each tree endpoint and NPV are calculated using the risk free rate. Finally, the optimal strategy is determined by backward induction within the decision tree.

Market Asset Disclaimer Approach

Unlike the classical ROA view, Copeland and Antikarov (Copeland & Antikarov, 2003) argue that it is pointless to search the economy for an adequate portfolio of twin securities to characterize real returns. Due to the incomplete nature of the economy, they assume that the best estimate of the market value of the project is the present value of the project itself, without flexibility. This is the Market Asset Disclaimer (MAD) assumption. The MAD approach uses mixture of risk-free (in the binomial tree used for the option value calculation) and risk-adjusted (in the simulation of the present value volatility used to calculate the risk-neutral probabilities) discount rates.

Real options methodology in the present study

The problem investigated in the present study includes mainly private risks that are related to the project itself. These risks include the ambiguity related to the probability of acceptance of a concession renewal offer from „PowerProduction" by the public authorities. Furthermore, there is an uncertainty related to the future development of the electricity prices. This uncertainty can be seen as a public risk, related to exogenous market factors. It was decided to use a decision tree for the real option analysis, in order to maximize the comprehensibility and perceivability of the model for decision makers within the company. A representation over a decision tree enhances the overview and understanding for non-experts. Hence, the real option analysis in the present study was based on the revised classical methodology.

2.3 The Choice of the Discount rate

Discounting is a fundamental financial technique based on the concept of time value of money (Brealy & Myers, 2000). It is the process of mathematically expressing the value of money, depending on the point in time at which accrues (as a transaction), to its value in another point of time in the past or the future. Economic theory tells us that each individual (person or company) seeks to maximize its utility function. In its effort to achieve maximum utility the individual is subject to two main constraints regarding its resource allocation; its production-possibilities and its consumption (or income) preferences. When analyzing the temporal variation of production and consumption of an economical agent the aforementioned constrains can be depicted by its productive-opportunity curve and its time-preference utility curves, as shown in Figure 2-1.

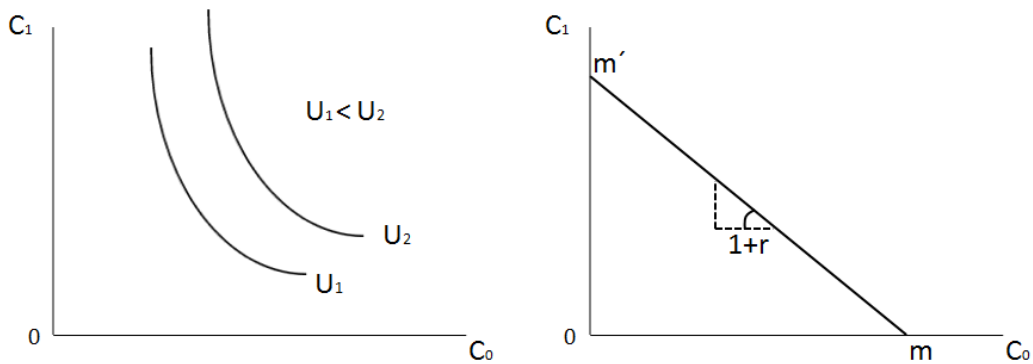

Figure 2-1: Time-preference utility curves (left) and market opportunity curve. C_0 is the current consumption and C_1 next year's consumption while r is the market interest rate (Trigeorgis, 1996).

In a perfectly competitive capital market, individuals can lend and borrow freely at the same constant rate (i.e. equal to the interest rate, r). Thus, their market opportunities curves are straight lines with a slope of 1+r (Figure 2-1). The meaning of this is that any individual can either borrow $C_1/(1+r)$ Euro today for C_1 Euro next year, or lend one Euro of his C_0 Euro today and pay back (1+r) Euro of his C_1 Euro next year. This is the concept of the time value of money, and r is called the discount rate.

Risk free interest rate

Shareholders and market participants are searching for the best investment options in the market to invest their money. Lending money to the government, hence, investing in government bonds, is considered by most investors as a absolutely safe investment (at least until some years ago). Thus, investors are sure that governments of countries with strong national economies will comply with their obligations, and pay back the corresponding dividends as well as the final value of the borrowed money. This is why the interest rate of the government bonds is considered as the risk free interest rate (r_f) for corporate finance calculations.

Capital Asset Pricing Method (CAPM)

Different sectors of the economy of a country, as well as different companies within a sector of an economic market may exhibit differing risk structure. These differences may result from the maturity of the company, its financial structure or several other factors. Depending on the riskiness of a capital investment in a company, investors will demand for a higher profit outlook to account for their risk taken. The difference of the interest rate demanded by investors on their investments in a company's stocks to the risk free interest rate in the market is called risk premium. A measure of how sensitive the stock of company is compared to the market movements (so the average of all companies in the market) is expressed in financial theory as beta (β). A company's stock with a beta of 1.0 will alter its value in accordance to the market. For beta values greater/lower than 1.0 the stock price will tend to amplify/dampen the overall movements of the market. The theory of the capital asset price model (CAPM) implies that, in fully competitive capital markets, the following equation can be used for the interest rate on a company's stock

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

Where r is the interest rate of the company's stock, r_f the risk-free interest rate, r_m the average market interest rate and β the company's beta.

Beta is normally calculated from historical data by analyzing the performance of the firm's stock in the stock-exchange market compared to the overall market performance.

Weighted Average Cost of Capital (WACC)

When assessing a project within a company, the riskiness of the project should be evaluated and, based on that, an appropriate value for the discount rate should be chosen. Nevertheless, many projects can be assumed to be neither more nor less risky than the average of the company's other assets. Thus, such projects can be discounted at the average discount rate of the company. The weighted average cost of capital (WACC) is defined as "the return on a portfolio of all the company's existing securities" (Brealy & Myers, 2000). It is used very often by financial practitioners as the discount rate in project valuation tasks.

$$WACC = \frac{D}{V} r_D + r_E \frac{E}{V}$$

where D is the debt value, E the equity value, V the total firm value. r_D and r_E are the expected returns on debt and equity respectively.

Discount rate in the present study

In NPV analysis and other traditional capital budgeting methods the discount rate used is a risk adjusted discount rate (RADR). In real options analysis since the uncertainty and flexibility is accounted for in the model itself the discount rate used is reduced to the risk free rate (Howell, et al., 2001). However in the current study it was decided to use the interest rate that is normally used by the company in all other studies. The WACC used in the broader study of the company "Electricity Outlook 2012" is 5% ("PowerProduction", 2012). This assumption is in line with the assumptions of the revised classical real options approach used in the study. Moreover, using the risk free

rate actually assumes that all different public and private risks linked to the project are identified and correctly quantified. In complex project constellations, as the one of the present problem, such a task is extremely difficult and a complete integration of the project's risks in the model is almost impossible. Therefore, using the WACC can be seen as a reasonable approximation.

3 Concession renewal assessment

3.1 Assumptions base-case scenario

The assessment of the concession renewal of „Alpine“ hydropower plants was based on the financial model created during the “Electricity Future 2012” study within „PowerProduction“ ("PowerProduction", 2012). This model uses as inputs the expected produced energy in the power plant, the expected electricity price, the o&m and other variable costs, service life as well as investment costs. One of the model’s outputs is the yearly cash flow of the plant operation.

For this study a base-case scenario has been defined. It is in line with the base case scenario of „PowerProduction“ in the aforementioned study. In this scenario „PowerProduction“ offers to the municipality a share of 25% of the produced energy after the renewal of the concession (correspondingly, 25% of the variable costs are carried by the municipality). The new (or renewed) concession is issued for 60 years. The discount rate was based on the WACC used within the company (5%). Finally, in the present study the amount of the reversion compensation (HFVE) was computed from the total share parameter. The total share parameter expresses the share of the expected value of a new concession of the hydropower plant over its whole service life that the municipality and canton are assumed to claim during the negotiations. Thus, the total share of the public authorities is equal to the amount of the reversion compensation plus the share they will own on the operation of the power plant after the concession renewal (in this study assumed to be 25%).

$$SH_{tot} \times V_{PP} = sh_{PP} \times V_{PP} + HFVE$$

$$\Rightarrow HFVE = SH_{tot} \times V_{PP} - sh_{PP} \times V_{PP}$$

where SH_{tot} is the total share of the authorities, sh_{PP} the share of the authorities on the hydropower plant, V_{PP} the value of the power plant operation.

Regarding the timing of the renewal of the concession, after discussion with the company management, it was assumed that the earliest year for a concession renewal taken into consideration is 2020. Further it is assumed that it takes two years of preparatory works and negotiations with the authorities from the moment of the decision to place an offer for a concession renewal to the time that the new concession comes into effect. The reversion compensation is assumed to be a one-time payment that is due in the year that the new concession starts.

It is sure, that the assumptions mentioned in the last paragraph have an influence over the results of the study. It is, therefore, of major importance to study their influence and get a profound insight of how the different parameters change the outcome of the model presented in this study. For this reason, in the last section of this chapter sensitivity analyses for several of the above mentioned parameters are presented to the reader.

3.2 NPV Analysis

In this section when we talk of the NPV of the „Alpine“ hydropower plants we refer to the expected net present value of the share of „PowerProduction“ on the operation business of the plants. Hence, the 25%-share of the public authorities is neglected and not introduced into the cash flow calculations. Table 3-1 shows the NPV calculations for the different years of concession renewal 2020-2040. For a certain concession year (e.g “Reconcessioning 2020”, in the second row) the total NPV at each year is the sum of the discounted future cash flows plus the cash flow at that year. NPV is smaller for years further in the future, since less years remain until the expiration of the concession. In the first row the remaining value of the present concession is presented. In this case (“No reconcessioning”), after the expiration of the present concession in 2039 no new concession is granted and, thus, „PowerProduction“ has no cash flows thereafter related to „Alpine“ power plants.

The net present values calculated in Table 3-1 are further used to derive the optimal time of concession renewal according to the NPV analysis. In each year „PowerProduction“ will face the decision dilemma of whether to invest directly in a renewal of the concessions of „Alpine“ power plants or not. We assume that the investment cost is equal to the amount of the reversion compensation to the public authorities (calculated as described in the last section). Other costs are neglected as they are expected to be of a much smaller magnitude and, thus, have no major influence on the results.

Each year after 2020, decision makers within „PowerProduction“, will compare the expected NPV of „Alpine“ power plants and if the NPV of a new concession two years after is higher than the NPV of all other possible starting years (and the NPV of not renewing at all), they will favor to start negotiations and place an offer for a new concession. In the contrary, if there is any other expected NPV that exceeds the NPV of a new concession two years after the respective year, „PowerProduction“ management will prefer not to apply for a concession renewal at that time being. Hence, from the NPV data, the expected NPV analysis decisions for each year between 2020-2040 have been computed and are presented in Table 3-2. In the same table the amount of the reversion compensation paid for each starting year of the new concession as well as the expected NPV at the decision year (two years before the concession start) is presented. It is noticeable that the reversion compensation is increasing the further in the future the renewal of the concession takes place. This is due to the increasing electricity prices that result in higher project values. The previewed prices (based on a fundamental study undertaken by an external consulting company) do not increase steadily, but they exhibit an increasing tendency over the years. After 2050, the prices are assumed constant, at a high level, leading to higher values of NPV of late concession renewals and consequently higher reversion compensations.

