Climate policy uncertainty and investment behavior: Evidence from small hydropower plants

WORKING PAPER (work in progress)

Authors:
Stein-Erik Fleten,[1] Ane Marte Heggedal,[1] Kristin Linnerud [2]

1: Norwegian University of Science and Technology, Alfred Getz vei 3, NO-7491 Trondheim, NORWAY, Stein-Erik.Fleten@iot.ntnu.no, Ane.M.Heggedal@iot.ntnu.no.
2: CICERO, Pb. 1129 Blindern, N-0318 OSLO, NORWAY, Kristin.Linnerud@cicero.uio.no

Abstract
Using real options theory and a multivariate discrete choice model, we investigate how investments in renewable electricity production are affected by climate policy uncertainty. More specifically, based on panel data of 214 licenses to construct small hydropower plants, we examine whether uncertainty with respect to the introduction of a market for green certificates has affected the timing of investments in small hydropower plants Norway from 2001 to 2010. We find that real options models, which translate uncertainty into investment risk, give better explanation of investors' behavior compared to traditional net present value analysis.

Keywords: *renewable energy, hydropower, investment under uncertainty, climate policy uncertainty, real options, empirical testing.*

1. Introduction
The political discussion on whether, when and how to support renewable electricity projects can have a powerful deterrent effect on immediate investments since it creates an incentive to wait until the political decision is made. The following quote is from a potential investor in a small hydropower plant in Norway: "Our power plant may be profitable now; however, the green certificates will significantly boost profitability, so we're waiting to see what the government has up its sleeve." [1] In their textbook on real option theory, Dixit and Pindyck (1994, p. 20) say: "If government wish to stimulate investment, perhaps the worst thing they can do is to spend a long time discussing the right way to do so."

[1] Steinar Røhme, spokesperson for Jamtåsbekken small hydropower company, Norway (Adresseavisen, 26th September 2009)

Recently, there have been several contributions to the literature which uses real option theory to predict investor's responses to climate policy uncertainty e.g. Kiriyama and Suzuki (2004), Laurikka and Koljonen (2006), Reedman et al. (2006), Rothwell (2006) and Fleten and Ringen (2009). These normative studies call attention to how climate policies like carbon emission trading schemes and cross subsidies of renewable energy production schemes may bring along additional risk to investors, making the investors demand a higher rate of return on their investments, which again leads to a slower investment rate in emission-reducing technology. The study by Fleten and Ringen (2009) is of special interest, since it has a similar focus as our study: the impact of a common Swedish-Norwegian green certificate market on investment in small hydro power plants in Norway.[2] They assume stochastic electricity prices and green certificate prices and show how the development paths will differ if the investor use a Real option analysis investment rule compared to a traditional Net present value investment rule.

While the focus of the above studies is on volatile prices, the focus of our study is on uncertain climate policy decisions. Thus, the following studies are worth noting. Fuss et al. (2008) consider two types of uncertainty: market-driven price volatility around a mean price and bifurcating price trajectories mimicking uncertainty about changing policy regimes. Assuming optimization under imperfect information, they find that the market uncertainty about CO2 prices gives incentive to invest in carbon-saving technology earlier than if the actual price path had been known on beforehand. On the other hand, policy uncertainty induces the producer to wait and see whether the government will further commit to climate policy. In the related studies by Blyth and Yang (2006, 2007), Blyth et al. (2007), IEA (2007) and Yang et al. (2008) the impact of uncertain shifts in the climate policy regime is represented by a price jump (either up or down) in carbon prices at a given date in the future. Based on their assumptions, the uncertainty created by such price jumps will dominate the uncertainty created by annual variation in carbon prices (IEA, 2007, p.13). In a forthcoming paper by Kristoffersen et al. (2011) They consider multiple sources of uncertainty under two support schemes for renewable electricity (feed-in tariffs and el certificates) and uncertainty with respect to any change of support scheme.

While the above studies are all normative, our study is empirical. There are few studies which test the validity of real option models in predicting investment decisions in real assets, and none of these considers the impact of climate policy uncertainty. Using data from 285 developed North American gold mines, Moel and Tufano (2002) empirically investigate the actual adoption of a real option model for mine opening and closing decisions. They utilize a discrete-choice regression model and do find support for real options behavior in mine opening and closing. Quigg (1993) examines the empirical predictions of a real option pricing model using data on 2700 land transactions. Regression analysis shows that the option value model has some explanatory power for market prices, over and above the net present value.

Our paper provides contributions to this growing strand of literature as it 1) focuses on the uncertainty created by shifts in climate policy regimes, 2) empirically tests the predictions given by normative real option models and 3) focus on the timing, as opposed to the value, of investments. Based on panel data of 214 licenses to construct small hydropower plants, we examine whether uncertainty with respect to

[2] Fleten and Ringen (2009) also consider investment in wind power plants.

the introduction of a common Swedish- Norwegian market for green certificates did affect the actual timing of investments in small hydropower plants in Norway during the period from 2001 to 2010. The license gives the owner a right, but no obligation, to construct a power plant within a limited time. Hence, the owner of the license is holding a real option.

The actual investment decision for each license owner is described based on data of planned costs and production, previous studies of the small hydropower industry and interviews with a major part of the investors. Then a set of real option models is derived under different assumptions of how the climate policy uncertainty was perceived by the investor. Our approach is similar to the one analyzed by McDonald and Siegel (1986) in which they compare whether the Real option analysis model in a better way can explain the actual investor behavior, compared to using the traditional Net present value model. Finally, the results of the Real option analysis model are tested using discrete-choice regression models. More specifically, we tested which of the following statements on climate policy uncertainty were supported by empirical evidence:

- The investors did not consider the possibility of a future common market for green certificates when making their investment decisions.
- The investors did consider the possibility of a future common market for green certificates when making their investment decisions.
  - They believed in the political promises of a transitional arrangement such that if green certificates were introduced, plants constructed as early as 2004 would be included.[3]
  - They did not believe in the promises of a transitional arrangement.

We find that real option models, which translate uncertainty into investment risk, give a better explanation of investors' behavior compared to traditional NPV models. Both uncertain electricity prices and uncertainty with respect to the introduction of green certificates did affect the timing decision of investments in small hydro power projects in Norway in the period from 2001 to 2010. Furthermore, political promises of a transitional arrangement did not seem to have reduced investors' perceived risk.

The structure of this paper is as follows: Section 2 gives a description of the investment decision and the dataset. Section 3 describes the real option model and how climate policy uncertainty and stochastic electricity prices are translated into investment risk. Section 4 presents the regression models and the results from the regression analysis. Section 5 summarizes the results of this paper and offers directions for future research in this area.

2. The investment decision and the dataset

When modeling the investment decision in a small hydropower plant, three challenges has to be overcome. First, the value of the plant is not observable as it is not traded in a market. Second, we do not completely know the firm's objective function because the choice set cannot be observed and/or all factors affecting the decisions cannot be observed. Finally, the preferences and other characteristics of

[3] The reason for why some may have believed in a transitional agreement are further elaborated in Section 2.

the investors will differ.[4] Sections 2.1 and 2.2 deal with these challenges, starting with giving a thorough description of the factors influencing the timing of an investment decision before presenting the availability and quality of relevant data.

2.1 The investment decision

In order to construct a hydropower plant in Norway, the investor must hold a license issued by the Norwegian Water Resources and Energy Directorate (NVE).[5] A license holder has the permission to start constructing a power plant within five years at which time the license expires. However, the license can normally be extended for another five years without going through the process of resubmitting a new application. Thus, the license to construct a hydropower plant has characteristics similar to an American option which can be exercised within a period of ten years.

