VOLATILITY EFFECTS

AND

VIRTUAL ASSETS:
HOW TO PRICE AND HEDGE
AN ENERGY PORTFOLIO

GME Workshop on “FINANCIAL MARKETS IMPACT ON ENERGY PRICES”

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Responsabile Pricing and Structuring
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Outline

- Virtual Assets: definition
- Pricing and hedging of structured products: what issues are involved?
- Is electricity storable?
- Pricing and optimisation of Virtual Pump Storage (VPS)
- Volatility effect on a Virtual Asset value

Virtual Assets: definitions

- In the last years, some complex financial instruments called virtual assets, have been traded in the OTC energy markets.

- These products are traded, between utilities or investment banks, in order to replicate some typical features of the underlying industrial world such as:
  a. being an alternative to a real asset investment;
  b. diversifying the industrial portfolio of real assets;
  c. merchant trading, with the objective of "trading around the asset".

- Common features of these instruments are:
  – volumetric flexibilities and constraints;
  – timing constraints;
  – multi-risk exposure.

- From a financial standpoint, a VA is an American option portfolio (call and/or put options); for this reason it is necessary to solve an optimal stochastic problem, computing the set of control variables (strategy), which maximises a weighted sum of cash flows over a certain time horizon, subject to some physical constraints.

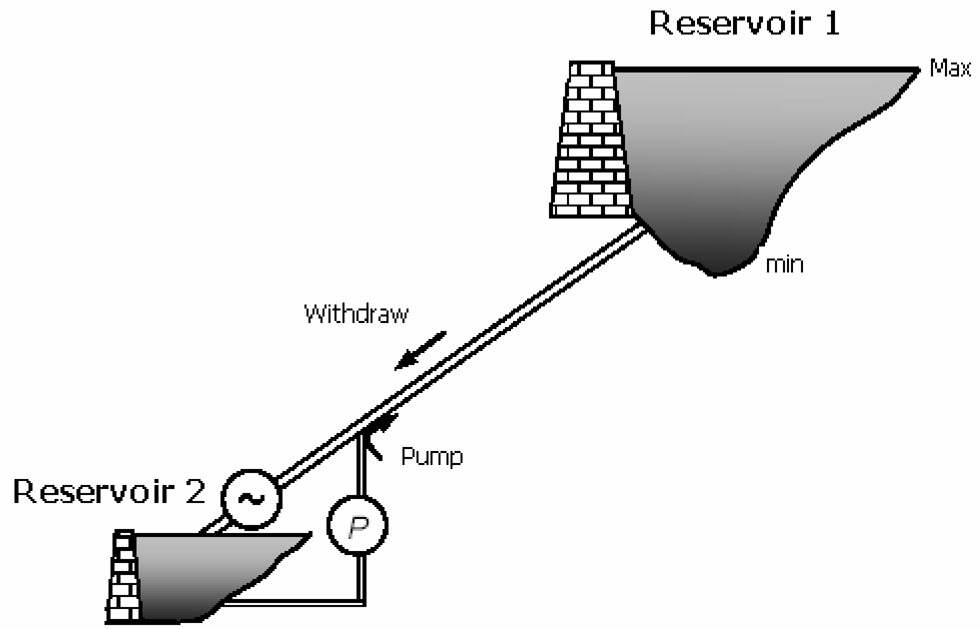
$$V_t(x_t) = \sup_{u_t} \left\{ \mathbb{E}_0 \left[\int_0^T e^{-rt} \pi(t, x_t, u_t) \mathrm{d}t + e^{-rT} \Omega(t, x_T, u_T) \right] \right\}$$

Is electricity storable?