	NPV DCF Analysis (Mio CHF			NPV Analysis With Investment																										
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
No reconcessioning	47.13	46.58	46.32	45.95	45.17	44.43	43.41	42.25	41.10	40.05	39.00	37.82	36.69	35.46	34.08	32.64	31.07	29.42	27.57	25.67	23.71	21.45	18.99	16.51	13.65	10.64	7.29	3.78	0.00
Reconsessioning 2020	37.38	36.34	35.57	34.65	33.32	31.98	30.34	28.53	**26.68**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2021	38.65	37.67	36.96	36.12	34.86	33.60	32.04	30.31	28.56	**26.89**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2022	39.85	38.93	38.28	37.51	36.31	35.13	33.64	32.00	30.33	28.75	**27.12**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2023	41.01	40.15	39.56	38.85	37.72	36.61	35.20	33.63	32.04	30.55	29.01	**27.34**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2024	42.08	41.27	40.75	40.09	39.03	37.98	36.64	35.14	33.63	32.21	30.76	29.18	**27.61**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2025	43.11	42.36	41.88	41.29	40.28	39.30	38.02	36.59	35.15	33.82	32.44	30.95	29.46	**27.87**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2026	44.12	43.42	43.00	42.46	41.51	40.59	39.38	38.02	36.65	35.39	34.09	32.68	31.28	29.78	**28.12**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2027	45.09	44.43	44.06	43.57	42.68	41.82	40.67	39.37	38.07	36.88	35.66	34.32	33.01	31.59	30.02	**28.38**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2028	46.02	45.41	45.09	44.65	43.81	43.01	41.91	40.68	39.44	38.32	37.17	35.91	34.68	33.35	31.86	30.31	**28.63**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2029	46.90	46.34	46.06	45.68	44.89	44.14	43.10	41.93	40.75	39.70	38.62	37.43	36.27	35.02	33.62	32.16	30.56	**28.89**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2030	47.78	47.26	47.03	46.69	45.95	45.25	44.27	43.16	42.04	41.05	40.04	38.92	37.84	36.67	35.35	33.97	32.47	30.89	**29.12**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2031	48.60	48.12	47.93	47.64	46.96	46.30	45.38	44.32	43.26	42.33	41.38	40.33	39.32	38.22	36.98	35.68	34.27	32.78	31.10	**29.38**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2032	49.38	48.93	48.79	48.54	47.90	47.29	46.41	45.41	44.41	43.53	42.65	41.66	40.71	39.68	38.52	37.30	35.96	34.56	32.97	31.33	**29.66**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2033	50.16	49.76	49.65	49.45	48.85	48.29	47.46	46.51	45.56	44.75	43.92	42.99	42.12	41.16	40.06	38.92	37.67	36.35	34.85	33.31	31.73	**29.88**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2034	50.92	50.56	50.49	50.33	49.78	49.27	48.49	47.58	46.69	45.93	45.16	44.30	43.49	42.60	41.58	40.51	39.34	38.10	36.69	35.24	33.76	32.01	**30.07**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2035	51.63	51.30	51.27	51.15	50.64	50.17	49.43	48.58	47.74	47.03	46.32	45.51	44.76	43.93	42.98	41.98	40.88	39.72	38.39	37.03	35.64	33.98	32.14	**30.31**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2036	52.32	52.02	52.03	51.94	51.47	51.05	50.35	49.54	48.75	48.09	47.43	46.68	45.99	45.23	44.34	43.41	42.38	41.29	40.04	38.76	37.46	35.89	34.15	32.42	**30.54**	[illegible]	[illegible]	[illegible]	[illegible]
Reconsessioning 2037	52.97	52.71	52.75	52.70	52.27	51.88	51.23	50.47	49.72	49.11	48.50	47.81	47.17	46.46	45.63	44.77	43.81	42.80	41.62	40.42	39.20	37.71	36.06	34.43	32.65	**30.78**	[illegible]	[illegible]	[illegible]
Reconsessioning 2038	53.63	53.40	53.48	53.46	53.06	52.72	52.11	51.39	50.69	50.12	49.57	48.93	48.34	47.70	46.93	46.13	45.24	44.30	43.20	42.07	40.94	39.54	37.98	36.45	34.77	33.00	**30.95**	[illegible]	[illegible]
Reconsessioning 2040	54.98	54.82	54.97	55.03	54.71	54.44	53.92	53.29	52.68	52.22	51.77	51.24	50.77	50.25	49.61	48.94	48.19	47.40	46.45	45.49	44.52	43.30	41.93	40.60	39.13	37.57	35.76	33.86	**31.30**

Table 3-1: **Net present values for different concession renewal years 2020 to 2040**

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2040
NPV two years earlier	30.340402	30.31441	30.32653	30.547173	30.760837	30.94515	31.28128	31.594196	31.86405	32.15735	32.47117	32.779218	32.96743	33.3111	33.761061	33.976136	34.14719	34.43303	34.76761	36.39122
DCF Analysis Decision	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer
HFVE Paid	23.35	23.53	23.73	23.92	24.16	24.39	24.60	24.83	25.05	25.28	25.48	25.70	25.95	26.14	26.31	26.52	26.72	26.93	27.08	27.39

Table 3-2: **Calculated net present value of concession renewal and the DCF analysis decision for the years 2020-2040 (base case scenario)**

In Figure 3-1 the net present values of all different cases with new concession starting in years 2020-2040, discounted to year 2012 are presented. The net present value calculations show that the remaining present value of the present concession until its expiration is 47 million Swiss francs. A renewal of the concession before 2030 results in lower net present values. From 2030 on, an agreement of a concession renewal has a higher NPV than the value of the running concession. Nevertheless the highest possible NPV is achieved by renewing the concession after expiration of the present concession in 2040, with a value of 55 million Swiss francs.

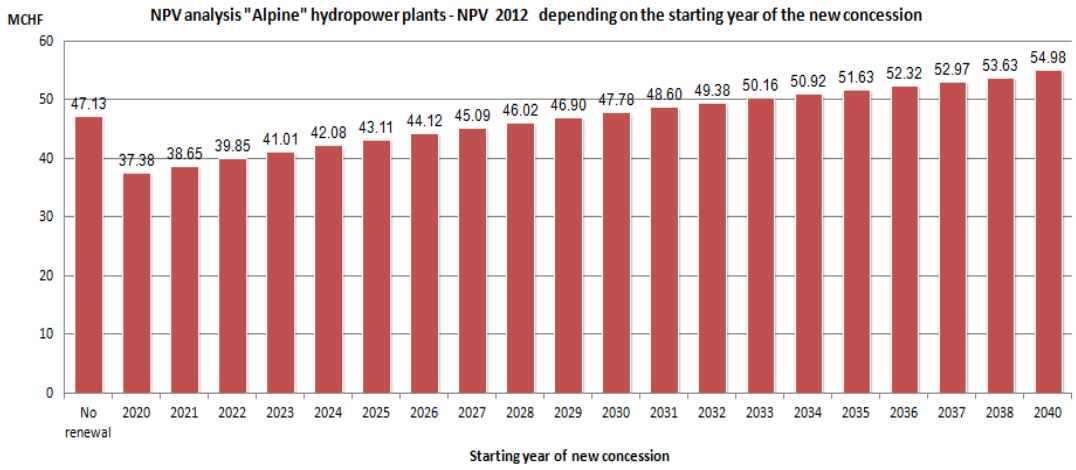

Figure 3-1: Net Present Value 2012 for the different renewal concession starting years

The results of the NPV analysis suggest that, based on the assumptions made, there is no economical justification of an early renewal of the concession of the „Alpine“ power plants. According to the NPV analysis the best strategy for „PowerProduction“ is to wait until the expiration of the present concession and then renew the concession for further 60 years.

3.3 Real Options Analysis

As described in section 2.2, real options are used in cases where flexibility in corporate actions as well as uncertainty of some parameters could influence the value of a project and, hence, of the best decision of the management are present. During the calculation of the net present values in the last section, it was implicitly assumed that the expected electricity values include no uncertainty. Moreover the NPV method assumes that there is certainty about the acceptance of a potential renewal offer that „PowerProduction“ would place to the public authorities. There is no ambiguity that the offer may be declined. These two implicit assumptions are not very realistic and, thus, the result of the NPV method should not be used without caution by the responsible decision makers. In this section we scrutinize the results obtained by NPV analysis with the support of the real options method. First, the real options model is introduced and, thereafter, the results of the static as well as the dynamic real options analysis are presented.

3.3.1 The RO-model

For the purpose of the real options analysis of „Alpine“ hydropower plants, an Excel-based model was built and Macros were programmed on Visual Basic that aim to capture the flexibility and uncertainty factors of the project.

Flexibility derives from the fact that „PowerProduction“ has the possibility to apply for a renewal of the concession each year until 2039. Nevertheless, if the concession has not been renewed before 2040, a call for tenders will be launched which any interested company can participate in. The model was first designed to account for the decision flexibility in terms of the possible offering years. This design is depicted on the left side of Figure 3-2. Except of the aforementioned action flexibility, there is also an uncertainty linked to acceptance probability of a placed „PowerProduction“-offer by the responsible public authorities.

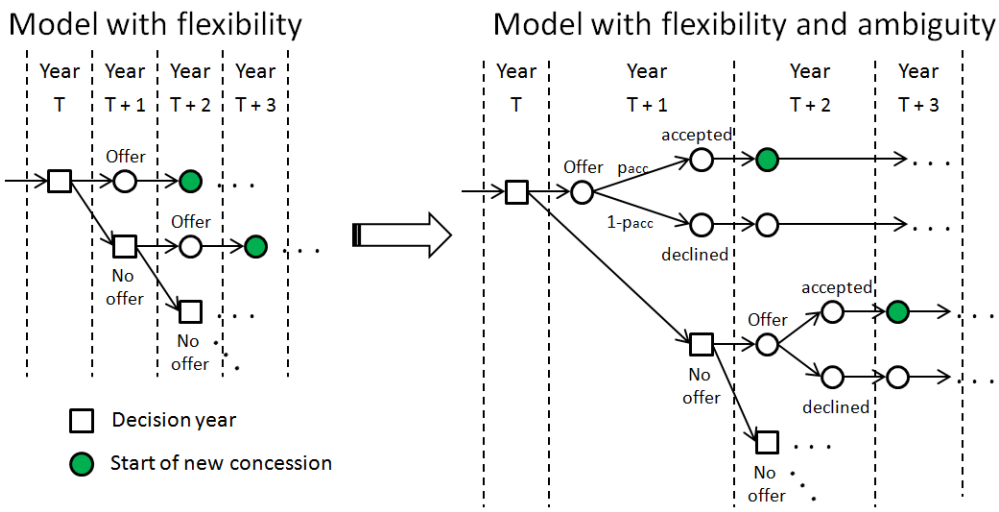

Figure 3-2: Schematic representation of the model structure. On the left the model only accounting for flexibility and on the right the final model that accounts for flexibility and ambiguity

This uncertainty is referred to in this study as ambiguity and is in aims to visualize and quantify the willingness of the authorities to entitle „PowerProduction“ with a new concession for the usage of the waters by „Alpine“ hydropower plants for the next 60 years. Quantifying such intentions is no trivial task. For this purpose, during the present study a consultation with experts within „PowerProduction“ was conducted and objective acceptance probabilities were defined. For the earliest possible starting year of a new concession (2020) an acceptance probability of 92% is assumed. The acceptance probability declines linearly each year by 5% and ends at 2% for a concession start in 2039. This development is justified by the argumentation that the public authorities (municipal and cantonal governments) will favor an earlier renewal of the concession since the terms of the new concession will be more favorable than the ones of the current concession (higher “water-taxes”, share of the power plant etc.). Moreover, the “temptation” of the one-time payment of the reversion compensation by „PowerProduction“ is assumed to have strong influence on the authorities, in favor of an early concession renewal. The closer we get to the expiry date of the current concession, the lower is the interest of the authorities in an early concession assumed

to be. This is because of the fact that the authorities will rather prefer to place a call for tenders in an open competition environment than to have only „PowerProduction“ as a negotiation partner. The former constellation represents a far better negotiation position for the authorities.