The time between a license is granted and the investment decision is made can be divided into the following steps (NVE, 2010): (1) choose organizational model, and if the developer and the landowners are two different entities, make agreements between the developer and landowners; (2) update the cost estimate to reflect changes in the license conditions and the results of any new water flow measurements; (3) undertake required topographic mapping, surveying and/or seismic /drilling in order to avoid landslides; (4) obtain contracts on electromagnetic components, pipes and building-related work, so that approximately 80 percent of the total costs are quality assured; (5) make the final choice of development layout and structural components;[6] (6) secure project funding and make sales agreements for delivering the power to the grid and revise the investment budget accordingly; (7) send the detailed plans for the plant development to NVE for approval; since 3 to 6 months processing time must be expected, these plans should be sent NVE and be approved before any investment decision can be made; and, (8) after receiving the responses from NVE, make a decision whether to invest or to postpone the investment decision.[7]

For some power plants, part of these tasks may have been undertaken before the license was granted, and if there are only few modifications to the original license application, the investment decision could be made almost immediately.[8] In other cases, there may be non-economic factors delaying the time of the decision. These may be related to the process explained in the last paragraph, and include for instance complaints filed by the license owners or other stakeholders, problems with access to the grid and problems with securing adequate funding. In our analysis, we control for these factors to ensure that delays for non-economic reasons are not misinterpreted as the result of economically rational

[4] For a discussion of the challenges confronting a researcher trying to model an empirically testable real option model, se Gamba and Tesser (2009).

[5] To simplify and speed up the processing of application, the competence to grant such licenses for plants with capacity below one megawatt (MW) has been delegated to the County administration.

[6] This must be within the license framework. Otherwise, it will require plan change application and a new hearing.

[7] It may also be relevant to post it for sale.

[8] In our dataset there are several examples of plants which are constructed and operating the same year as the license was granted.

investors balancing the value of immediate investment against the value of putting the project on hold and see how the market conditions and policies evolve.

The investors are dominated by farmers and other local landowners. During the last decade, professional corporations specializing in small hydropower plants are to an increasing extent investing in this market. In our dataset, which includes licenses granted to small hydropower plants between 2001 and 2008, 99 of the 214 licenses are today controlled by professional investors of which 32 licenses by the single biggest investor.

Most often the ownership of the river and the power plant is split into two separate companies, one owning the rights to utilize the water in the river and one owning the power plant. The company which owns the power plant will rent the right to use the river from the company which owns the river. While the river is most often fully controlled by local landowners, the power plant may be owned, fully or partly, by a professional investor. In circumstances where the power plant is fully owned by a group of local landowners, the power plant and the river may be organized in one company. We consider these differences in organization to have only minor impacts on the net cash flows to the investor and will therefore use the same cash flow setup for all investors irrespective of organizational form.[9] However, professional and non-professional investors may differ with respect to preferences and risk attitudes, and we will consider such differences in our empirical analysis in Section 4.

The investment decision is affected by factors influencing the cash flows of the project. The main factors deciding the annual cash flows are the revenues (from the electricity price and potentially the support scheme), the operational and maintenance costs, the income tax, the resource tax and the property fee. By calculating the discounted cash flows we can decide whether the investment in a specific plant is profitable. Furthermore, uncertainty with respect to any of the factors affecting the cash flows can be translated into investment risk by using a real option approach. On this basis we can decide whether the investment should be undertaken immediately or be postponed. Before presenting the valuation framework, the next section introduces the data sources for estimating the cash flows.

2.2 The dataset

We have constructed a database of 214 licenses to construct small hydropower plants granted by Norwegian authorities in the period from 2001 to 2008. With a few exceptions, it includes all licenses to construct plants with capacity between one and ten MW (179 plants), and a selection licenses to construct plants with installed capacity below one MW (35 plants).

An important source of information has been NVEs database over hydropower licenses. For each license NVEs database includes the name of the owner, geographic location of the power plant, the date when the application for a license was received by NVE, the date when the license was granted, the year when the investment decision was taken (if it has been taken), the year when operation of the plant began (if

[9] For instance, although the last model does not involve the rental payments for the right to use the river, these cost should be included as the local landowners can choose to not invest in a power plant and instead rent the right to use the river to others.

it has begun), investment costs in thousand Norwegian kroner, capacity in MW and annual production in MWh. The dataset reflects the information given by the investor to NVE in the initial application for a license. This information has to some extent been updated by NVE to reflect revisions in the agreed upon characteristics of the plant. The database does also include information on whether and when complaints has been filed and settled and in a few cases information on other kinds of delays like problems with access to the net and changes in the organization of the investor group has been added.

However, what we wanted to know was, for each license and for each year, the license holders' expectations with respect to all parameters affecting the value of the investment and the value of waiting. Thus, to complete the information we received from NVE, we interviewed the owners of 185 of the 214 licenses (85 percent) in our dataset to find the time of the investment decision, the expected investment outlay, capacity and production level at this point in time and to check whether investment had been delayed by non-economic reasons not included in the information from NVE.

We consider the quality of the information gathered through the interviews to be high, as we were able to explain the purpose of our questions and clear up misunderstandings if they occurred. Furthermore, we do not expect the license holders to have a desire to under- or overestimate the cost and capacity measures. In some instances, however, the license holder could just remember the actual investment outlay, which may have deviated from the expected investment outlay at the time when the investment decision was made. Using the deflated actual investment cost as a proxy for the expected investment cost we may have introduced an upward bias in the investment costs since unexpected costs are included. On the other hand, as 80 percent or more of the total investment cost is normally secured by enterprise contracts (see Section 2.1); we do expect the deviations to be limited. In other instances, the license holder could not remember the exact year the investment decision was made, and we had to rely on public announcements of tenders or start of construction to determine the year the investment decision was made.

For the remaining 29 of the 214 licenses (15 percent) we had to rely on the information given by NVE and supplement this with publically available information like advertisement of tender, media covering the opening of a new plant etc.

In order to conduct investment analysis, we needed to make assumptions regarding the lifetime of a power plant, the lifetime of a license, discount rates, annual costs and tax rates. This information was collected from studies on the economics of small hydropower plants and scientific papers. Our assumptions on central parameters were finally checked against our reference group consisting of stakeholders from the industry and governmental agencies. In the upcoming paragraphs, our panel dataset is explained in detail.

The timing of the investment decision. For most licenses we know the year the decision was made based on interviews with the investor or information in publicly available sources. For the remaining licenses we must deduct the year the investment decision was made based on the year the operation began.

According to NVE and the Norwegian small hydropower plant association,[10,11] the time required to construct a small hydropower plant is approximately 1 to 1.5 years. From the information received from NVE we see that some plants are constructed in the same year as the license was granted. Thus, where we lack detailed information, we assume that investment decisions are made one year before operation began.

Lifetime of license/option. As mentioned in Section 2.1 the license to construct a hydropower plant has characteristics similar to an American option which can be exercised within a period of ten years.

Delays. For each license and at each year we have collected information on non-economic reasons for delaying the investment project. Our sources of information have been interviews and comments in NVEs database.

Lifetime of a small hydropower plant. According to NVE (2010) a lifetime of 40 years on invested capital is advisable for net present value calculations for small hydropower plants. However, the economic lifetime may be shorter due to reinvestments. Econ Pöyry (2008) uses a lifetime of 50 years for tax purposes and argues that this is lower than the average lifetime of small hydropower capital investments. Balancing these points of view, we use a lifetime of 40 years in our calculations.

