Trading the weather

Summer internship at the Department of Mathematics.

Supervisor: Professor Fred Espen Benth

One project (position) available, for a 6 weeks period covering week 26, 27, 28, 33, 34, 35. The successful candidate should hold a bachelor degree with a strong background in mathematics, statistics and programming (MAMI or MAEC programs).

Project description:

Temperature is an important driver of demand for power in the Nordic region, but with the gradual increase of renewable power like wind, it also enters on the supply side. In this summer internship project, we aim at understanding how one can apply modern machine learning techniques to manage price and weather risk in power markets. In particular, we focus on how we can "trade the weather" with exotic insurance products to protect against undesirable risks.

Temperature and the power price are statistically dependent, as are solar and wind power production. The markets offer various financial contracts that may be used in order to offset production/demand and price risk. For example, at the German power exchange EEX, one can now speculate on wind power production, while in the US one can trade temperatures. Traditionally, one can also trade power financially at different exchanges, like for example NordPool. These products are known as "futures" in the markets.

The internship project poses the following problem: How to optimally construct a strategy using futures in weather and power price, to remove undesirable risk? The methodology to solve this problem will be taken from machine learning, where we apply reinforcement learning. Mathematically, we assume that we are facing a risk described by a function of the power price and a weather factor, temperature say,

$$f(Price, Temperature)$$

Here, *f* is some function. If we assume we are power producer in the Nordic region, we may face a risk towards low prices combined with high temperature. High temperatures usually leads to lower demand (for heating in winter), and thus we may sell less of our power production, to low prices. To create an insurance against this, we find a strategy that buys and sells futures on power price and on temperature, and try to get as close as possible to the risk function *f*, or, in mathematical terms, try to minimise

$$(x + \sum_t u(t)F_P(t) + v(t)F_T(t)) - f(Price, Temperature)$$

where *u* and *v* are the positions in power price and temperature futures, resp., and *x* is the initial cost. The price dynamics and the risk function are stochastic, so we are facing a decision problem in a random environment. In the project, we will define suitable stochastic processes to model the random time dynamics of the involved elements.

The decision problem is a case of a stochastic control problem, and the internship aims at applying recent machine learning methodology to solve it. More specifically, we want to adapt reinforcement learning techniques to solve the optimisation problem. Reinforcement learning, based on simulated paths of the stochastic processes, has been developed recently to option problems in finance by Igor Halperin at NY University, in a setting relevant for the internship. This approach will be extended into the context of energy markets as outlined above. Reinforcement learning to decision problems will find the best way to “hedge” the risk, but also provides the cost of this insurance (which is x) as well as the uncovered “residual” risk. The framework and methodology constitute an alternative to the classical mathematical finance approach of so-called risk neutral hedging and pricing, which is a mathematical theory based on strong assumptions on the market not met in practice.

The internship will result in the development of computer algorithms (and their implementation) for finding optimal investment strategies covering price and weather risk. Analysis of the reinforcement learning technique to solve such problems will be reported, building up knowledge in the applicability and potential of machine learning techniques in the energy markets. Finally, various case studies will demonstrate how this can be used in practice by different actors in the markets, such as producers, retailers or energy-intensive industry. The findings will be documented in a report and disseminated in an industry seminar at the end of the project period.