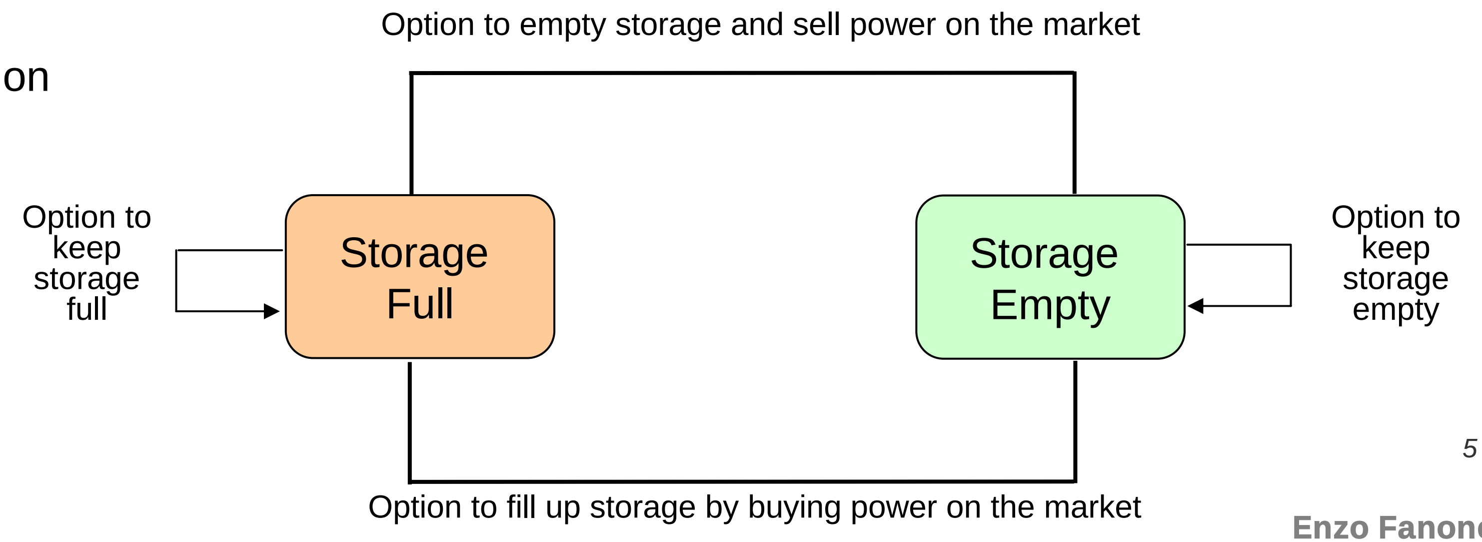
- Unlike electricity, water can be a storable commodity, to be converted into electrical energy by generators.
- Some of the hydro storage plants also have pumps; in this case, the owner also has the additional option to pump water back to the reservoir.
- **Could we imagine thus storing electricity?**
- When the demand is low, such as in off-peak hours, power is injected into virtual storage.
- When the demand is high, such as in peak hours, power is withdrawn to meet peak demand.
- A **Virtual Pump Storage** (VPS) attempts to replicate financial flexibility of a pump-hydro storage plant, giving the owner the possibility of <u>calling</u> power previously stored for sale in the spot market or of <u>putting</u> power into storage for future delivery.

Is electricity storable?

Engineering description



Financial description



Input data of a VPS

- We can define a virtual pump storage contract through the following features:
  a. contract duration
  b. maximum pumpimg and withdrawal rates
  c. minimum and maximum inventory levels
  d. frequency of decisions
  e. pumping/withdrawal costs

- Pumping and withdrawal quantities can be a function of time and the inventory levels. These levels are defined within a range: there's a minimum and maximum rate.

$$q_{min}^{pump}(t, \mathrm{inv}(t)) \leq q^{pump}(t) \leq q_{max}^{pump}(t, \mathrm{inv}(t))$$

$$q_{min}^{with}(t, \mathrm{inv}(t)) \leq q^{with}(t) \leq q_{max}^{with}(t, \mathrm{inv}(t))$$

- Maximum and minimum inventory levels represent constraints on the total volume that can be put into storage at any time. Those values can also be functions of time

$$\mathrm{inv}_{min}(t) \leq \mathrm{inv}(t) \leq \mathrm{inv}_{max}(t)$$

- Usually within a contract initial and final inventory levels are also specified. The terminal inventory level is particularly important since it represents a constraint for the buyer. If the constraint is not respected penalties might be applied.

Pricing and hedging: what are the problems?

- The value of pump storage can be defined as the maximum expected revenue that the buyer can obtain by the optimal injection and withdrawal strategies, capturing favorable spreads between the spot and the forward markets.