In each node of the model, as presented in Figure 3-2, the corresponding net present value is calculated (NPV_T). The equations for the NPV calculations are shown below. CF_T is the cash flow in year T, $HFVE$ the reversion compensation and p_{acc} the acceptance probability.

For a simple node (no decision, offer placement or concession start):

$$NPV_T = \sum_{i=1}^{\infty} \frac{CF_{T+i}}{(1+WACC)^i} + CF_T$$

For a node with concession start:

$$NPV_T = \sum_{i=3}^{\infty} \frac{CF_{T+i}}{(1+WACC)^i} + CF_T - HFVE_T$$

For node with offer placement:

$$NPV_T = p_{acc} \times NPV_{T,accepted} + (1 - p_{acc}) \times NPV_{T,declined}$$

For a node of a decision year:

$$NPV_T = \frac{MAX\left(NPV_{T+1,offer}\,, NPV_{T+1,no\,offer}\right)}{(1+WACC)} + CF_T$$

The real options model's criterion is included in the NPV calculation of decision year nodes. It is assumed that „PowerProduction“ acts economically rational and decides whether to place an offer or not depending on the best outlook to increase the company's value. Thus, at a decision year, the next year's NPVs for both possible actions are compared and the path that leads to the highest NPV is chosen.

The modeling of the offering process is based on several assumptions (see Table 3-3). A preparation and negotiation time span of two years is assumed from the moment at which the decision to place an offer is taken until the offer is accepted and the new concession comes into effect. The earliest year for a renewal of the present concession is set to be 2020, as derived by discussions with the experts within the company. On the other hand, it is assumed that if no offering for a concession renewal is placed until 2030 (i.e. concession start 2031) then „PowerProduction“ will wait for the expiration of the present concession at the end of 2039 and decide whether to participate in the call for tenders or not. Moreover, in case of a rejection of a concession renewal offer by the public authorities, it is assumed that „PowerProduction“ can place (or not) a new offer after 5 years. If such a consecutive offer is again declined by the authorities, no further offer will be placed by „PowerProduction“ until the expiration of the present concession. Further assumptions are introduced to the model with respect to the ambiguity of acceptance of the offer. The rationale behind these assumptions is discussed in the paragraphs above.

The real options model developed in the present study was designed with the aim to be as user friendly as possible. The input parameters are inserted in the model's input-mask shown in Figure 3-3. The necessary parameters are $WACC$, $p_{acc,2020}$ (acceptance probability in 2020), dp_{acc} (decline of acceptance probability per year), SH_{tot} (total share

of the public authorities on the total value of „Alpine“ PP), $sh_{PP,\text{“}PowerProduction\text{“}}$ (share of „PowerProduction“ on the production of „Alpine“ PP), N_{comp} (number of competitors in 2040) and f_{mb} (market-entry barrier factor).

Assumptions for the real options model regarding the offering process
Decision taken by „PowerProduction“ 2 years before the desired start date of the new concession
First possible starting year of new concession is 2020
If no offer has been placed until 2030, then „PowerProduction“ has to wait until expiry of the current concession (2040)
If an offer of „PowerProduction“ has been declined by the authorities, the next offer can be placed after 5 years
If offers of „PowerProduction“ have been declined twice by the authorities, next possible offer can be placed at expiry of the concession
The acceptance probability of an offer is 92% for a new concession starting in 2020, drops linearly by 5% each following year and is 2% for a new concession that starts in 2039
The acceptance probability of the offer for a new concession starting in 2040 depends on the number of competitors and the existence of entry barriers for the competitors

Table 3-3: Summary of the real options model's assumptions with respect to the offering process

The model uses some of the input parameters for the finance sheets' calculations. Thereafter, the resulting yearly cash flows for all different concession possibilities (years 2020 to 2040) are used as inputs in the decision tree of the model. The decision tree is a graphical representation of the decision process from 2018 to 2020 and includes NPV calculations for all different options (see Figure 3-4). This representation enables the user of the model as well as the decision makers to visualize the decision problem and aids them through the optimal decision path. The structure of the decision tree is similar to the theoretical model design shown in Figure 3-2, accounting for action flexibility as well as for the assumed offer acceptance ambiguity. In a later phase a Monte-Carlo method is used to account for the electricity price uncertainty. In this case simulations of the electricity price development over the future years are included in the model (see section 3.3.3).

Based on the input parameters and the assessment calculations, several outputs are resulting from the real options model. Firstly, the net present value of the „Alpine“ power plants is presented for the time span 2018-2040. Moreover, the amount paid to the authorities as reversion compensation is graphically represented for each of the concession renewal years. The real option analysis, further, provides the optimal decision path for „PowerProduction“ and, hence, the optimal year for concession renewal. Finally, in the case of dynamic real option analysis the probability distribution of the net present value of the project can be graphically represented. An overview of the real options model is shown in Figure 3-5.

Static Real Option Analysis "Alpine"

Legend

	Decision Path
	Start of new concession (Investment due)
	Option (Decision to place offer or not)
	Concession expired (No Cash Flow)
	Inputs

Inputs / Annahmen 1

Risk-free interest rate r :	5.00%	orig. 5%
Beteiligung ewz nach Rekonzessionierung	75%	(Wenn geändert muss auch die Produktion angepasst werden) orig. 75%
Exchange rate (EUR/CHF)	1.45	(Wenn geändert müssen auch B&U Kosten angepasst werden) orig. 1.45
Sum of possible outcomes	135	Berechnet
Number of competitors in 2039	4	orig. 4
Market barrier factor (>1 if barrier exists)	1.2	orig. 1.2
Acceptance Probability @ 2020	92%	orig. 92%
Probability declines every later year by	5%	orig. 5%

Create New Price Samples

Start Monte Carlo Simulation

Start data analysis

Apply standard layout to histogram plots

Inputs / Annahmen 2

Total share of Municipality in reconcesionning	60%	orig. 60%
Percentage of Max HFVE as Investment before 2039	not used	orig: 46.667%
Percentage of Max HFVE as Investment 2039	not used	orig: 86.667%
Number of samples for Monte-Carlo Run	2000	
Monte Carlo input sheet name:	Parameter10	
Monte Carlo output sheet name:	ROAMC10_2msINCsd_new	

Figure 3-3: Input mask of the real options model developed in the present study

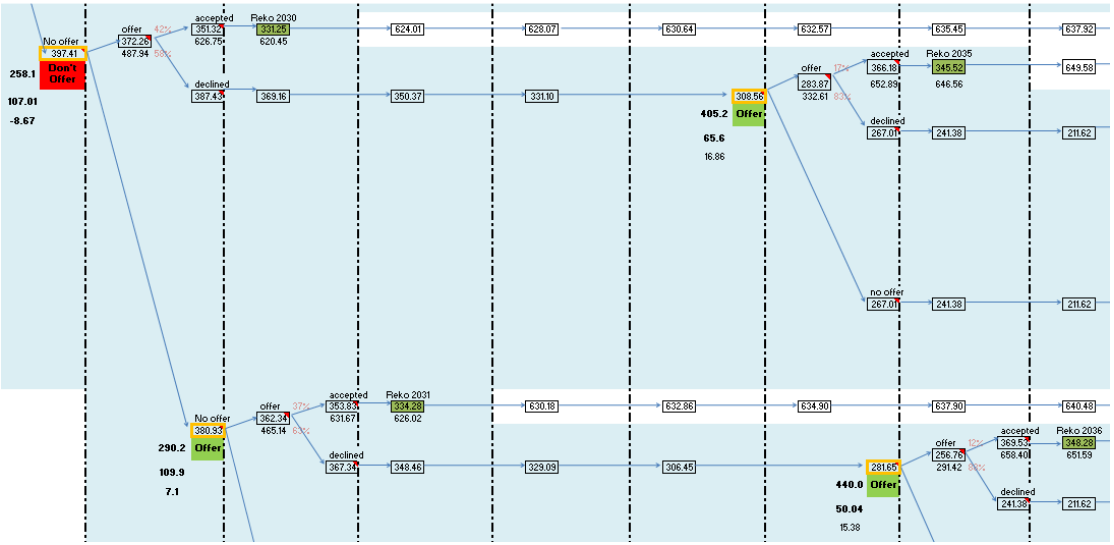

Figure 3-4: Excerpt of the graphical representation of the decision tree of the real options model

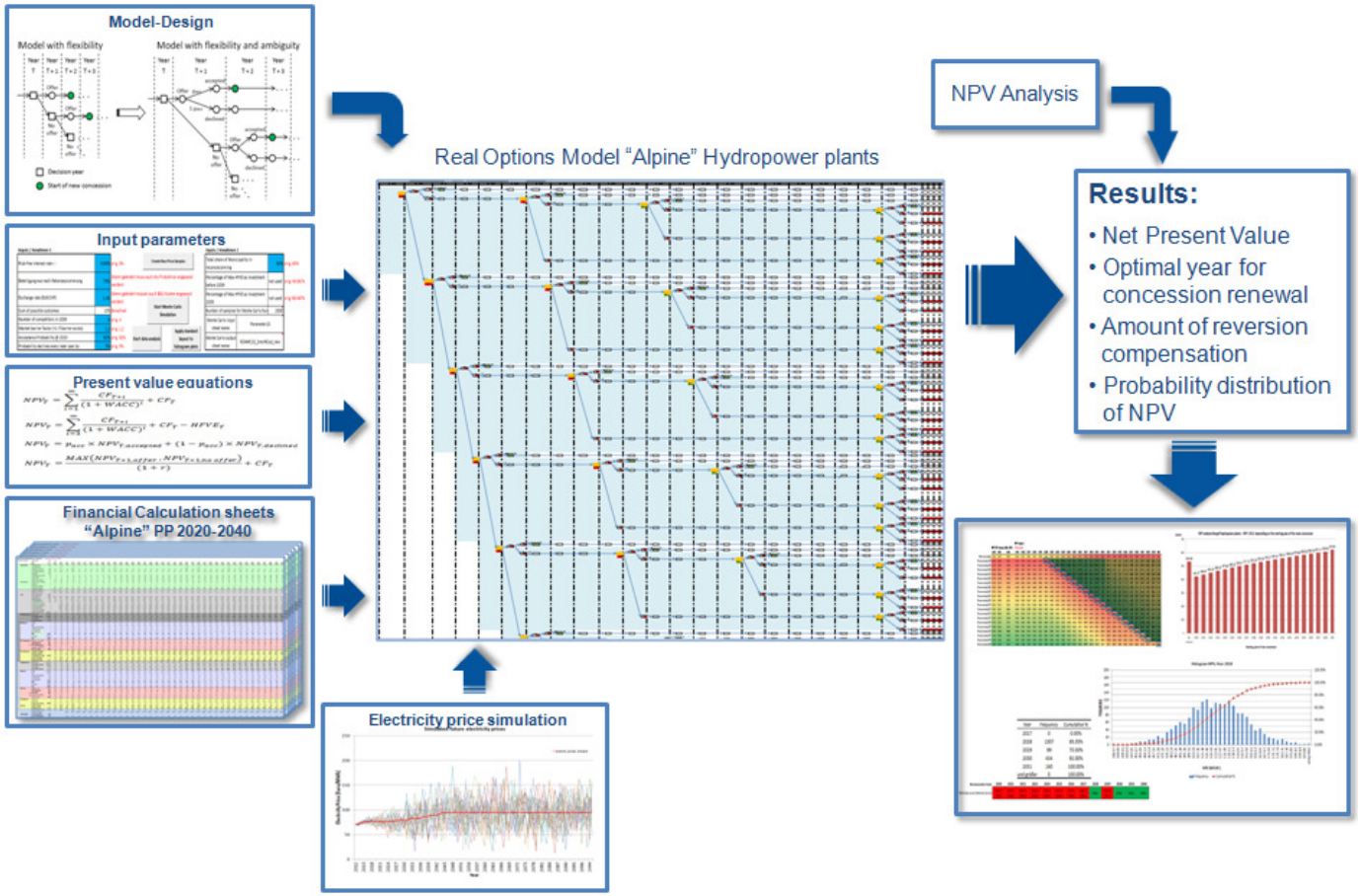

Figure 3-5: **Graphical overview of the real options model structure (inputs/outputs)**

3.3.2 Static RO analysis

In this section the results of the static real options analysis are presented. The static analysis refers to the fact that in this case no electricity price uncertainty is introduced in the model calculations. The development of the future electricity prices is being treated as given. The electricity prices used in the study are based on the results of a fundamental economic study conducted by an external consultancy office on behalf of „PowerProduction“.

