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Pumped-storage project: A short to long term investment analysis including climate change

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ABSTRACT

New renewable energy needs flexibility, which can be provided by storage-hydropower. Climate change affects the potential of this technology in both a negative and a positive way, on one hand by altering runoff, and on the other hand by creating new investment opportunity. This paper provides an economic and financial analysis of a future project in a pumped-storage facility that may be initiated in the Swiss Alps following the glacier retreat. The area released may be considered for building a new reservoir. A complete and integrated model is developed based on the tools of analysis provided by econometrics, finance and operational research. The results show that under the present market conditions such an investment is not profitable. Unexpectedly, the sensitivity analysis shows that most of the time higher price volatility reduces annual revenue. Furthermore, the project's lifetime only has a marginal impact on the Net Present Value. The value of the concession, which is the right to use water, is also assessed on the basis of a real option analysis including a long-term horizon. Its present value is substantial even if the project is currently unprofitable. In the discussion, we go beyond the Swiss case study and highlight the implications for energy policy and market design.

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1. Introduction

Climate change not only brings about negative dynamics but also opportunities as long as we are able to take advantage of them. Public and private investors can turn what is generally viewed as an unwanted fatality into a source of revenue. In some fields, the negative impact of global warming should therefore be compensated by well-designed projects, which may even become factors of development and economic growth.

The glacier retreat releases new areas where natural lakes may appear or artificial lakes are built. They will represent not only

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new sources of power but also revenue. This case is illustrated by a project envisaged in the Swiss Alps. A pumped-storage plant could be built between an existing reservoir and a new artificial one, once the area is released from ice. The volume of the new lake is known and the future runoff has been computed.

However, the question remains whether this project is economically viable. The Net Present Value (NPV) method and Real Options Analysis (ROA) are used to clarify this issue. Future cash flows are simulated using Mean-reversing Jump Diffusion (MRJD) and Geometric Brownian Motion (GBM) models. Their application depends on the time horizons considered and issues addressed. Operational research allows us to link annual revenue, prices and runoff. Ten combinations of global climate model and regional climate model (GCM-RCM) are taken into consideration.

The NPV shows that this project is not profitable under present market conditions. The sensitivity analysis highlights the key parameters and proves that a greater volatility does not mean higher profitability for the pumped-storage installation. The NPV's time horizon (40 or 80 years) does not change significantly given that the turbines have to be replaced after 40 years. This result is relevant for decision-makers in view of the water concessions' end.

ROA provides a way of addressing uncertainty from another perspective and allows the consideration of longer-term horizons. The project represents an option that can be exercised in 2041, when a new water concession should be granted by the Authority, and the glacier tongue will retreat to the location of the planned dam. I show that the option has a positive value due to the 'time value'. The present value of the concession is between 60 and 170×10^6€ depending on the project design. Therefore, the decision-makers should bring the option 'in the money' to realize this opportunity.

Starting from this case study, the discussion is therefore extended to highlight the implications for energy policy and market design. I explore the conditions that should be met in order to value the storage capacity. The creation of a green and decarbonized economy may be facilitated if these problems are fixed. This study is not limited to an investment analysis. Because I apply various methods of evaluation and provide a sensitivity analysis, I can discuss the results in a broader context.

This paper includes five sections. It starts with a literature review (Section 2). It follows with a presentation of the model and data (Section 3). Thereafter, the future annual revenue and investment profitability are investigated (Section 4). Discussion follows, which encompasses broader questions related to energy policy and market design (Section 5). The conclusions and future research perspectives are presented in the final (Section 6).

2. Literature review

With 3672 TWh in 2012, hydropower represented 16% of World electricity supply and 76% of the renewable electricity production [1]. According to the World Energy Outlook 2014s New Policies Scenario, hydropower energy production will increase by 2550 TWh by 2040. However, the share will not change since electricity consumption will grow over the same period. In the OECD countries, most of the economic hydropower potential is exhausted and the most important projects take place in the non-OECD countries [1]. In 2010, the pumped-storage installed capacity was between 121 and 127 GW, and represented 99% of the installed storage capacity [2,3]. This is due to its technical features as well as, for the moment, a lack of storage alternatives.

In Switzerland, where our case study is based, hydropower represents about 56% of the electricity mix. As the Swiss government decided to phase out nuclear energy, which represents 40% of the electricity mix, hydropower may play a central role in the so-called 'energy turnaround'. The energy strategy seeks to increase annual hydropower production by 2.7 TWh by 2050 [4], although new environmental rules will have a negative impact on its potential [5]. In 2014, the total pumped-storage capacity is 1839 MW [6], of which 456 MW are closed-loop systems (pure). The latter includes plants without natural runoff intakes. At present, two large pumped-storage installations are under-construction: Nant-de-Drance, situated in Valais, and Limmern, in Glaris, for which the planned installed capacity is respectively 900 MW and 1000 MW [6]. However, new projects are pending' as a recovery in profitability for pumped-storage installations is expected by 2020 [7].

The demand for flexibility increases with the increased penetration of new renewable energy into the power system. Hydropower with reservoirs provides this flexibility and to some extent can compensate for the natural intermittency of solar and wind energy. In other words, the operator can schedule the supply some time before real time and deliver backup energy almost instantaneously.

Intermittent energy should be stored when production exceeds consumption. Pumped-storage installations currently represent one of the best electricity storage technologies. The general principle is to pump water when prices are low from a low-altitude reservoir to a higher one. The electric energy is thus transformed into potential energy, which in turn will be transformed into kinetic energy, as soon as the operator requires it. In principle, the turbines are activated when peak prices are high. The efficiency of the whole cycle is high, about 80%, and the self-discharge time is low, meaning that once stored there are minimal losses. One should stress that pumped-storage that does not possess natural water intakes consumes energy. It allows the transfer of energy from times of potential surpluses to times of potential deficits. The most important parameters in the design of a pumped-storage installation are the capacity, which determines the power, and the reservoir volume, which determines the amount of energy that may be stored. Gaudard and Romerio [8] provide further details as well as an overview on the technical and economic features of hydropower.

According to Godde and Engels [9], current European energy policy jeopardizes investment in pumped-storage installations. High subsidies toward new renewable energy, the fall in the price of carbon emission certificates, and the economic crisis have provoked a dip in electricity spot prices [10]. The gap between peak and off-peak prices also diminished, as shown in Fig. 1. With an efficiency of 80%, the electricity has to be sold at a price 1.25 higher than the electricity price occurring during pumping process [8]. Under these conditions, operators only cover variable cost. In fact, in the present situation, most pumped-storage installations are unable to recover fix costs [7].

Hydropower is also impacted by climate change. This impact is well documented [11–14]. Seasonality and annual water volume may

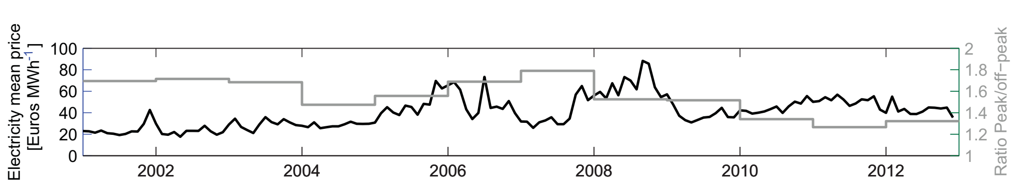

Fig. 1. Mean electricity spot price and ratio between peak and off-peak price from 2001 to 2013 (Source: based on European Energy Exchange [41]).