Cash flows and discount rates. [12] All cash flows and discount rates are given in nominal, after tax terms and relevant for total capital considerations. We have used the Capital Asset Pricing Model (CAPM) for estimating the nominal, after tax required rate of return on total capital in hydropower plant investments. Gjølberg and Johnsen (2007) have analyzed the required rate of return in the renewable power sector in Norway. Using their average estimated beta value for total capital expenditure in the renewable power sector of 0.7, a market premium of five percent and a risk free rate of return equal to the tax adjusted 12 months NIBOR interest rate, we arrive at the following discount rates:

Table 1 Required rate of return

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Required rate of return (nominal, after tax, on total capital)	8 %	8 %	7 %	6 %	6 %	6 %	7 %	7 %	6 %	6 %

Investment cost. Through the interviews of the license holders we have received information on the expected investment outlays at the time when the investment decision was made; if the investment decision has not yet been made we have got their updated expectations as per 2010 on the investment

[10] Name in Norwegian is Småkraftforeningen.

[11] This assumption was discussed with Henrik Glette in the Norwegian small hydropower plant association and Håvard Hamnaberg in NVE in a meeting at NTNU 16. November 2010.

[12] See Linnerud (2011) for a more detailed discussion of the cash flows, taxes and discount rate used in this paper.

outlay. To estimate the expected immediate investment costs [13] in earlier years, we have deflated these values using a price index reflecting actual growth in the cost of road construction.[14]

In the few cases (15 percent) were we did not get contact with the license holder we had to rely on data received from NVE on the investment cost of each project. These data include some measurement errors. First, the upfront cost of access to the grid may or may not be included in the data.[15] Second, license modifications are not included in the NVE investment data. The license conditions may reduce the profitability of the investment through requiring more expensive plant layouts or reduced production/capacity. Third, the expected investment outlays in the applications are based on a rather weak foundation, and before making an investment decision the license holder will have conducted more thorough calculations as well as got information from a public tender. To get around these problems, we have considered the licenses were we do have values representing both the time of the application and the time of the investment decision (85 percent of the licenses) and calculated the average annual growth between these two. This cost index (including a variety of factors) is used to inflate the application values.

Annual costs. A small hydropower plant will have annual costs consisting of 1) maintenance and operational costs, 2) annual costs for access to the grid and 3) cost of selling the power to a bigger power company which will sell the power on the grid and 4) payment to the owner of the river. We have followed the advice from the Norwegian small hydropower plant association which estimate these costs to 70 NOK/MWh (9 EUR/MWh) as per 2010.

Taxes. Hydropower plants are exposed to taxation through income tax, resource tax and property fees. The annual payment for the right to use the river for power production is deductible when calculating the resource tax. Power plants with an installed capacity above a certain level are exempt from resource tax. The tax rates are summarized in Table 2.

Table 2 Tax rates

	2001	2002	2003	2004	2005	2006	2007	2008
Income tax	28 %	28 %	28 %	28 %	28 %	28 %	28 %	28 %
Resource tax	27 %	27 %	27 %	27 %	27 %	27 %	27 %	30 %
Power plants which must pay resource tax, ≥ MW	1.35	1.35	1.35	5	5	5	5	1.35

[13] When calculating the continuation value, we used the consumer price index to reflect license holders expectations with respect to the development of the investment cost.
[14] Source: Statistics Norway.
[15] The cost of access to the grid depends on the grid capacity in the relevant part of the Norwegian transmission infrastructure, which again depends on the balance between supply and demand for power. Access to the grid infrastructure has a cost of between two and three percent of the power plant investment costs according to NVE.

	0.7 %	0.7 %	0.7 %	0.7 %	0.7 %	0.7 %	0.7 %	0.7 %

Installed capacity and annual production. The information we received from NVE contained the planned installed capacity and annual production. For the majority of the dataset, this information is checked and updated. We do not have information regarding the seasonal variation in production volume. These seasonal variations tend to be different for small hydropower plants compared to large hydropower plants with a reservoir and the opportunity to manage the production to accommodate changes in market prices. Thus, a small hydropower plant may achieve a lower market price on average. This cost is reflected in the annual costs above.

3. Real option valuation and stochastic processes

3.1 Real option valuation

A license to construct a power plant is a real option, where the investor has the right, but not the obligation, to pay the investment cost to get the cash flows from the project. Faced with a risky irreversible decision, investors will value the opportunity to gain additional information about likely future conditions affecting the project including market.

In contrast to the traditional net present value (NPV) approach, the investor must consider not only whether to invest but, also when to invest. Thus, the value of immediate investment, NPV, must be compared with the expected value of keeping the option alive—also called the continuation value (CONT). And, the real options value (ROV) is given by the following equation:

$$\mathrm{ROV} = \max\,[\mathrm{NPV}, \mathrm{CONT}] \tag{1}$$

The right to start construction of the power plant expires ten years after the license is granted, thus the license has characteristics similar to an American option where the option expires at time $\mathcal{T}$. The value of the license and its real options value is found using the following equation:

$$ROV = \mathbb{E}_0\left\{e^{-\mu \cdot t^*} \cdot [PV_{t^*} - F]\right\} \tag{2}$$

in which ROV is the value of the investment opportunity with expiration at time $\mathcal{T}$, PV_t is the discounted cash flows when the option is exercised at time t and F is the investment cost. The optimal time to invest is given by t^*, and at this point in time the NPV is equal to or greater than the CONT.

The present value of investment in plant k at time t throughout the option lifetime can be found by the following equation:

$$PV_{k,t} = \left\{ \sum_{i=t+l}^{t+L+l} \left[\frac{(P_i+S_i)\cdot c_k - v_i}{(1-r)^i} - s_k^g - s^b - s^p\right]\right\} \cdot \frac{1}{(1+r)^l}, k \in 1,2,\dots,\mathcal{K},\ t \in 1,2,\dots,\mathcal{T} \tag{3}$$

in which P is the electricity price, S is the subsidy, and v is variable costs—all measured as EUR/ kWh. Furthermore, P_k is the production in kWh of power plant k and the risk adjusted discount rate is given by r. The construction lag, that is, the time between the investment decision is made and the power plant is completed, is given by l. Resource tax, income tax and property fee are denoted s_k^g, s^b and s^p, respectively. Note that the resource tax varies both across licenses (according to generator capacity) and across time (see Table 2). The number of power plants in the analysis is given by $\mathcal{K}$.

We find the NPV, the CONT and the ROV for each power plant from the license was granted until the decision of investment was made. The dataset contains licenses granted in the period from 2001 to 2008, and for each year, we update the parameters for the electricity price process, subsidy regime, tax rates, which plants are eligible for paying resource tax, the size of the tax and discount rates. If no investment decision has been undertaken, the procedure of finding the NPV, the CONT and the ROV is repeated from the year the license was granted until 2010. The NPV, the CONT and the ROV serve as input in the regression analysis presented in Section 4.

Longstaff and Schwartz (2001) suggest a numerical procedure which employs simulations for approximating the value of and American option, where they calculate the expected payoff to the option holder, that is, the CONT, by using least squares. The method uses backward iterations and dynamic programming, and it calculates optimal time to invest and thereby finds the CONT of the option. This approach is well suited for options with American style exercise features and offers opportunity to include more than one stochastic variable. It offers flexibility regarding the behavior of the stochastic variables so that changes in climate policies can be easily implemented. It also allows for inclusion of the variables important to investors in small hydropower plants and it allows for the option to expire, which is the case for licenses to construct hydropower plants. In this paper, we aim to test different subsidy policy regimes and the framework of LSM allows for easy adaption of different assumptions in the parameters.[16]

Using the power function as a basis function, the estimates for parameters used in calculating the CONT is found by running a least squares regression as follows: [17]

$$\mathrm{E}[\mathrm{Y}_{t+1}|\mathrm{X}_t] = \alpha + \sum_{i=1}^{n} \beta_i \cdot \mathrm{X}^i \qquad (4)$$

in which Y_{t+1} is the NPV in period $t+1$ and X_t is the PV in period t while α and β_i are estimated parameters. Using the estimated parameters from Eq.(4), the CONT is found as follows:

$$CONT_t = \bar{\alpha} + \sum_{i=1}^{n} \bar{\beta}_i \cdot \mathrm{PV}_t^i \qquad (5)$$

---

[16] A drawback of the LSM procedure is the number of simulations required for the results to converge and the time required for conducting the simulations. However, with time increments of one year, this is not constraining in our analysis.