- The pump storage pricing problem is basically an optimization problem. The objective function of this problem can be formulated as follows

$$V(t) = \max_q \left\{ \mathbb{E}\Big[\int_t^T e^{-\rho(s-t)} \Pi(s, q(s)) \mathrm{d}s \Big] \right\}$$

$$\forall s \in [t, T] \qquad q(s) = \begin{cases} q_{pump}(s) \\ 0 \\ q_{with}(s) \end{cases}$$

$$q_{min}^{pump}(s, \mathrm{inv}(s)) \leq q^{pump}(s) \leq q_{max}^{pump}(s, \mathrm{inv}(s))$$

$$q_{min}^{with}(s, \mathrm{inv}(s)) \leq q^{with}(s) \leq q_{max}^{with}(s, \mathrm{inv}(s))$$

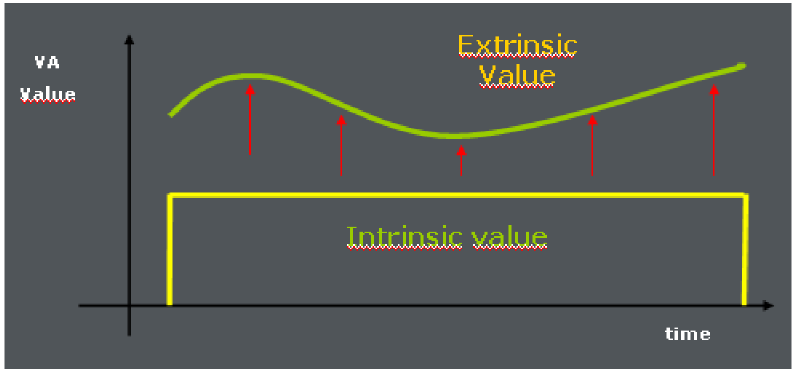
Pricing and hedging: what are the problems?

- As a consequence of the Bellman's optimality principle, the previous expression for the value function V(t) may be simplified and reduced to a recursive equation

$$V(t) = \max_q \left\{ \mathbb{E}\Big[\int_t^{t+\mathrm{d}t} e^{-\rho(s-t)} \Pi(s, q(s))\mathrm{d}s + e^{-\rho \mathrm{d}t} V(t+\mathrm{d}t) \Big] \right\}$$

- This recursive equation for the value function V(t) is known as the Bellman equation of a stochastic dynamic programming problem.

- The total value of a VPS is given by the sum of two components:
  1. *intrinsic value* : is the value that comes from the shape of the power forward curve;
  2. *flexibility* or *extrinsic value* : is the value that comes from the possibility of capturing price and demand fluctuations.



Pricing and optimisation of VPS

Let's assume we are pricing and optimizing a simple storage contract with the following features:

Contract data

Valutation date	16-jun-08
Start Date for the dispatch	1-jul-08
End Date for the dispatch	31-jul-08
Yearly interest rate (%)	4
Frequency exposure	hourly
Optimization method (1-LSMC 2-DPMC)	2