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2040
NPV ROA two years earlier	45.83	44.80	43.77	42.86	41.94	40.92	39.93	38.87	37.66	36.40	35.01	33.56	15.88
ROA Decision	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer	Offer

Table 3-4: Overview of the net present values and the optimal decisions for the different years 2020-2040 based on the RO analysis model

The results of the static real options analysis are shown in Table 3-4. It can be seen that by inserting flexibility and ambiguity, the optimal year for concession renewal is shifted to 2031. Thus, real options analysis renders for the first time an economical argumentation that backs the (implicit) tendency of „PowerProduction“ management to consider early concession renewals. The calculated net present values for the „Alpine“ power plants are higher for the real options analysis than the values resulting from the simple NPV analysis. This fact exhibits the option value that arises from the action flexibility that is considered in real options analysis. NPV in year 2018 is calculated to be 45.8 million CHF.

3.3.3 Dynamic RO analysis

The development of future electricity prices is not certain. Thus, electricity prices may follow several development paths and influence the results of the optimal year for a concession renewal. Up to now the uncertainty of the future electricity prices was not included in the real options model. In this section the electricity prices are assumed to be uncertain and, hence, volatility is introduced to their future development.

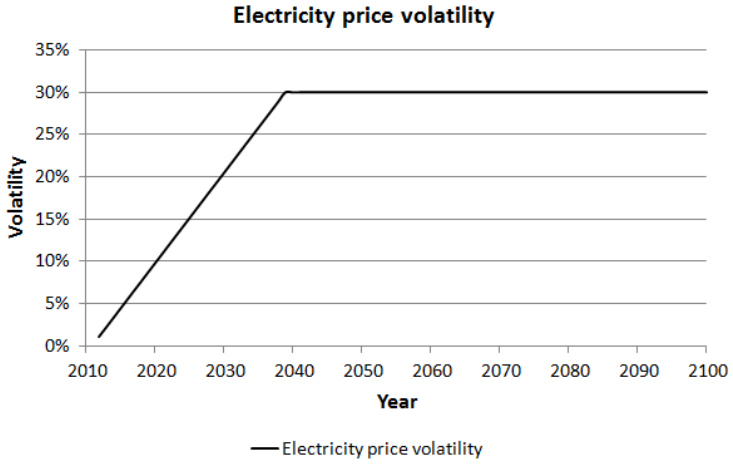

Figure 3-6: Volatility of the future yearly electricity prices used in the dynamic real options analysis

For the electricity price uncertainty, it is assumed that in each year the prices are normally distributed around a mean equal to the corresponding yearly price value of the fundamental study (as used in the static real options analysis, see section 3.3.2). Further, it is assumed that the uncertainty is increasing with time. The volatility used in this study starts at 0% in 2011, increases linearly to 30% in year 2040 and remains constant thereafter. The development of the electricity price volatility is shown in Figure 3-6. It has to be mentioned that this assumption for the development of the electricity prices (i.e. no correlation between future and past prices) will generally overestimate the volatility of the future electricity prices, since in most cases the electricity price development will derive and depend to some extent on the past year's value.

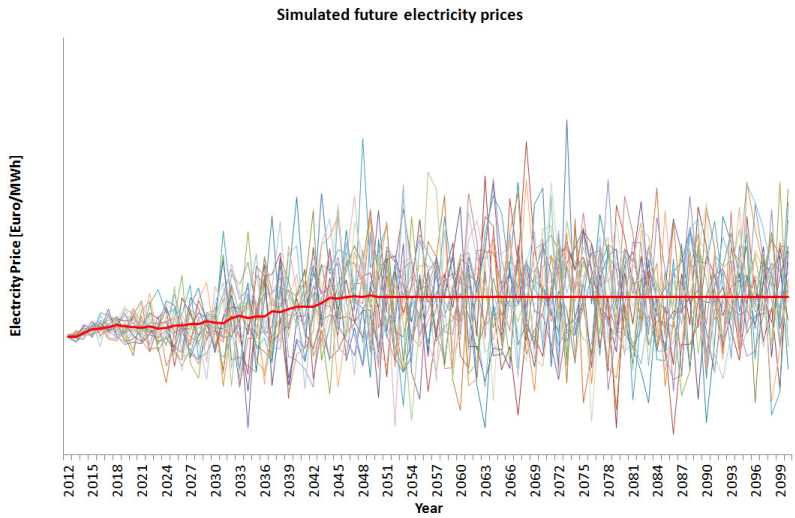

Figure 3-7: Example of 20 different electricity price development paths together with the mean electricity prices from the fundamental study.

For the dynamic real option analysis, 2000 random electricity price development samples were created. Figure 3-7 shows the development paths of 20 of these random samples together with the original yearly electricity price development projection from the fundamental study that serves as a mean. The resulting electricity price samples are then consecutively inserted in the model and for each path the corresponding optimal concession renewal year as well as the net present value is calculated. Hence, the dynamic analysis results to a probability distribution of the output values.

An overview of the base-case scenario results, for the dynamic real options analysis, is shown in Figure 3-8. It can be seen that the mean values of the net present values as well as the optimal concession renewal year are the same as for the static analysis (depicted in the lower two tables). Nevertheless, in the upper table of Figure 3-8 it is seen that by including electricity price uncertainty into the model reveals that an early concession renewal in year 2031 is optimal in about 76% of the cases. In 24% of the cases, the results indicate that it is optimal for „PowerProduction“ to wait until the expiration of the current concession in 2039 and, then, take part in the call for tenders for a new concession starting in 2040.

Year	Frequency	Cumulative %
2031	1525	76.25%
2040	475	100.00%

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2040
ROA Decision (Monte Carlo)	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer	Offer

Reconcession Start	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Real Option PV (Monte Carlo)	45.9	44.9	43.8	42.9	42.0	41.0	40.0	38.9	37.7	36.5	35.2	33.7	16.0
Real Option PV (Static)	45.8	44.8	43.8	42.9	41.9	40.9	39.9	38.9	37.7	36.4	35.0	33.6	15.9

Figure 3-8: Overview of the results for the base case scenario of the dynamic real option analysis

As described in the real options model presentation (see section 3.3.1), the decision criterion, upon which offer placement or not is based, is which of the two decisions leads to a higher NPV. Thus, the model calculates for each decision year the difference between the present value in case of an offer placement and the present value in case of no offer placement. If this difference is positive, the decision to place an offer is chosen and vice versa. The three following figures depict the frequency and cumulative probability distributions of the decision criterion for the decision years 2029, 2024 and 2018 (corresponding to concession start years 2031, 2026 and 2020 respectively). For the concession start year 2031 (Figure 3-9), it can be seen that an almost normal distribution of the decision criterion results from the dynamic analysis. There is clear tendency to positive values, whereas (as discussed above) there are some 24% of the cases where a negative value results. In those cases the decision not to offer is taken and the offer placement takes place in 2040. The distribution of the decision criterion for a concession renewal in year 2026 is skewed to the left but all cases result in negative criterion values, pointing out that an offer placement by „PowerProduction“ is at that time not favorable for the company (Figure 3-10). The resulting negative values are far below zero, indicating that the decision in year 2024 is not very sensitive on small parameter changes. Even more negative values result for the criterion calculations at a concession starting year 2020, as depicted in Figure 3-11. The probability distribution is less skewed in that case.

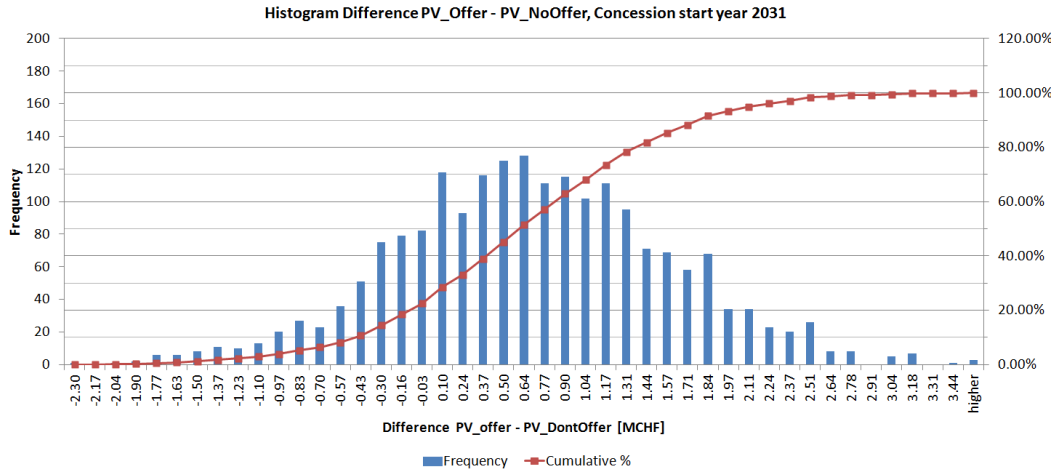

Figure 3-9: Probability distribution of the decision criterion in decision year 2029 (concession start 2031)

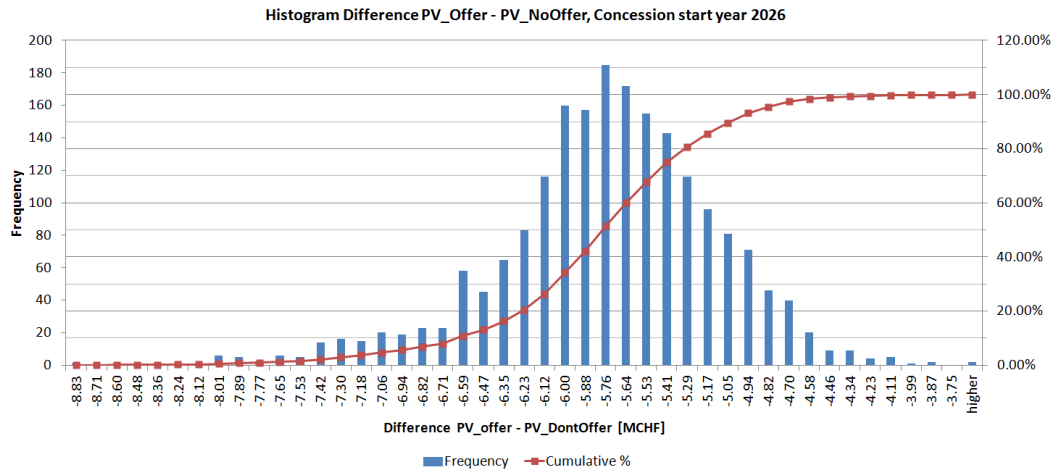

Figure 3-10: Probability distribution of the decision criterion in decision year 2024 (concession start 2026)