[17] Longstaff and Schwartz (2001) argue that the basis function in the LSM only to a certain extent affects the results. We tested four different sets of basis functions, namely power functions, Laguerre polynomials, Hermite polynomials and trigonometric functions. The option values were not affected by the choice of basis functions to the 4th decimal number.

When evaluating hydropower projects, there is uncertainty with regards to many parameters. In this paper we aim to decide whether climate policy uncertainty has affected investor behavior; thus, stochastic climate policies should be considered. Furthermore, we include stochastic electricity prices as the electricity price is the single most important source of uncertainty for a hydropower producer. Other sources of uncertainty which could have been considered are: the required rate of return, the legislation regarding taxation and the total investment cost of the project. Although additional stochastic variables could have been readably included using the LSM approach, we have chosen not to, as this would make the model less tractable, and hence make the results more difficult to interpret. In the following two sections, we present the two sources of uncertainty, electricity price and climate policy uncertainty.

3.2 Electricity price

Pindyck (1999) analyses the long-run evolution of energy prices, such as oil, coal and natural gas. He claims that the use of GBM models is unlikely to lead to large errors in optimal investment rules despite the arguments for the long-run energy prices to be mean reverting. This since the rate of mean reversion is low. This is confirmed by Schwartz (1998) who shows how a simple one-factor model has the same implications as a two-factor model when applied to valuing long-term assets. Following this approach, we let the electricity price follow a geometric Brownian motion, as expressed in the following equation:

$$\Delta P_{m,t} = \alpha_{m,t} \cdot P_{m,t-1} \cdot \Delta t + \sigma_m \cdot P_{m,t-1} \cdot \Delta W_{m,t}\ , \quad m \in 2001, .., 2010, \quad t \in 1 + l, \dots L + l + \mathcal{T} \quad (6)$$

where $P_{m,t}$ is the electricity price in year t when starting in year m, $\alpha_{m,t}$ is the drift parameter and σ_m is the volatility parameter. $\Delta W_{m,t}$ is a standard Wiener process.

Whereas the volatility parameter of the price process is constant, given the starting year of m, the drift parameter is not constant. The process for the drift parameter is outlined in Eq. (7).

$$\Delta\alpha_{m,t} = \mu \cdot (\bar{\alpha} - \alpha_{m,t}) \cdot \Delta t, \quad m \in 2001, .., 2010 \quad (7)$$

We find the starting point of the drift parameter by analyzing forward contracts with two and three years to maturity. The drift implied by the difference in contract prices represents short term drift. In the long term, we assume that the drift converges towards the inflation target set by the Norwegian Government. The inflation target is represented by $\bar{\alpha}$ in Eq. (6). We assume that the drift reverts to the inflation target, and the rate of mean reversion, μ, is set to 0.6. This implies that the drift of the price process is approximately equal to the inflation rate within ten years. By letting the drift parameter converge to the inflation target, we assume no real long term growth in electricity prices.

If a power plant is not constructed within the first year of getting the license, the investor will gain more information and have new estimates for the drift and volatility parameters.[18,19] These, in addition to the starting point of the price process, are outlined in Table 3.[20]

[18] The volatility is found by analyzing the return on three years forward contract. The dataset for each year is a rolling window of derivatives from the two previous years.

Table 3 Drift, volatility and starting price in Norwegian kroner of the price process

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
$\alpha_{0,k}$	0.071	0.061	0.056	0.022	-0.004	0.015	-0.006	0	0.016	0.044
σ_k	0.099	0.101	0.119	0.128	0.123	0.133	0.172	0.152	0.210	0.249
P_0	136	157	165	202	234	356	423	406	334	317

3.2 Climate policy uncertainty

In order to explore whether climate policy uncertainty has affected investment in renewable energy, we test whether uncertainty regarding the introduction of a market for green certificates has affected the timing of investments in small hydropower plants in Norway. This approach requires probability distributions which reflects the investors' expectations on the following two aspects; whether a subsidy regime will be implemented and which power plants will be eligible for support.

Consider an investor in year t that has a license to construct a plant with capacity a within $\mathcal{T}$ years. The authorities are discussing whether to implement a new subsidy scheme from year T_t where $T_t > t$. If investment is undertaken now, the power plant is not eligible for subsidies. If the investment decision is postponed until year T_t, subsidies will be received with the probability given in Eq. (8).

$$PR(T)_{a,t} = PRS(T)_t * PRI(T)_{a,t} \tag{8}$$

where $PRS(T)_t$ is the probability in year t for the support scheme to be introduced in year T_t and $PRI(T)_{a,t}$ is the probability that, conditional on the support scheme being implemented, a plant with installed capacity a will be included in the scheme in year T_t if the decision is made and construction starts in year t.

Based on publicly available statements by politicians, government declarations, public documents like green and white papers and parliamentary decisions, we have assigned values to the probabilities in Eq. (7). We divide the probabilities into five categories. These are: very unlikely (0 percent), more unlikely than likely (25 percent), as likely as not (50 percent), more likely than unlikely (75 percent) and very likely (100 percent). The subjectively decided probabilities were reviewed by a reference group consisting of power companies, the Norwegian small hydropower plant association and public energy

[19] The starting point of the drift parameter is found by analyzing the implied drift of three and two years forward contracts. The dataset for each year is a rolling window of derivatives from the two previous years.

[20] The starting point of the price process is found by discounting three years forward contract by the drift rate estimated as outlined in footnote 2. Here, the rolling window includes the last half of the previous year and the first half of the present year. That is, for the starting value of 2002, we use data from July 2001 to June 2002. The values are in Norwegian kroner.

institutions. The information used is summarized in Table A1 in the Appendix and the resulting probabilities are given in Table 4.

Table 4: The Overview of subsidy probabilities, level of support and introductory year

T	$PRS(T)_t$	$PRI(T)_{[0MW,1MW],t}$	$PRI(T)_{<1MW,10MW>,t}$	T_t	$\bar{s}_t$ (NOK/kWh) *
2001	25 %	100 %	50 %	2004	0.175
2002	25 %	100 %	50 %	2004	0.175
2003	25 %	100 %	50 %	2004	0.175
2004	25 %	100 %	50 %	2006	0.170
2005	75 %	100 %	50 %	2006	0.190
2006	25 %	100 %	50 %	2008	0.190
2007	75 %	100 %	100 % up till 3 MW** 0 % from 3 to 10 MW.	2008	0.040
2008	25 %	100 %	50 %	2012	0.180
2009	50 %	100 %	75 %	2012	0.229
2010	75 %	100 %	100 %	2012	0.269

* The certificate prices received is denoted $\bar{s}_t$. The Swedish market for green certificates opened in May 2003. For year 2001 and 2002 we do not have historic Swedish certificate prices, and use the average Swedish certificate price for 2003. For 2003, we also use the historical prices from 2003 and for 2004, we use the average from 2003 and 2004. From 2005 and onwards, with the exception of 2007, we use a rolling window of two years. In 2007, the feed-in tariff for hydro power approved by the Parliament in 2007 is included. The subsidy is granted per kWh produced. Reflecting the content of draft bills for certificates and feed-in schemes, we assume the payment is made for the first 10 years after production started in the period from 2001 to2006, and for the first 15 years after the production started in period from 2007 to 2010.
** Only for the three first MW installed.