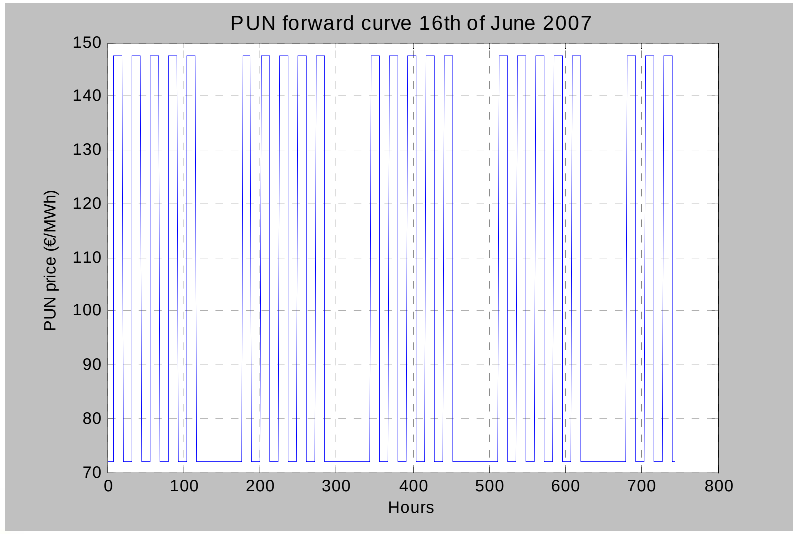
Storage constraints

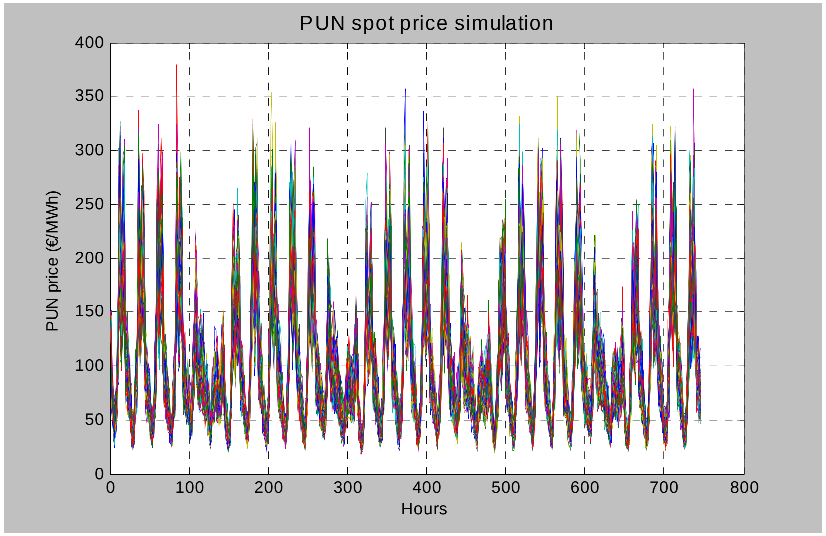
Max inventory level (MWh)	100
Min inventory level (MWh)	0
Start-End volume (MWh)	0
Pump rate (MWh)	10
Withdrawal rate (MWh)	20

Costs (€/MWh)

Fixed Pump cost	0
Fixed Withdrawal cost	0
Variable Pump cost (%)	0
Variable Withdrawal cost (%)	0

	16 June 2008 - TFS platform		
	Bid	Offer	Mean
Base	99.50	100.50	100.00
Peak	146.65	148.65	147.65
Off-Peak	70.90	72.90	71.90