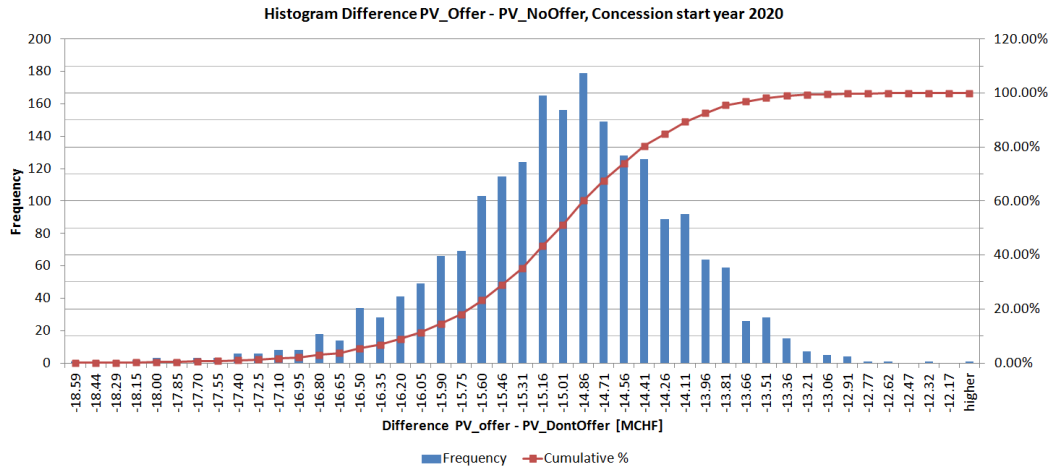

Figure 3-11: Probability distribution of the decision criterion in decision year 2018 (concession start 2020)

Figure 3-12 shows the probability distribution of the NPV in year 2018 for the base-case. The mean is almost the same as in the static analysis (45.9 million CHF), and the distribution is almost normal. The 80%-confidence interval of the net present value in 2018 is (42.8, 49.3) million CHF.

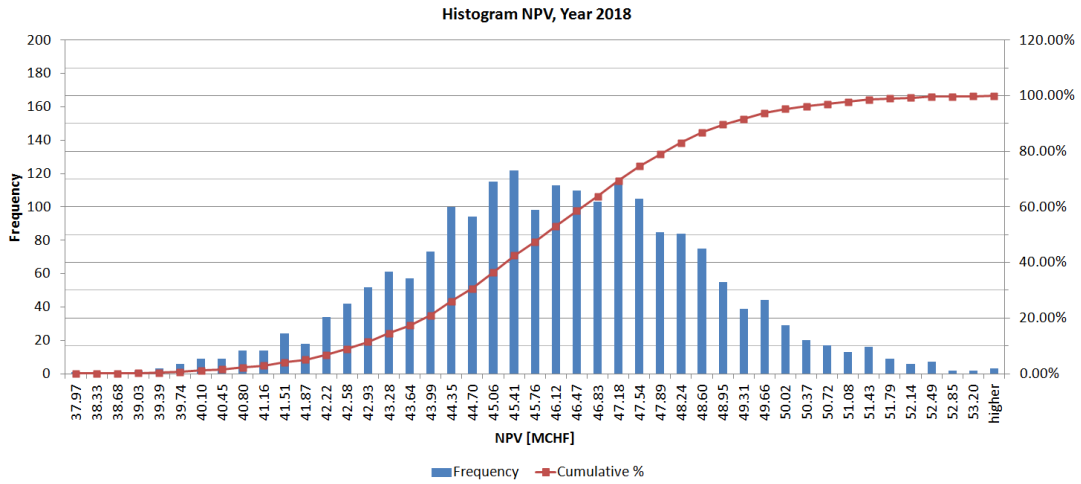

Figure 3-12: Probability distribution of the net present value in 2018.

3.4 Sensitivity Analysis

In order to estimate the influence that several input parameters of the model have on the results of the study, sensitivity analyses were carried out and their results are presented in this section. Sensitivity analyses for the interest rate (WACC)as well as the total share of the public authorities on the project's total NPV were conducted.

3.4.1 Interest rate sensitivity

Low interest rate (WACC=2%)

The results of a decrease of the WACC from 5% to 2% are shown in Figure 3-13. It can be seen that decreasing the WACC has, ceteris paribus, no effect on the average optimal concession renewal year. Nevertheless, even though the optimal year in average is still 2031, the distribution of possible optimal concession renewal years is substantially broader in the case of a WACC of 2%. In 25% of the cases the optimal year is 2028, in a few cases (1.5%) 2029, in another 25% of the cases „PowerProduction“ would be better off when renewing its concession in 2030. 2031 would still be in most cases the best renewal year, but this applies in some 47% of all cases.

Year	Frequency	Cumulative %
2028	508	25.40%
2029	29	26.85%
2030	518	52.75%
2031	945	100.00%

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2040
ROA Decision (Monte Carlo)	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer	Offer

Figure 3-13: Overview of the dynamic real option analysis results for an WACC of 2%

Hence, lowering the interest rate to 2%, results in a shift of the optimal renewal time to earlier years. The probability distribution of the calculated net present value in 2018 for the lower interest rate is shown in Figure 3-14. As expected the net present values for a lower interest rate are shifted towards larger values. This is because of the lower discount factor that increases the weight of the cash inflows from „Alpine“ power plant's operation in the years further in the future. In the case of WACC of 2% the 80%-confidence interval of the 2018 NPV is (66.2 ,76.6) million CHF.

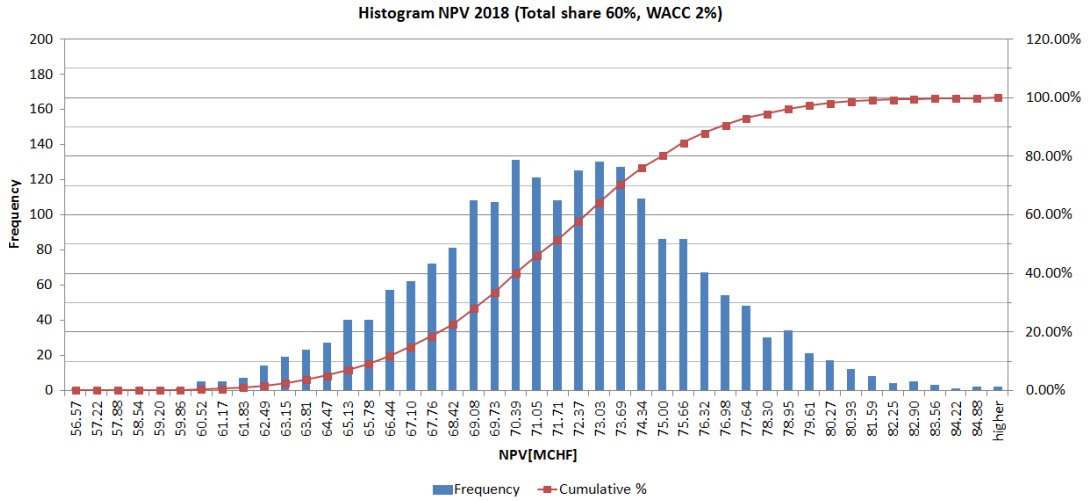

Figure 3-14: Probability distribution of the net present value in 2018 for a WACC of 2%

High interest rate (WACC=8%)

Increasing the interest rate to 8%, leads to a shift of the optimal concession renewal time to later years. The cash inflows of the present concession are more valuable today and therefore the opportunity cost of an early concession renewal increases. As the results of a higher interest rate show (Figure 3-15), in almost all cases the optimal year for „PowerProduction“ to apply for a new concession is shifted to 2040. Thus, there exists a threshold for the interest rate above which an early concession renewal is not the optimal strategy for the company (at least in economical terms). The distribution of the net present value of the project is shifted to the left and results in lower values (Figure 3-16). The 80%-confidence interval of the 2018 NPV is (32.6, 37) million CHF.

Year	Frequency	Cumulative %
2031	10	0.50%
2040	1990	100.00%

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2040
ROA Decision (Monte Carlo)	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer

Figure 3-15: **Overview of the dynamic real option analysis results for an WACC of 8%**

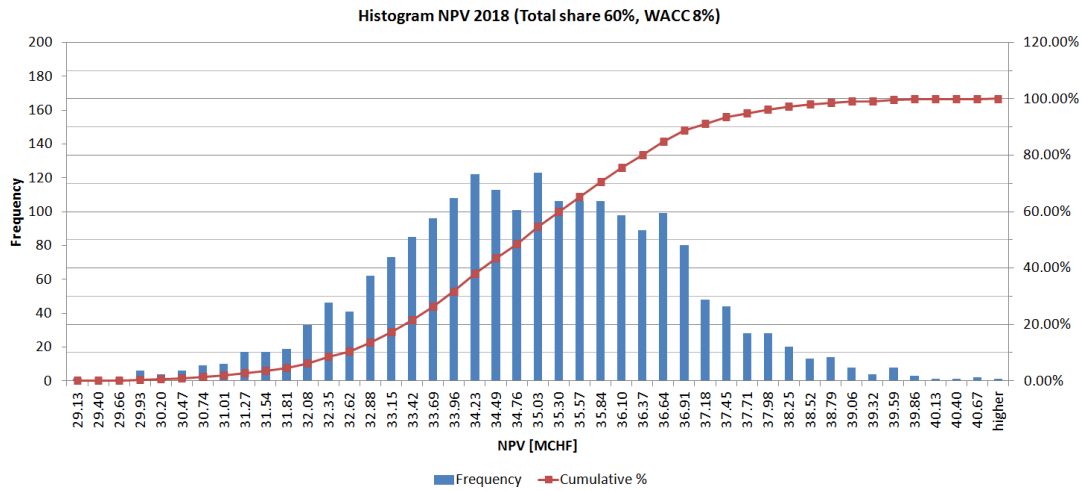

Figure 3-16: **Probability distribution of the net present value in 2018 for a WACC of 8%**

3.4.2 Public authorities total NPV share sensitivity

Low total share (SH_{tot}=40%)

The assumption that the public authorities demand a lower share of the total new concession's value for their own, keeping their percentage share on the operative part (production) of the power plant constant at 25%, results in a lower reversion compensation. In other words, the investment cost for the concession renewal is decreased. Therefore, the optimal time for a concession renewal is shifted to earlier years. This is depicted in the results of the real options analysis for public authorities' total share of 40% (Figure 3-17). In 65% of the cases the optimal concession renewal year is 2028, in 5% 2029, in 22% 2030 and finally in 8% of the cases 2031 is the optimal year. In average, the decision criterion for a concession start in 2029 is slightly negative, favoring on average the decision not to offer (see Appendix A). Nevertheless, this discontinuity in year 2029 is caused by a decrease in the mean electricity prices in this time span. A lower investment cost results also in higher values of NPV, as it can be seen in Figure 3-18. The 80%-confidence interval for the 2018 NPV is (47.3, 53.7) million CHF.