The probability regarding whether a subsidy regime will be introduced has changed over time, and the political debate can be divided into four phases. (1) In the period from 2001 to 2004 the idea of a common Norwegian and Swedish green certificate market was launched and debated. Due to lack of political foundation, investors found it not very likely that the market would be introduced. (2) In 2005, the Norwegian government declared its commitment to green certificates and the first round of negotiations of a common market took place in the winter 2005/06. However, optimism in 2005 was replaced by pessimism in the beginning of 2006 when the negotiations failed. (3) For subsidy regime, the certificates were replaced by a detailed, national feed-in tariff system in 2007. This became a short-lived intermezzo, but its simplicity made many believe that it was more likely than not that the tariff would be implemented. (4) The second round of negotiations with Sweden started in December 2007 and did gradually change the sentiments from disbelief to belief as an understanding between the two countries was signed in June 2008, followed by an agreement in September 2009 and finally a draft Norwegian law on green certificates in December 2010.

There has also been uncertainty regarding which power plants would be included in a support regime. The political climate has favored hydropower plants with installed capacity below one MW, thus making it almost certain that these power plants would be included if a subsidy scheme were introduced. These attitudes are reflected by the fact that the new government in 2005 only included power plant with installed capacity under one MW in their promise to work for a common Norwegian-Swedish market of green certificates and that only micro and mini hydropower plants were included in the draft on a new law for green certificates presented in December 2010 (see Table A1 in the Appendix for further details). The feed-in tariffs suggested in 2007 included the first three MW installed on all hydropower plants. With this exception, there has been uncertainty with respect to the inclusion of power plants with installed capacity up to ten MW. This uncertainty was gradually reduced as the agreement with Sweden was detailed in the years from 2008 to 2010, as explained in the previous paragraph.

In addition, there has been a political debate on whether the scheme, if implemented, should be applied retroactively and be valid for plants constructed as early as January 1st 2004 reflecting the promise made by the Petroleum and Energy minister Einar Steensnæs in 2003.[21] The promise was restated at the annual meeting of the Norwegian small hydropower plant association in April 2004 where minister Steensnæs gave a speech.[22] The argument used by politicians preceding minister Steensnæs for not having a transitional agreement has been that the government in 2003 could not commit later governments to introduce support schemes. It is important to note that *if* the investors believed strongly in a transitional arrangement, the subsidy policy uncertainty have had a smaller impact on their timing decision comparing to if they did not believe in the promises of minister Steensnæs. We will therefore in Section 4 include two alternative ROV models, one in which the investors believed that they would be entitled to subsidies only for plants constructed after the scheme was implemented, and one in which investors believed the scheme would be applied retroactively for plants which started construction after January 1st 2004.

4 Regression models and analysis

4.1 Regression models

To conduct a formal examination of whether investments decisions in small hydro power plants are consistent with the predications from our real option model, we employ a multivariate discrete-choice model, with the investment decision as the observed dependent variable.[23] More specifically, we compute the discrete-choice model as given in Eq.(9).

$$\Pr ob(y_{it} = 1) = F(\boldsymbol{\beta}' \boldsymbol{x}) = e^{\boldsymbol{\beta}' \boldsymbol{x}}/(1 + e^{\boldsymbol{\beta}' \boldsymbol{x}}) \ , \qquad (9)$$

[21] Press release 138/03 from the Ministry of petroleum and energy 19th of December, 2003.

[22] Speech at the annual meeting of the Norwegain small hydropower plant association on the 27th of April 2004. Cited 03.05.2011 http://www.regjeringen.no/nb/dokumentarkiv/Regjeringen-Bondevik-II/oed/Taler-og-artikler-arkivert-individuelt/2004/Gronne-sertifikater-og-strategi-for-okt-.html?id=423716

[23] Actually, we do not always observe the investment decision itself. Rather we observe the year when operations of the plant

started from which we deduct one year to find the year when the investment decision was probably done.

in which y_{it} is a dummy variable that is equal to one if an investment decision is made for license *i* in year t, $F(\cdot)$ is the cumulative probability model and $\boldsymbol{x}$ is a vector of regressors. We use the logistic cumulative probability model.

The discrete-choice model in Eq.(9) is computed using the vector of regressors $\boldsymbol{x}$ in Table 5. This includes dummies for situations when the ROA model and the NPV model predict investment. In addition, we control for non-economic variables which may affect the timing of investment decisions:

Investor types. Investors who already has invested in hydropower plants and who perhaps represents professional energy company may be less risk adverse, be less restricted with respect to capital, have less concern for local conflicts arising because of the plant as compared to a group of local land owners (farmers) considering whether to invest in a small hydropower project for the first time. The professional investor may also have different attitudes towards risk and put different values on aspects like size as compared with non-professional owners. Furthermore, professional investors may be better informed about the various factors (including green certificates) affecting the investment's profitability than are non-professional owners. To account for possible systematic impacts of investor types, we use a dummy which is equal to one if the investor already owns one or more hydropower plants.

Size. It may be that investors attach a separate value to the absolute value or the size of the project. For instance, although two investments yield the same rentability, the biggest project may be preferred because it generates more revenues. Conflicts with your neighbors and the local society must also be weighed against economic gains, and may render the smallest projects unattractive. It may also be that size covariates with variables which are omitted or not sufficiently included in our model. For instance, it may be that the managerial competence and capacity and the money and time available to make a detailed prospect on which an investment decision can be made and loan be granted is higher for a big project than for a small project. To account for possible systematic impacts of size, we use a regressor which measures installed capacity in MW.

Micro hydropower plants. We have included 33 licenses on plants with a capacity below one MW in our dataset of 214 licenses. In Norway, there has been a special political emphasis on stimulating the construction of micro hydropower plants as compared to small hydropower plants. This is reflected in the draft bill on green certificates presented in December 2010 in which only micro hydropower plants are included in the transitional arrangement reaching back to 2004. Our model reflects this political emphasis by assuming that investors believed that if green certificates were introduced it was certain that micro hydropower plants would be entitled to such revenues (see Table 4). However, we include a dummy variable for plants with installed capacities below one MW to control for possibly omitted impacts, negative or positive, of investing in this group of hydropower plants.

Non-economic reasons for delay: NVE has documented, for each license, whether and when NVE has received a complaint and whether and when the complaint has been dealt with. Also, NVE has documented which licenses are delayed because they do not have access to the transmission grid. As this documentation is not complete, we have interviewed 185 of a total of 214 license owners to ask if there have been non-economic reasons for delay. Reasons we have discovered include time required to settle legal complaints, credit rationing, problems with net access, local conflicts, detailed project descriptions to meet requirements set by NVE and attempts to include new and more professional investors. To control for this, we use a dummy which is equal to one for licenses and for years in which such delays occur.

Table 5: Dependent and independent variables used in estimation of the regression model presented in Eq.(9).