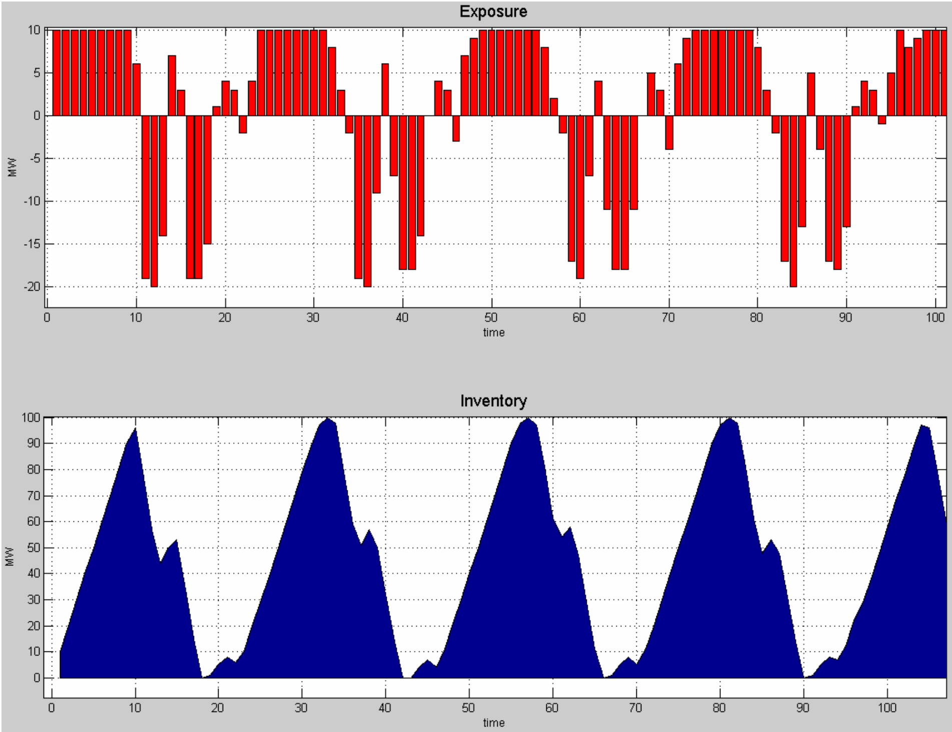


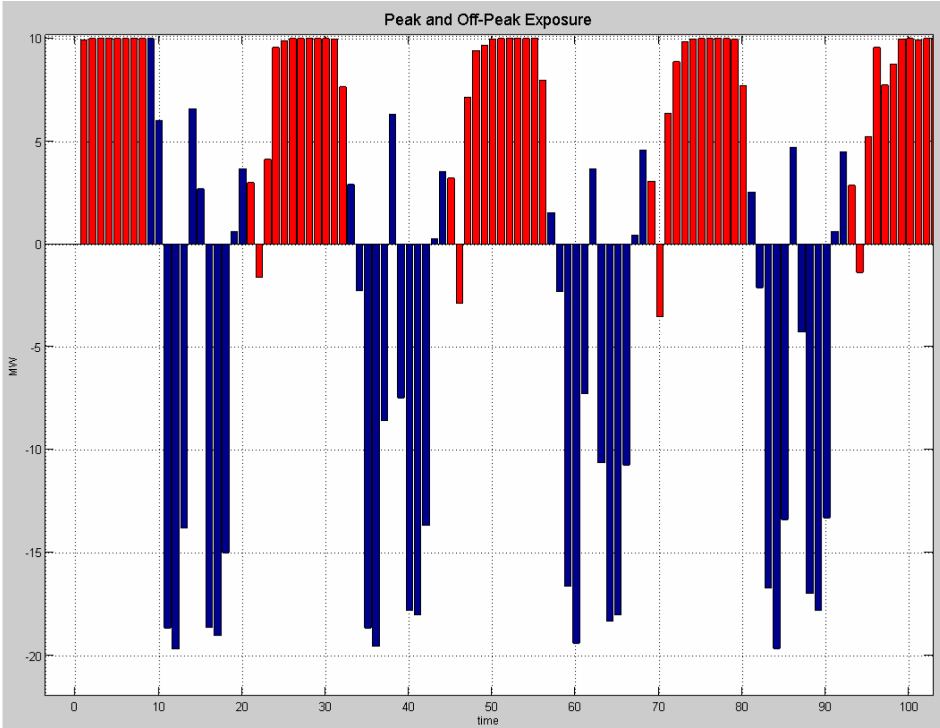


Hourly power exposure

- A VPS buyer would try to sell (*withdrawal*) power during peak hours to maximize the profit and to store it (*pump*) during off-peak hours.

- Therefore, the buyer will have a power:
  - LONG position during peak hours;
  - SHORT position during off-peak hours.





Are the constraints respected?

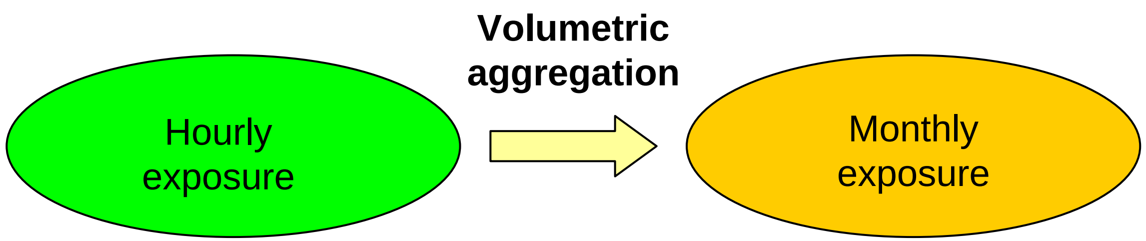
Which are the injection and withdrawal hours?