Year	Frequency	Cumulative %
2027	0	0.00%
2028	1307	65.35%
2029	99	70.30%
2030	434	92.00%
2031	160	100.00%
und größer	0	100.00%

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2040
ROA Decision (Monte Carlo)	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer	Don't Offer	Offer	Offer	Offer

Figure 3-17: Overview of the dynamic real option analysis results for a total share of the public authorities of 40%

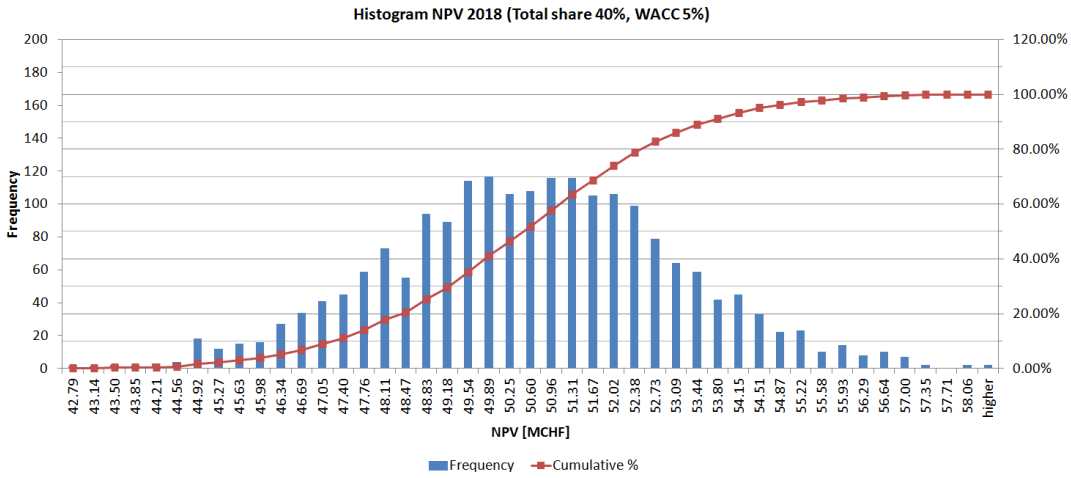

Figure 3-18: Probability distribution of the net present value in 2018 for a total share of the public authorities of 40%

High total share (SH_{tot}=80%)

Increasing the total share of the public authorities to 80% of the total value of the new concession leads to the conclusion that „PowerProduction“ should not place any offer for an early concession renewal. Again, this indicates that there exists a maximum threshold for the total share of the public authorities for which „PowerProduction“ will be willing to place an offer for an early concession renewal. Above this threshold the company should wait until the current concession expires. As expected, the net present value of the project is reduced for higher total shares of the authorities. The 80%-confidence interval is (40.6, 47) million CHF.

Reconcession Start	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2040
ROA Decision (Monte Carlo)	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Don't Offer	Offer

Figure 3-19: Overview of the dynamic real option analysis results for a total share of the public authorities of 80%

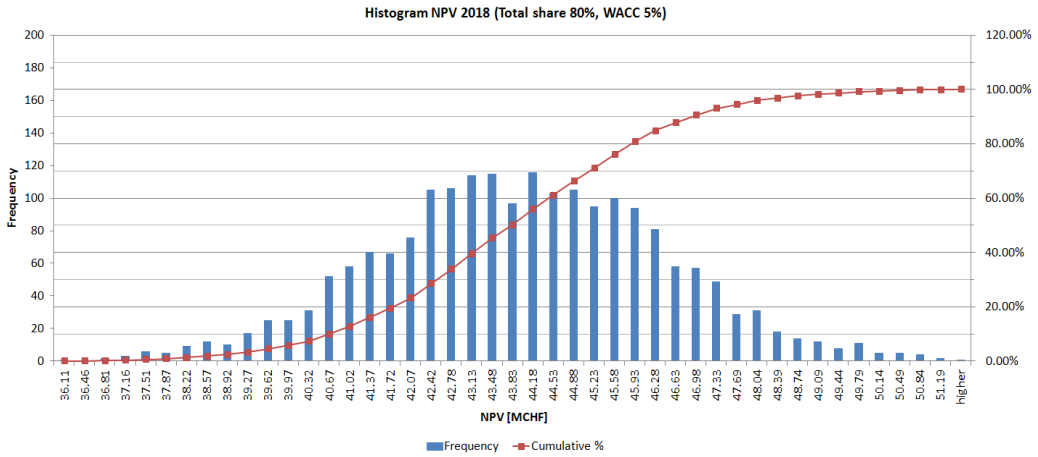

Figure 3-20: Probability distribution of the net present value in 2018 for a total share of the public authorities of 80%

4 Conclusions and Outlook

In the present study the assessment of the „Alpine“ power plants of „PowerProduction“ was conducted. The assessment was firstly based on the traditional net present value analysis. NPV analysis showed that, based on economically rational behavior, „PowerProduction“ should not aspire an early concession renewal for the „Alpine“ power plants. According to the results of the NPV analysis it was shown that the best strategy for „PowerProduction“ is to wait for the expiration of the current concession and place an offer for a new concession in 2040.

NPV analysis is based on expectation values and approaches the problem on a static, inflexible way. Nevertheless, it was shown that the problem constellation includes substantial action and decision flexibility that „PowerProduction“ has to take into consideration when assessing the optimal strategy path. Further, assuming certainty of acceptance of „PowerProduction“ offers by the responsible public authorities is not a good representation of the reality. Ambiguity over the willingness of the authorities to accept or decline a concession renewal offer exists. Finally, the development of electricity prices in the future can also not be treated as certain. Uncertainty has to be included in the future electricity price paths. For this reason a more appropriate capital budgeting method was necessary; a method that accounts for the above inflexibilities, ambiguities and uncertainties. Thus, a real options model for the assessment of „Alpine“ power plants was developed.

A base-case scenario was assessed with the help of the real options model. The static real options analysis, where action flexibility and offer acceptance ambiguity were included, resulted in an optimal concession renewal year 2031. Hence, in contrast to the NPV analysis, the real options model indicated that early concession renewal can be economically favorable for „PowerProduction“. Further, including electricity price uncertainty into the model led to probability distributions of the calculated NPV and of the optimal concession renewal year. The exact year may vary depending on the input parameters used. Nevertheless, all parameter combinations used in the present study resulted in optimal years around 2030. The earliest optimal concession renewal year observed in the study was year 2028.

Sensitivity analyses were conducted to study the influence of certain input parameters on the model outputs. Increasing the interest ratio resulted in a shift of the optimal concession renewal time towards earlier years. Moreover a wider distribution of the results was attained. The resulting net present values were higher for lower interest ratios and vice versa. Similar results were attained for a variation of the public authorities’ total share on „Alpine“ power plants’ total project value. Decreasing the authorities’ total share shifts the optimal timing for concession renewal towards earlier years and the NPV to higher values. This is because of the lower reversion compensation paid by „PowerProduction“ to the authorities. For both parameters (interest ratio and total share), the results of the real option analysis indicate that there exists a maximum threshold above which an early concession renewal becomes unattractive for „PowerProduction“. For such values, the optimal strategy for

„PowerProduction“ would be to exploit the current concession until its expiry and take part in the call for tenders for a new concession starting in 2040.

In general the present study has highlighted the strengths and weaknesses of real options models in practice. The development of the real option model was not a trivial undertaking. Defining the option for the present problem constellation was one of the main bottlenecks at the beginning of the study. For „PowerProduction“ the flexibility regarding the option for an early concession renewal is already given; no investment is needed to acquire this flexibility, as it is the case in many other real option problems (e.g. option to expand). Furthermore, a concession renewal that includes the investment costs for the reversion compensation would result in worse concession conditions (and thus, less cash inflows) than the current concession. These two facts, made the definition of the option in the present study highly complicated. The main insight was that for the present business case the added value in the use of real options emerges from the combination of action flexibilities, offer acceptance ambiguities and electricity price uncertainties. Generally, the present study underlined the wide spread assumption that the use of real options analysis is more complex and time consuming than a simple NPV analysis. However, using a capital budgeting method solely because it is easier and less time consuming is obviously not per se a good management tactic. Especially in cases where the easy-to-use method may lead to wrong decisions.

The results did show that real options analysis is a very strong capital budgeting method, that should be used together with the NPV analysis to assess investment plans that include flexibility, uncertainty and ambiguity. A sound examination of the problem constellation and the relevant parameters is highly helpful for the overall understanding of the investment project. Supporting the real options analysis with a graphical representation of the decision path (decision tree) is highly advantageous. In that way decision makers and managers within the company are aided to understand the assumptions and hot spots that are influencing the decision process.

The real options model developed in the present study can be further optimized and its use can be tested in several projects with shorter project life. The importance of a thorough discussion of the acceptance probabilities was highlighted from this study. Expert groups within the company could follow this goal, in order to enhance the validity of the model. Furthermore, the volatility of future electricity prices can be simulated in a even more sophisticated way, as there is a wide spectrum of scientific work in this direction (Volpe, 2009) exists. Finally, advances in the research of discounting methods allow for novel non-constant discount rates (Laibson, 1998). Their compatibility for the present problem can be investigated and, if positive, implemented in the model.

Acknowledgements

The author would like to cordially thank Dr. Silvia Banfi from the Production Development Department (PPA) of „PowerProduction“ for giving me possibility to work and come in touch with the highly interesting field of real options as well as her support during the present study. Furthermore, the author is deeply grateful to Prof. Didier Sornette for his interest, his highly motivating support and ideas whenever my limited knowledge in the field of decision theory was too little for the seamless progress of the study.

A great thanks to all colleagues from the Production Development and Middle Office for their professionally and personally inspiring moments that , beyond dispute, assisted in the successful completion of the present study.

Appendix

A. Sensitivity analyses - Probability distributions

Low interest rate (WACC=2%)

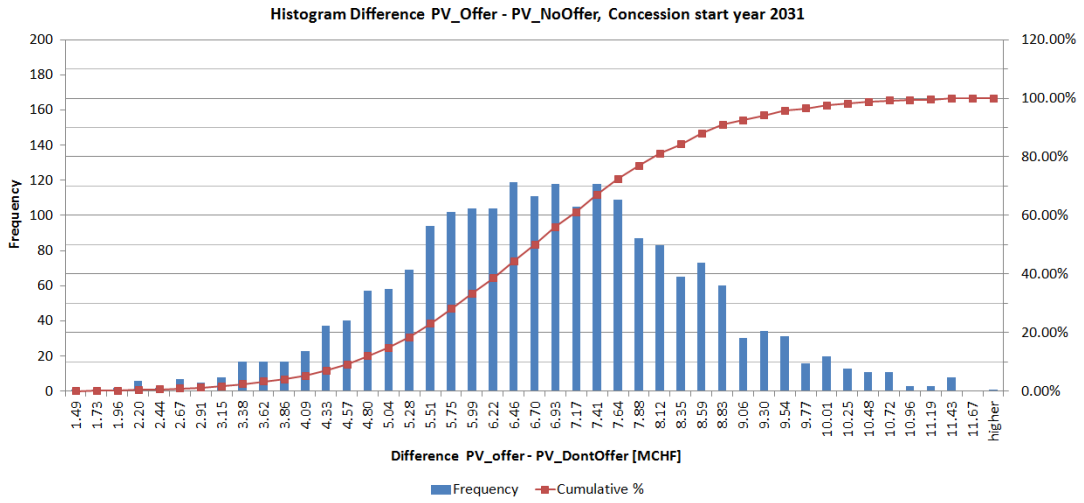

Figure A 1: Probability distribution of the decision criterion in decision year 2029 (concession start 2031)