	Variable name/values:
Dependent variable	
Investment decision	y_{it}={1,0}
Independent variables	
Dummy for ROA model investment signal	D_ROA={1,0}
Dummy for NPV model investment signal	D_NPV={1,0}
Dummy for professional investors	D_prof={1,0}
Installed capacity in MW	CAP $\in R^{+}$
Installed capacity in MW * Dummy for professional investors	D_prof_CAP $\in R^{+}$
Dummy for capacity less than 1MW	D_1MW={1,0}
Dummy for non-economic reasons for delays	D_delay={1,0}

Finally, the discrete-choice model (4) is computed fitting generalized least square models for panel data using the GEE approach described in Liang and Zeger (1986). The dependent variable is assumed to be binomially distributed; the link function is assumed to be LOGIT; and, the within-group correlation structure for the panels is assumed to be independent. The last assumption imposes only the constraint that the diagonal elements of the working correlation matrix are

$$R_{t,s} = \begin{cases} 1 & if \quad t = s \\ 0 & otherwise \end{cases}, \tag{10}$$

First, we want to test the hypothesis that the Real option analysis model, which compares the value of immediate investment with the continuation value, provides a better explanation of investors' behavior than the Net present value models. If this is true, we expect the coefficients for D_ROA to be significantly different from zero, while the coefficient for D_NPV is not.

Second, we want to test the hypothesis that investors' decision on when to invest is influenced by the uncertainty of future electricity prices. If this is true, we expect models which include stochastic electricity prices to provide a better explanation than models which include deterministic electricity prices.

Finally, and most important, we want to test the hypothesis that uncertainty with respect to whether, when and how a common market for green certificates is introduced did provide an additional risk factor for investors which further delayed the investment decision. In doing so, we compare three models which include different assumptions with respect to how the climate policy uncertainty was perceived by investors: investor ignored the discussion on green certificates; investors did consider the possibility of a future common market for green certificates and believed in the political promises of a transitional arrangement; and, investors did consider the possibility of a future common market for green certificates but did not believe in the political promises of a transitional arrangement.

4.2 Regression analysis

Table 6 shows the results of estimations of the discrete-choice model presented in Eq.(9) under different assumptions with respect to the stochastic variables: electricity price and the introduction of green certificates. The models are fitted using the generalized least square model for panel data using the GEE approach described in Liang and Zeger (1986) and assuming a binomially distributed dependent variable y.

The following conclusions can be drawn based on these three regression tables. First, electricity price uncertainty plays a major role in determining whether and when to invest. The Wald statistics of models A*, B* and C*, in which electricity prices are stochastic, are higher than the Wald statistics for models A, B and C, in which electricity prices are deterministic.

Table 6: Fitting generalized least square models for panel data using the GEE approach described in Liang and Zeger (1986). Family (binomial), link(LOGIT) and within group correlation (independent).

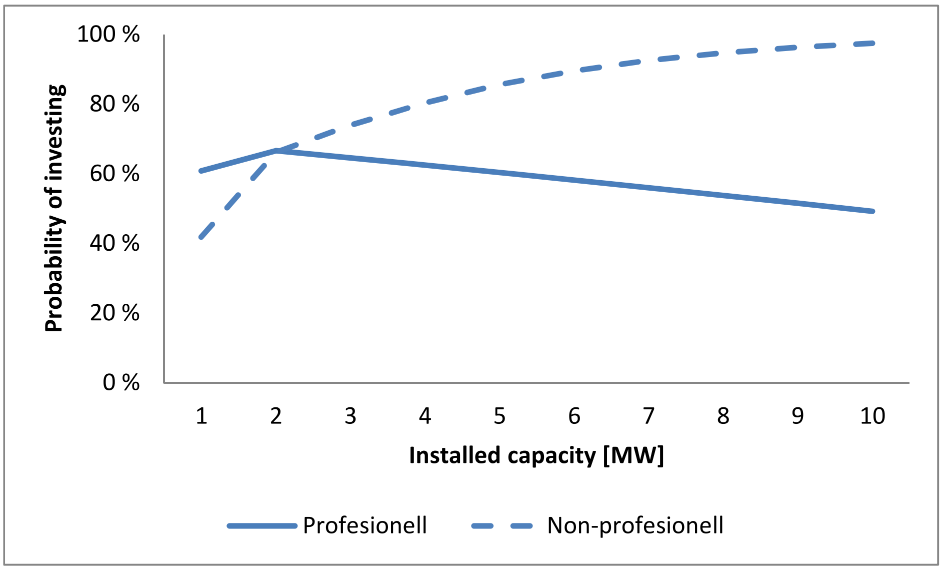
Subsidies	**No subsidies**		**Subsidies, no transitional arrangement**		**Subsidies, transitional arrangement**	
Electricity prices	Deterministic	Stochastic	Deterministic	Stochastic	Deterministic	Stochastic
	(A)	(A*)	(B)	(B*)	(C)	(C*)
D_NPV	+0.52 (0.47)	+0.10 (0.68)	+0.30 (0.34)	+0.04 (0.88)	-0.06 (0.89)	+0.02 (0.93)
D_ROV	-0.41 (0.56)	+0.55 (0.23)	-0.27 (0.32)	+0.80 (0.05)*	+0.15 (0.68)	+0.60 (0.14)
Capacity	+0.39 (0.01)**	+0.36 (0.01)**	+0.38 (0.01)**	+0.37 (0.01)**	+0.39 (0.01)**	+0.36 (0.01)**
D_prof_cap	-0.47 (0.01)**	-0.44 (0.01)**	-0.46 (0.01)**	-0.46 (0.01)**	-0.47 (0.01)**	-0.44 (0.01)**
D_prof	+0.91 (0.07)	+0.90 (0.08)	+0.91 (0.08)	+0.94 (0.07)	+0.91 (0.08)	+0.89 (0.08)
D_1MW	-0.67 (0.13)	-0.65 (0.14)	-0.67 (0.12)	-0.63 (0.15)	-0.67 (0.13)	-0.67 (0.13)
D_delay	-4.83 (0.00)**	-4.81 (0.00)**	-4.82 (0.00)**	-4.81 (0.00)**	-4.83 (0.00)**	-4.79 (0.00)**
Constant	-0.91 (0.05)*	-0.89 (0.05)*	-0.89 (0.05)*	-0.91 (0.05)*	-0.88 (0.06)	-0.84 (0.07)
Obser-vations	508	508	508	508	508	508
Groups	214	214	214	214	214	214
Wald test Prob>Chi2	50 (0.00)*	51 (0.00)**	51 (0.00)**	53 (0.00)**	50 (0.00)**	51 (0.00)**

The first number in each cell is the regression coefficient. The numbers in the parenthesis are the *p*-values for the significance of the coefficient.

Second, climate policy uncertainty does seem to influence the timing decision of investors. The model which achieves the highest Wald statistics and most significant variables is model B* which includes both uncertain electricity prices and an uncertain introduction of green certificates. Furthermore, model B* is based upon the assumption that investors did *not* believe in the political promises of a transitional arrangement for plants constructed after 2004.

Third, the Real option analysis model is better in explaining the timing of investment than the Net present value model. The coefficient of D_ROA is significantly greater than zero assuming a five percent significance level in model B* in Tables 6. The coefficients of D_NPV are never significantly different to zero. Moreover, the size of the D_NPV coefficient is very small, yielding only a percentage point increase in the probability of investment if the NPV signals investment compared to a situation where it does not.[24] Thus, we will focus on the predictions given by the Real option analysis model in the following.

Figure 1: The probability of investing when the Real option analysis model signals invest.



Based upon the estimated regression coefficients in Table 6 for model B*. The dummy variables D_NPV and D_ROA are both set equal to one. The dummy variable D_delay is set equal to zero. So is the dummy variable D_1MW, except for plant size equal to 1MW (which explains the kink in the lines). The dummy variable D_proff is set equal to one for professional investors, and zero for non-professional investors.

Figure 1illustrates how the probability of investment is affected by the Real option analysis investment rule and how this probability varies with plant size.