Static Hedging of VPS

- The non-storability of electricity (VPS) and hence the impossibility to achieve cash-and-carry strategies in combination with the fact that futures and other standardized derivatives only are available at a limited number of nodes in the maturity grid (weekly/monthly forward products) makes it difficult to find perfect hedges for electricity positions.

- With perfect hedge we mean a hedge that totally eliminates the price risk in a position.

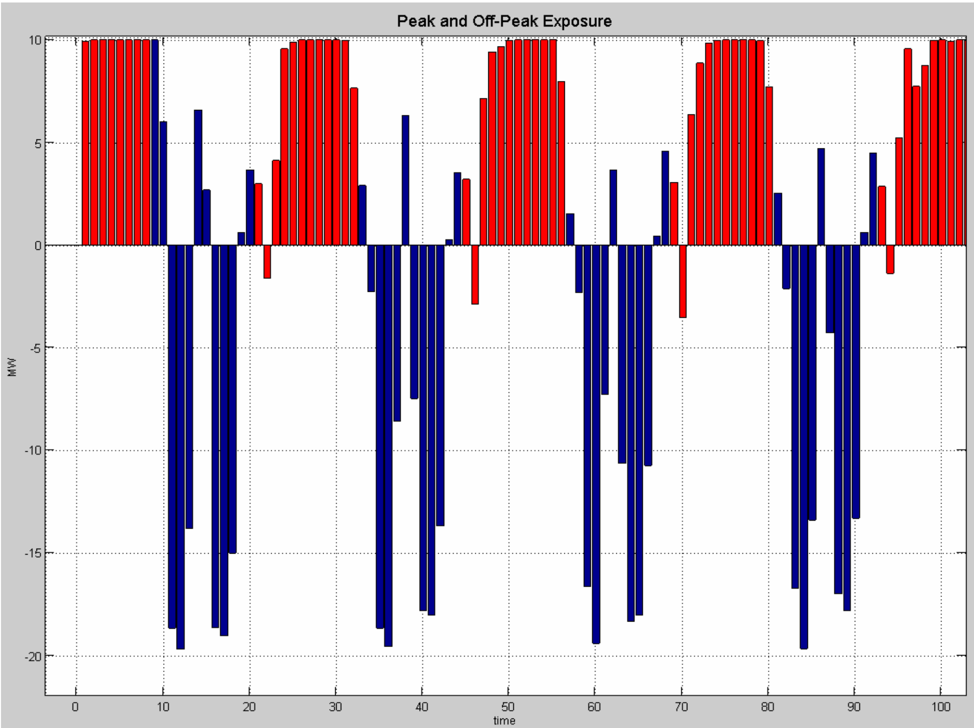
- A simple approach to hedge VPS contracts is based on a static perspective and on the concept of volumetric equivalence.