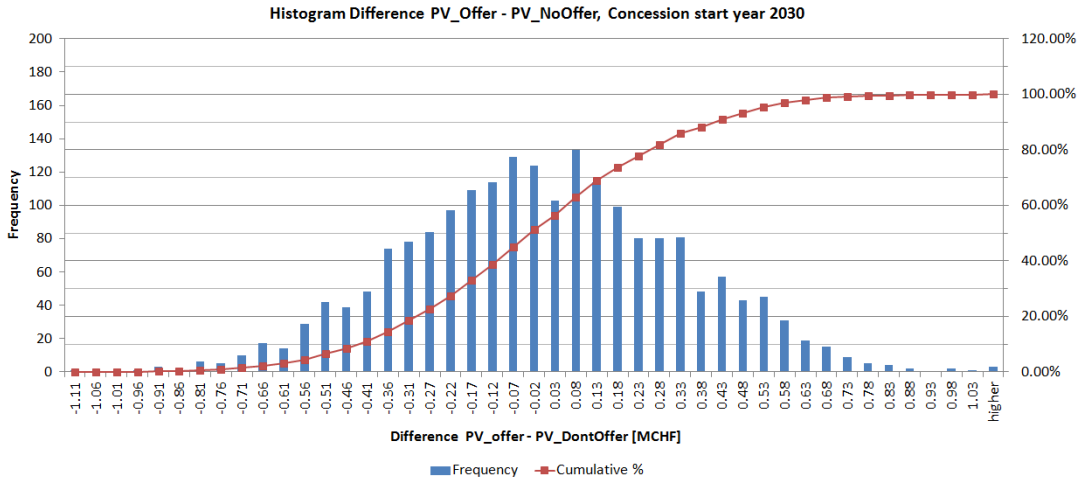

Figure A 2: Probability distribution of the decision criterion in decision year 2028 (concession start 2030)

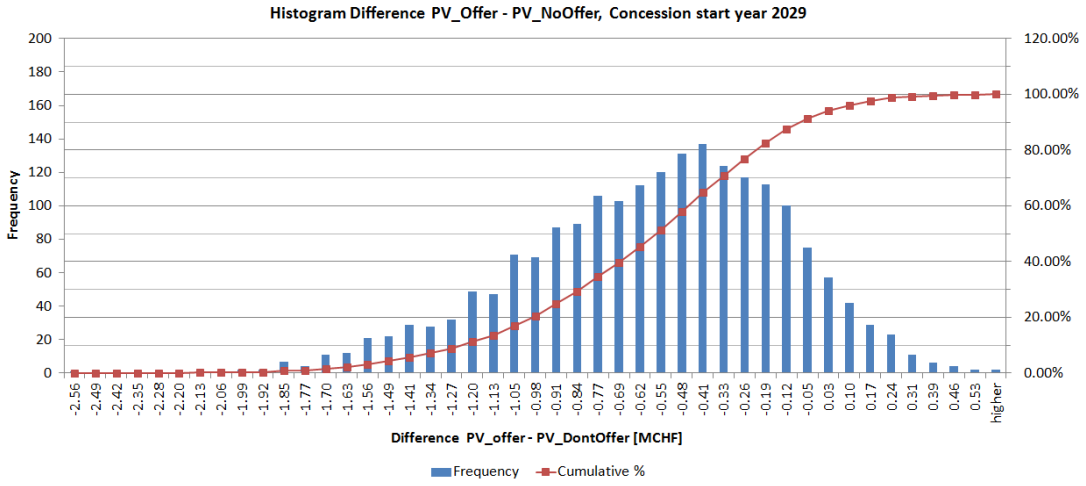

Figure A 3: Probability distribution of the decision criterion in decision year 2027 (concession start 2029)

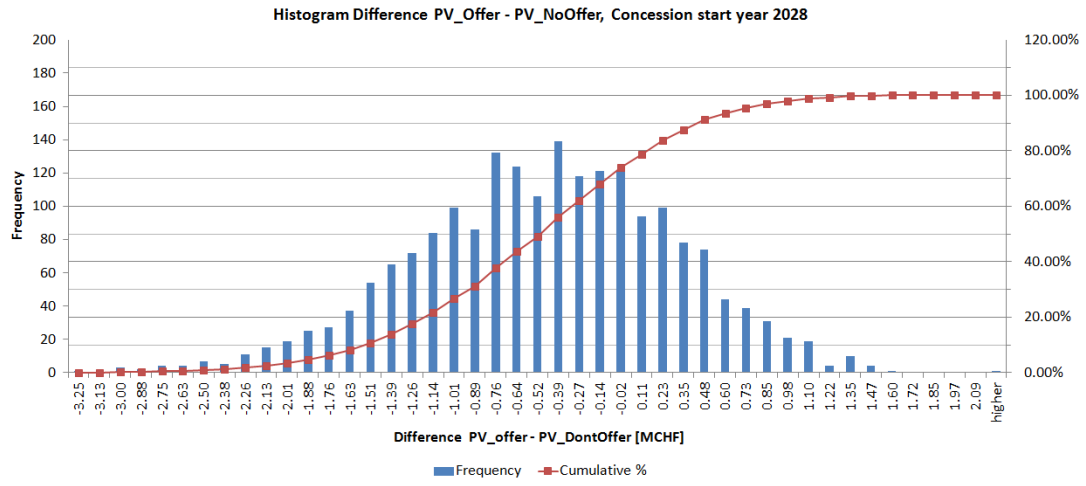

Figure A 4: Probability distribution of the decision criterion in decision year 2018 (concession start 2020)

High interest rate (WACC=8%)

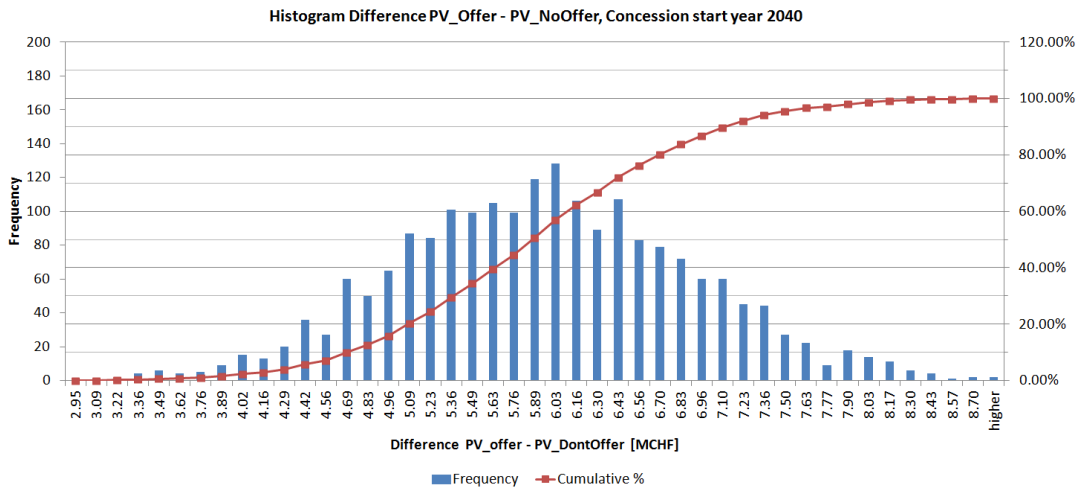

Figure A 5: Probability distribution of the decision criterion in decision year 2038 (concession start 2040)

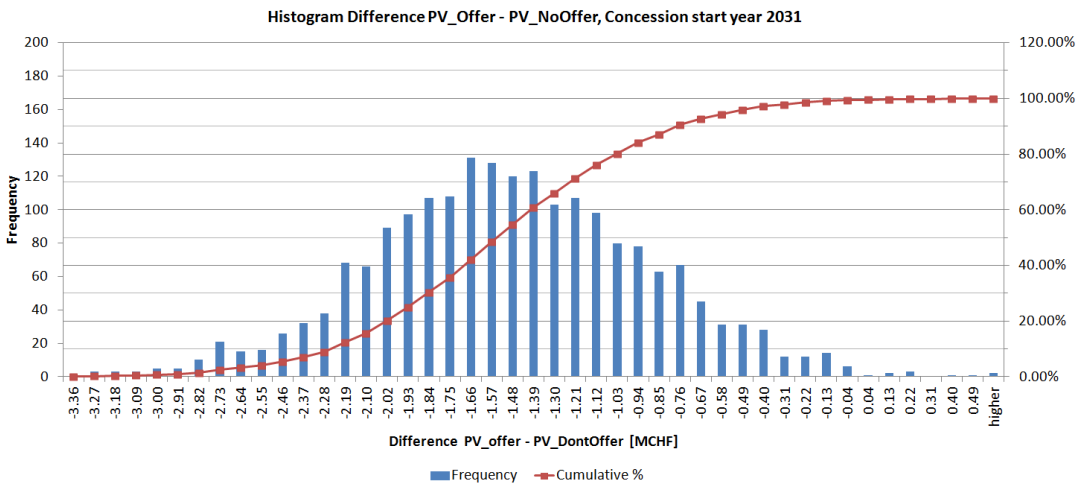

Figure A 6: Probability distribution of the decision criterion in decision year 2029 (concession start 2031)

Low total share (SH_{tot}=40%)

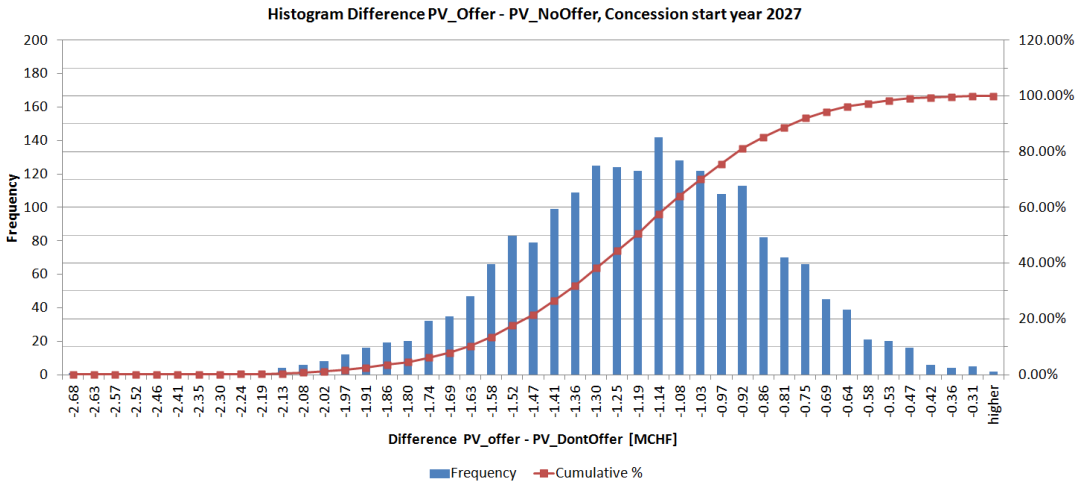

Figure A 7: Probability distribution of the decision criterion in decision year 2025 (concession start 2027)