[24] However, since the two dummies, D_ROA and D_NPV, are highly correlated, the standard errors of the respective coefficients will be high and it may be difficult to prove that they are significantly higher than zero. Thus, we reran the models including only one of these dummies at the time. The result of the estimated models when D_NPV is omitted is given in Table 6, and we see that the coefficients of D_ROA have become even more significant, while the Wald statistic and the coefficients of the other variables have hardly changed.

Both investor groups are more likely to invest than not if the Real option analysis model signals invest. More precisely, the expected probability to invest is greater than 50 percent for capacities between two and nine MW for both investor groups. For instance, considering a 5MW plant, it is a 60 percent probability that a professional investor will invest and at 86 percent probability that a non-professional will invest if the Real option analysis models signals invest.

Figure 1 indicates that while non-professional investors are more inclined to invest the greater the power plant, the professional investors prefer smaller plants. Only the first impact is significant however; that is, for professional investors the sum of coefficients for the variables Capacity and D_prof_cap is not significantly different from zero as shown in Table 7.

Table 7: Test of the sum of coefficients for Capacity and D_prof_cap. (1) Capacity+1.D_prof_cap =0

D_investment	Coef	Std. Err.	Z	p>$\lvert Z \rvert$
(1)	-0.09	0.07	-1.24	0.22

After fitting model B* in table 6, a sum of the coefficient for variables Capacity and D_prof_cap is tested.

Non-professional investors' responses to size may be due to misspecification of our models and/or it may reveal differences in attitudes towards risk and investments worth noting. To illuminate this issue, we presented Figure 1 for our reference group to discuss possible explanations. We also scrutinized our interviews with non-professional investors.

First, the non-professional investors seem more eager to invest in small hydro power plants than their professional partners. That is, for plant sizes between 3 and 10 MW, the probability of investing when the Real option analysis model signals invest is considerably higher for the non-professional compared to the professional investors. One reason for this may be managerial constraints in professional companies investing in small hydro power plants. One of the big, professional investors[25] pointed out that even though they had many profitable investment opportunities they chose to start constructing one plant at a time to retain control of the developments. Another reason for this difference in responses between professional and non-professional investors may be that the non-professional investors are often farmers and that they may attach additional values not quantified in our models to investing in a plant on their farm. The Norwegian small hydro power plants association also suggests that non-professional investor seem to have made up their mind when applying for the license and not after the license is granted, thus explaining the high probability of investment in Figure 1. Furthermore, it may be that the projects are not evenly distributed between professional and non-professional owners; that is, it may be that the local landowners choose to keep the most profitable projects for themselves, and that this extra profit is not adequately captured by our cash flow calculations.[26] Finally, local landowners may also have fewer investment opportunities, thus increasing their propensity to invest in this plant. The reasons are not clear, and require further investigations in subsequent research.

---

[25] Svorka Energiverk AS

[26] This probable explanation was suggested by as suggested by the Norwegian Water Resources and Energy Directorate. It has also been put forward by a couple of our small non-professional investors as an explanation on why they didn't want to include professional investors,.

Second, non-professional seem to be more willing to invest in big compared to small plants. That is, they seem to value size in addition to profitability when deciding on when to invest. One reason for these results may be that non-professional owners may face credit constraints which are not sufficiently included by using the dummy variable D_delay.[27] It may be that banks are on average more willing to give loans to projects of a certain size as these may be backed by more than one investor and these investors may have put more money and time into developing a prospect detailing the profitability of the investment. Our interviews revealed the belief that after the finance crisis, the banks had required a higher equity share in order to give loans, and that this had affected the non-professional investors especially.[28] Also, for large projects, sunk cost of project planning may be so great that the non-professional investor experience that these costs are forcing a decision. This line of reasoning can also apply the other way around; that is, the absolute benefits of realization may be so small that the projects will remain in the tray.[29]

5. Conclusion

To sum up, the Real option analysis model prove to be better than the Net present value model in predicting investment timing in small hydropower plants. Our analysis suggests that both uncertain electricity prices and uncertainty with respect to the introduction of green certificates did delay these investments. Furthermore, political promises saying that the subsidy scheme, if introduced, would include a transitional arrangement for power plants constructed after 2004, did not seem to have reduced investors' perceived risk.

When investment signals are given by the Real option analysis model, the probability that the investor will invest is on average 58 percent and 82 percent for professional and non-professional investors, respectively. The non- professional investor seem more eager to invest and his/her inclination to invest increases with size. The probable reasons vary and include values not captured by our model, sunk cost and credit restrictions.

[27] It is included by setting D_delay equal to 1 for lisences and years for which interviewed investors have revealed such problems.
[28] This explanation was put forward by the hydro power company Tussa Kraft.
[29] This line of reasoning was presented by the Norwegian Water Resources and Energy Directorate.

Appendix

Table A1: The political process on green certificates in Norway – 10 years of discussions.

Year:	The political status of green certificates in Norway:	Phase/prob.
2001	01.12.2000: The Energy- and Environment Committee asks the Government to explore the consequences of a system with green certificates adapted to suit the Norwegian and Nordic situation (Budsjettinnst. S.nr. 9 (2000-2001)). 21.09.2001: The Government says it has started its work on examining the consequences of a green certificate market in Norway/the Nordic countries similar to those under consideration in EU countries(St. Prp. nr. 1 (2001-2002)).	Idea launched (25 %)
2002	08.04.2002: The Government refers to six research reports which are made to examine the impact of a Norwegian/Nordic market for green certificates (Press release). 13.09.2002: The Government will present an evaluation of green certificates compared with other support schemes for renewable electricity for the Parliament autumn 2002. (St.Prp. nr. 1 (2002-2003)). 01.11.2002: The Ministry of Petroleum and Energy recommends the introduction of a mandatory certificate market for renewable electricity. The Ministry is positive to the creation of an international market, and believes that Norway should be part of such a market (St. meld. nr. 9 (2002-2003)).	
2003	01.05.2003: Sweden starts up a national market for green certificates. ……………: The Petroleum and Energy Minister Steensnæs promises a transitional arrangement: "I want to emphasize that those who start constructing power plants shall not lose out on the introduction of a market for green certificates. Certificate eligible power plants that started construction after 1 January 2004 will have the opportunity to participate in a system of green certificates, even if such a system would be established after this date." ……………..: The Ministry of Petroleum and Energy orients on efforts to establish a common certificate market with Sweden, and draw up the framework for further work (St. meld. nr. 47 (2003-2004)). 19.12.2003: The Government argues for the introduction of green certificates. This is supported by the Parliament which asks the Government to take an initiative to establish a common Swedish-Norwegian market for green certificates. This should result in a proposal spring 2004, at the latest (cf. St.meld. nr. 9 (2002-2003)).	
2004	14.05.2004: Based upon St.meld nr. 18 (2003-2004) the Energy and Environment Committee recommends that a common market for green certificates should be implemented from 1th of January 2006. The committee supports the transitional arrangement promise made by Petroleum and Energy Minister Steensnæs last year. 10.09.2004: The Ministry of Petroleum and Energy says it has started exploring the possibilities of a common market on green certificates with Swedish authorities (St.prp. nr. 1 (2004-2005)). 24.11.2004: A draft law on green certificates is distributed to consultative bodies for comments. All plants which have started construction after 01.01.2004 are included. There are no limits on installed capacity. Plants eligible for support will receive subsidies for 10 years. The bill provides that the certificate scheme will be operating as of January 1, 2006. It is planned that the law will be submitted to Parliament in spring 2005 and that the law only takes effect when the necessary clarifications with Sweden are made (Draft law).	
2005	21.02.2005: The results from the public hearing on the draft law on green certificates are published. 13.10.2005: A new Government is elected which confirms its commitment to introduce green certificates from 1.1.2006. In a public declaration (Soria Moria I, p. 58) it says: "Government will introduce a mandatory green certificate market for renewable energy and mini and micro power plants". Negotiations with Swedish authorities start up.	First round of negotiations (75 %, 25 %)
2006	27.02.2006: The negotiations between Norway and Sweden are terminated. Prime Minister Stoltenberg says the system would result in too high costs for the Norwegian consumers and the industry. The Government would instead strengthen the focus on	

	already established instruments. (Press release). 05.10.2006: The Ministry of Petroleum and Energy says that a new support system for electricity production from renewable energy sources will be introduced from 1 January 2008. Hydropower producers will receive 0.04 NOK/kWh as a feed-in tariff for production representing the first 3 MW of the installed capacity. Support will be paid during 15 years. The transitional arrangement established when preparing for a Norwegian-Swedish green certificates' system, will be continued. (Press release). 24.11.2006: The Government proposes the new Feed-in tariffs (St.meld. Nr. 11 (2006-2007)).	
2007	19.03.2007: The Parliament approves the Government's proposal for feed-in tariffs. 04.10.2007: A draft Directive on feed-in tariffs is distributed to consultative bodies for comments (Press release). 07.12.2007: The Government announces it will start a new dialogue with Sweden on a Norwegian-Swedish market for green certificates. The initiative is supported by the political opposition in Norway. If the negotiations do not succeed, the Government will seek to implement a national subsidy scheme. The transitional arrangement for plants constructed after 1.1.2004 will be continued (Press release).	Feed-in tariffs (75 %)
2008	23.05.2008: Sweden signals that it needs time to explore the implications of EU's Renewable Directive. The Ministry of Petroleum and Energy says that if this results in a delay of the common market for green certificates, other support schemes must be considered (Press release). 27.06.2008: The Norwegian Petroleum and Energy Minister Riis-Johansen and the Swedish Industry Minister Olofsson signs an "Understanding" on cooperating for a common Swedish-Norwegian market for green certificates (Press release).	Second round of negotiations (25 %, 50 %, 75 %)
2009	07.09.2009: A Swedish-Norwegian Agreement is signed outlining the main principles of the common market including ambition level, start-up date 1.1.2012 and the technology neutrality principle (Press release). 26.11.2009: The Government proposes a transitional arrangement, stating that all plants, where constructing had started after 7. September 2009, and hydro power plants with a smaller capacity than 1MW, where constructing had started after 1. January 2004, should receive subsidies. The transitional arrangement gives a right to take part in the common green certificate market when and if it starts up. The number of years between the plant started its production and the green market was implemented should be deducted from the number of years plants normally receives subsidies (15 years) (Press release).	
2010	May 2010: The political opposition sets Document No. 8: 91 S (2009-2010) proposal: "Parliament requests the Government to ensure that all facilities with construction starting from 1 January 2004, and who are eligible for green certificates from 2012, are included in the transitional arrangement." 03.06.2010: Document No. 8 is voted down in Parliament. 08.12.2010: The Norwegian Minister of Petroleum and Energy, Riis-Johansen and Swedish Industry Minister, Olofsson, signs a Protocol concluding the discussions on a system for green certificates that started September 2009. The new system is expected to generate 26.4 TWh by 2020, each country financing 13.2 TWh (Press release). 08.12.2010: The Government presents a draft Norwegian law on green certificates.	
2011	11.04.2011: It remains to be seen if and how the law is implemented. Both the Norwegian and the Swedish Parliament must enact a new law on electricity certificates during 2011. And, the whole agreement is dependent on the ratification of the EU Renewable Directive in Norway.	

Sources: Press releases and public documents from the Ministry of Petroleum and Energy, the Parliament and the Government in Norway.

References

Blyth, W., R. Bradley, D. Bunn, C. Clarke, T. Wilson and M. Yang (2007). Investment risks under uncertain climate change policy. Energy Policy 35, pp. 5766-5773.

Blyth, W. and M. Yang (2006). Impact of climate change policy on power generation investments. Working paper for the IEA for COP12, LTA/2006/01, Paris.

Blyth, W. and M. Yang (2007). Modeling investment risks and uncertainties with real options approach. Working paper for an IEA book: Climate policy uncertainty and investment risk. LTO/2007/WP 01, Paris.

Dixit, A.K. and R.S. Pindyck (1994). Investment under uncertainty. University Presses of California, Columbia and Princeton.

Econ Poyry (2008). Memo, Provenyvirkninger av bunnfradrag for nye små vannkraftverk, 30. januar 2008, http://kraftverk.net/downloadfile.php?blobId=10

Fleten, S.-E. and G. Ringen. (2009). New renewable electricity capacity under uncertainty: the potential in Norway, Journal of Energy markets, 2(1), 71-88.

Fuss, S., J. Szolgayova, M. Obersteiner and M. Gusti (2008). Investment under market and climate policy uncertainty. Applied Energy, 85: 708-721.

Gamba, A. and M. Tesser (2009). Structural estimation of real option models, Journal of Economic Dynamics and Control, 33, 798-816.

Gjølberg and Johnsen (2007)

IEA-International Energy Agency (2007). Climate policy uncertainty and investment ris. The International Energy Agency , ISBN ….., Paris.

Ishii, J. and J. Yan (2004). Investment under regulatory uncertainty: US electricity generation investment since 1996. GSEM WP 127, University of California Energy Insitute, California.

Kiriyama, E. and A. Suzuki (2004). Use of real options in nuclear plant evaluation in the presence of uncertainty with CO2 emission credit. Journal of nuclear science and technology, 41(7), pp. 756-764.

Kristoffersen, T.K., N. Meade and S.-E. Fleten (2011). Valuing wind power investments under different renewable energy support schemes, work in progress.

Laurikka, H. and T.Koljonen (2006). Emissions trading and investment decisions in the power sector—a case study in Finland, Energy Policy 34(9), 1063-1074.

Longstaff, F. A. and E. S. Schwartz, (2001), Valuing American Options by Simulation: A Simple Least-Square Monte Carlo Approach, The Review of Financial studies, /v 14 n l 2001

Moel, A. and P. Tufano (2002). When are real options exercised? An empirical study of mine closings, The Review of Financial Studies, 15(1), 35-64.

McDonalds, R. and D. Siegel (1986), The value of waiting to invest, Quarterly Journal of Economics, 101, 707-727.

NVE(2003) Veileder i planlegging, bygging og drift av små kraftverk. Veileder nummer 2/2003. Utgiver: Norges vassdrags- og energidirektorat. Forfatter: Norconsult/NVE ISSN: 1501-0678

NVE (2010). Veileder I planlegging, bygging og drift av småkraftverk, Veileder 1,2010. NVE, Oslo.

Olje- og energidepartementet (2010), Høringsnotat (forslag til lovvedtak) 08.12.2010 om lov om elsertifikater.

OECD (2009). The economics of climate change mitigation. Policies and options for actions beyond 2012, Paris.

Quigg, L. (1993), Empirical testing of real option-pricing models, The Journal of Finance, 48(2), 621-640.

Reedman, L., P. Graham and P. Coombes (2006). Using a real-options approach to model technology adoption under carbon price uncertainty: an application to the Australian electricity generation sector. The Economic Record, 82, special issue, pp. 64-73.

Rothwell, G.(2006). A real options approach to evaluating new nuclear power plants. The Energy Journal, 27(1), pp. 37-53.

Yang, M., W. Blyth, R.Bradley, D. Bunn, C. Clarke and T. Wilson (2008). Evaluating the power investment options with uncertainty in climate policy, Energy Economics, 30(4), pp. 1933-1950.