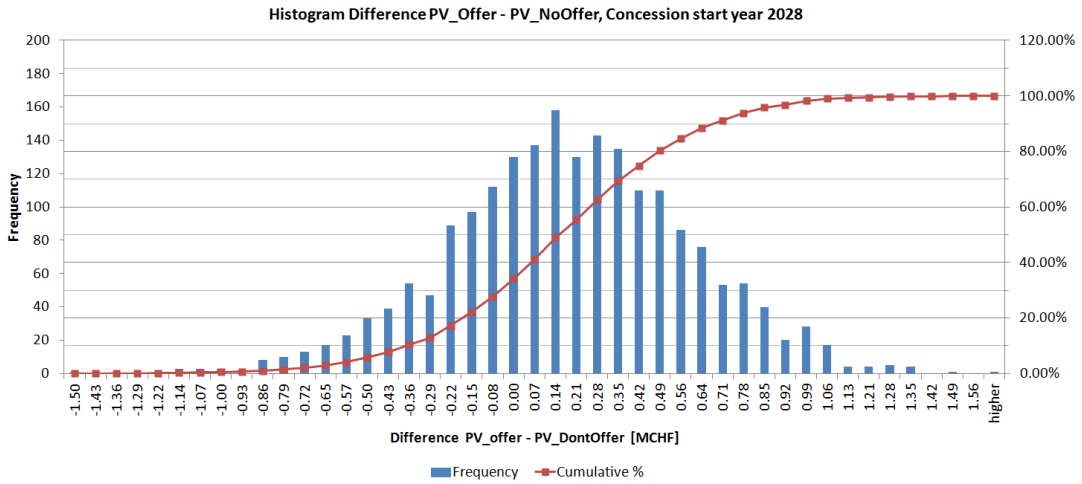

Figure A 8: Probability distribution of the decision criterion in decision year 2026 (concession start 2028)

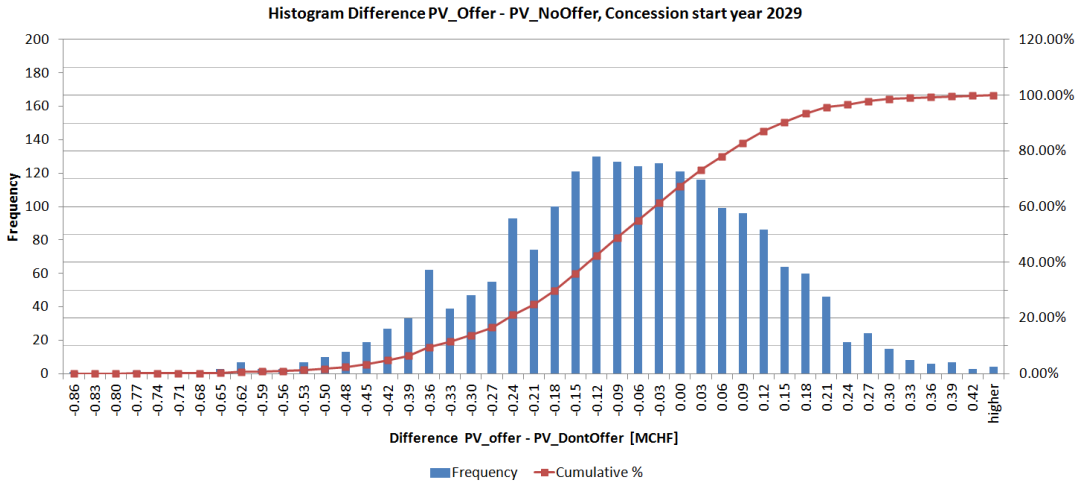

Figure A 9: Probability distribution of the decision criterion in decision year 2027 (concession start 2029)

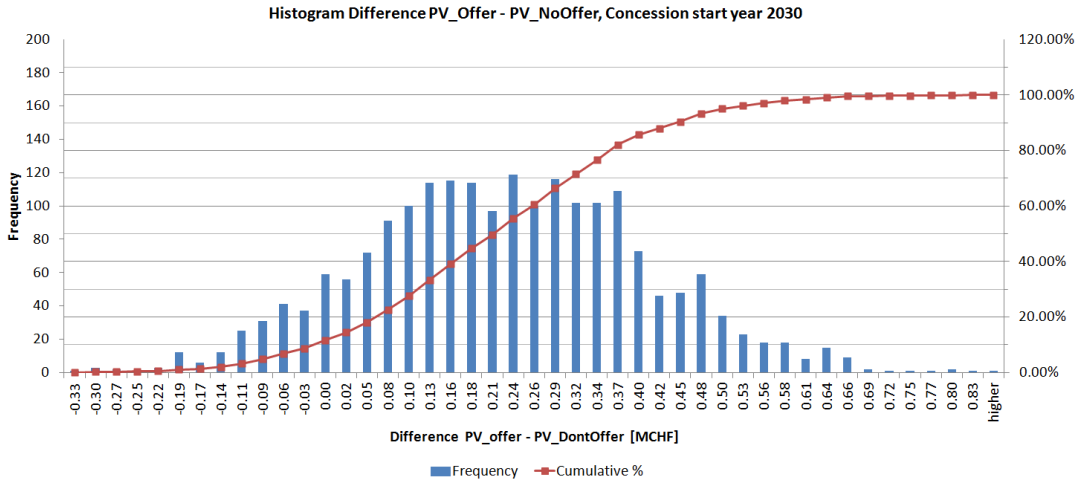

Figure A 10: Probability distribution of the decision criterion in decision year 2028 (concession start 2030)

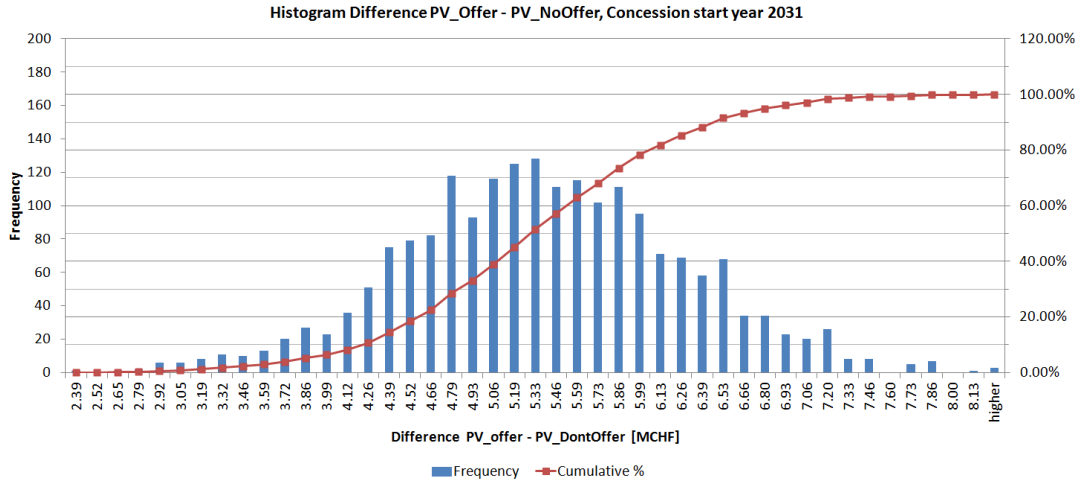

Figure A 11: Probability distribution of the decision criterion in decision year 2029 (concession start 2031)

High total share (SH_{tot}=80%)

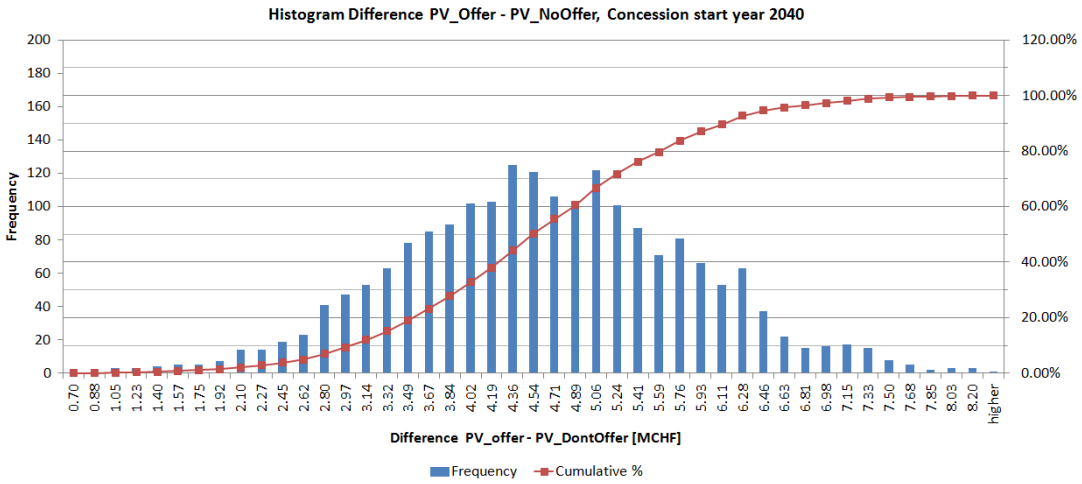

Figure A 12: Probability distribution of the decision criterion in decision year 2038 (concession start 2040)

References

"PowerProduction". (2012). *"PowerProduction" Stromzukunft 2012.* "PowerProduction".

Barton, K., & Lawryshyn, Y. (2010). Reconciling real options models: an approach to incorporate market and private uncertainties. *14th Real Options Annual Conference.* www.realoptions.org.

Black, F., & Scholes, M. (1973). The priceing of options and corporate liabilities. *Journal of political economy, 81* , pp. 637-659.

Borison, A. (2005). Real Option Analysis: Where are the Emperor's Clothes. *Journal of Applied Corporate Finance, Volume 17* , pp. 17-31.

Brealy, R. A., & Myers, S. C. (2000). *Principles of Corporate Finance.* Irwin McGraw-Hill.

Copeland, T., & Antikarov, V. (2003). *Real Options: a practitioner's guide.* London: Penguin Group.

Dixit, A. K., & Pindyck, R. S. (1994). *Investment under Uncertainty.* Princeton, NJ: Princeton University Press.

Guthrie, G. (2009). *Real Options in theory and practice.* Oxford: Oxford University Press.

Hommel, U., & Lehmann, H. (2001). Die Bewertung von Investitionsprojekten mit dem Realoptionenansatz - Ein Methodenüberblick. In U. Hommel, *Realoptionen in der Unternehmenspraxis* (pp. 113-129). Berlin: Springer.

Howell, S., Stark, A., Newton, D., Paxson, D., Cavus, M., Pereira, J., et al. (2001). *Real options: Evaluating Corporate Investment Opportunities in a Dynamic World.* London: Prentice Hall.

Laibson, D. (1998). Life-cycle consumption and hyperbolic discount functions. *European Economic Review* , 861-871.

Meyers, S. (1977, November). Determinants of corporate borrowing. *Journal of Financial Economics* , pp. 147-175.

Mun, J. (2006). *Modeling Risk.* New Jersey: Willey & Sons.

Nembhardt, H. B., & Aktan, M. (2010). *Real Options in Engineering Design, Operations and Management.* London: CRC Press.

Reuer, J. J., & Tong, T. W. (2007). *Real Options Theory.* Oxford: Advances in Strategic Management, Volume 24, Elsevier.

Schulmerich, M. (2010). *Real Options Valuation, Second Edition.* Berlin: Springer-Verlag.

Trigeorgis, L. (1996). *Real Options.* Cambridge: MIT Press.

Volpe, V. (2009). *The Electricity price modelling and derivatives pricing in the Nord Pool market, PhD Thesis.* Institute of Finance, Universita della Svizzera italiana.

WRG. (2012). *Federal Law for the usage of the waters (SR 721.80).* Bern: Swiss Federal Government.

WRG Kanton GR. (2012). *Water-rights law of the canton of Graubünden (SR 810.100).* Chur: Kantonsregierung Graubünden.