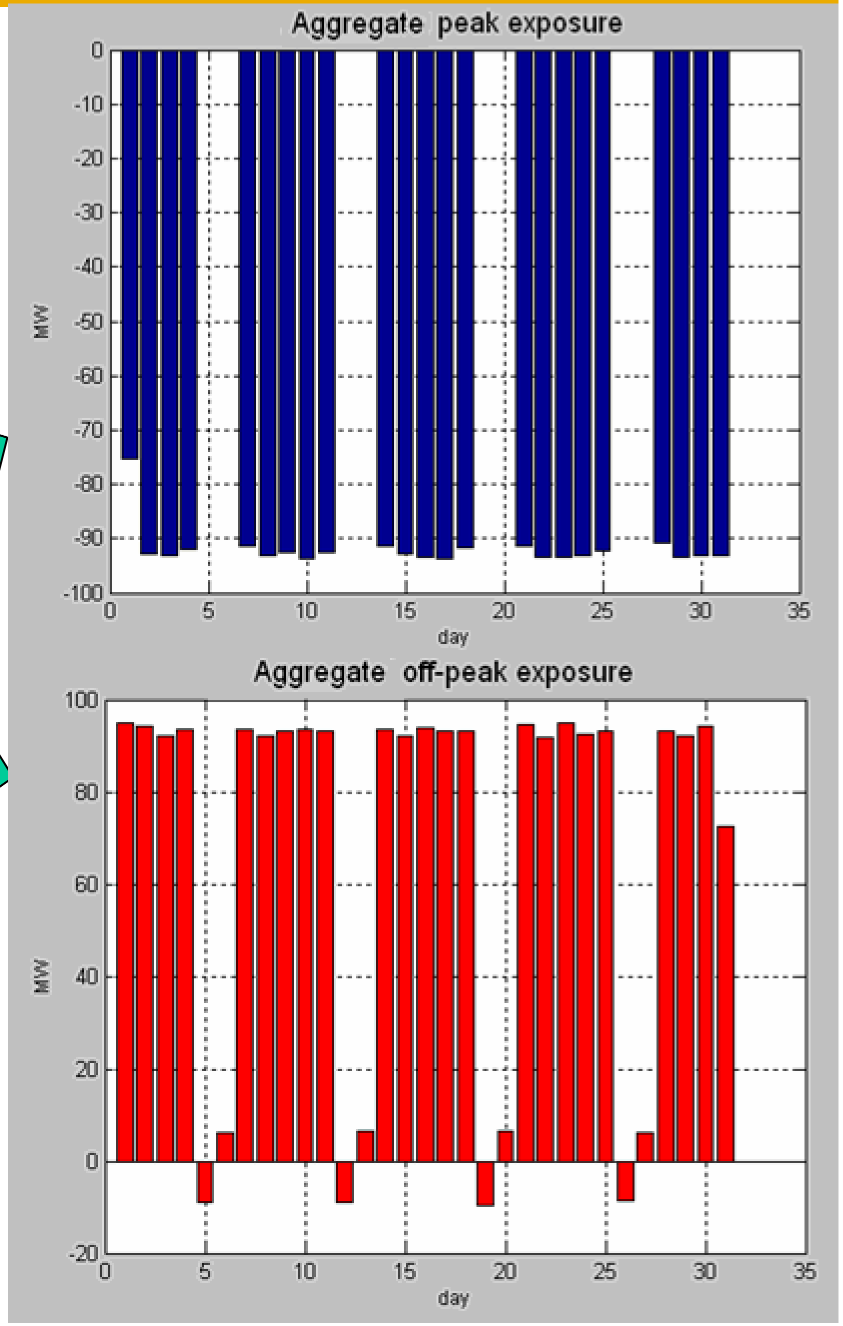


- This simple hedging approach doesn't properly consider the non perfect co-dependence between the price of a monthly block and the strip of hourly prices.

Static Hedging of VPS

From an hourly exposure, a peak and off-peak aggregate exposure is computed.





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Volatility effect on a Virtual Asset

- Physical peculiarities of electric power, such as non-storability, confer to day-ahead electricity price a typical dynamic behaviour:
  - High volatility levels
  - Complex periodic behaviours
  - Price spikes
  - Mean reversion

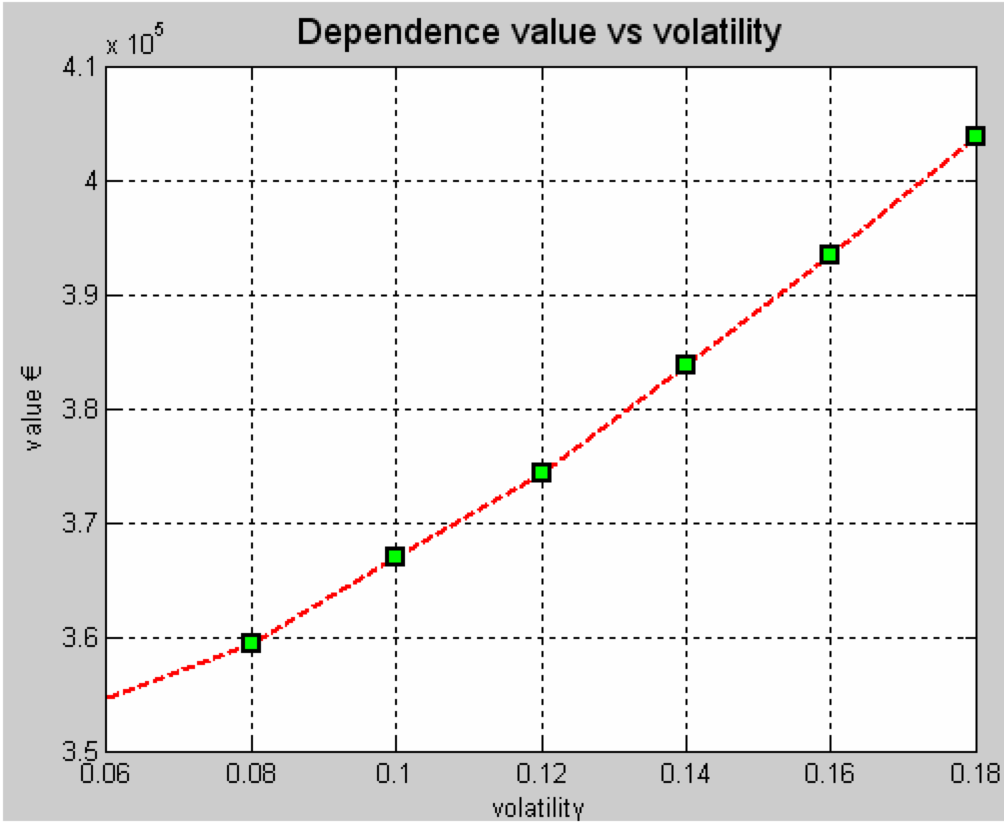
- Let's assume a simple one-factor Barlow (2002) model for the spot price simulation:

$$E_t = \begin{cases} (1 + \alpha X_t)^{1/\alpha} & \text{if} \quad 1 + \alpha X_t > \epsilon_0 \\ \epsilon_0^{1/\alpha} & \text{otherwise} \end{cases}$$

$$\mathrm{d}X_t = -\lambda(X_t - a)\mathrm{d}t + \sigma \mathrm{d}W_t$$

Volatility effect on a VPS

- As expected, the VPS value increases with volatility; the relationship is almost linear.



- Questions:
  1. Where can we find the volatility parameter?
  2. What is the peak and off-peak volatility effect on storage value?

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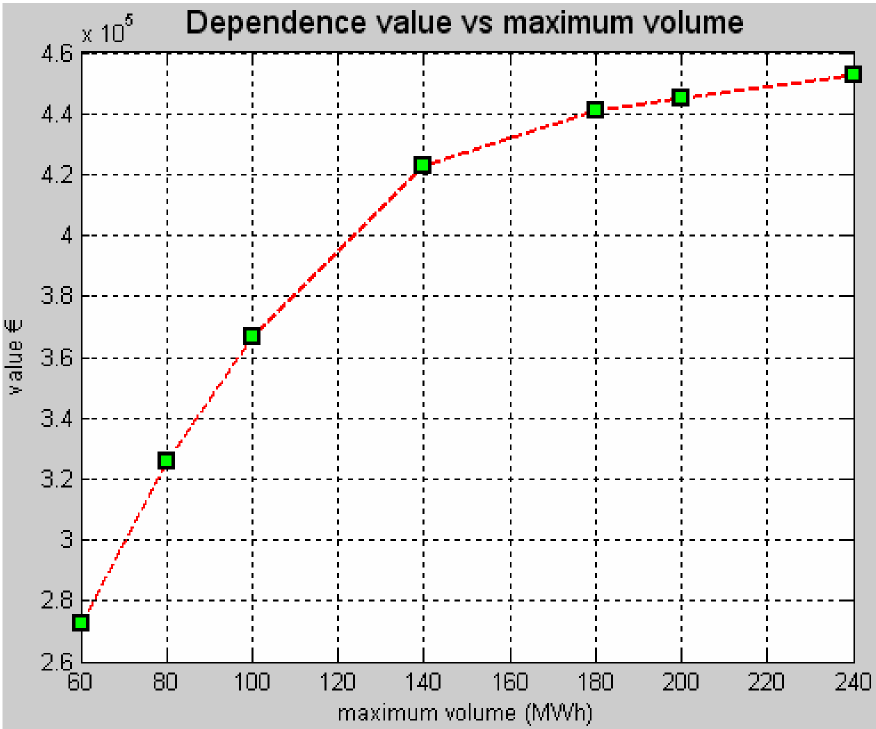
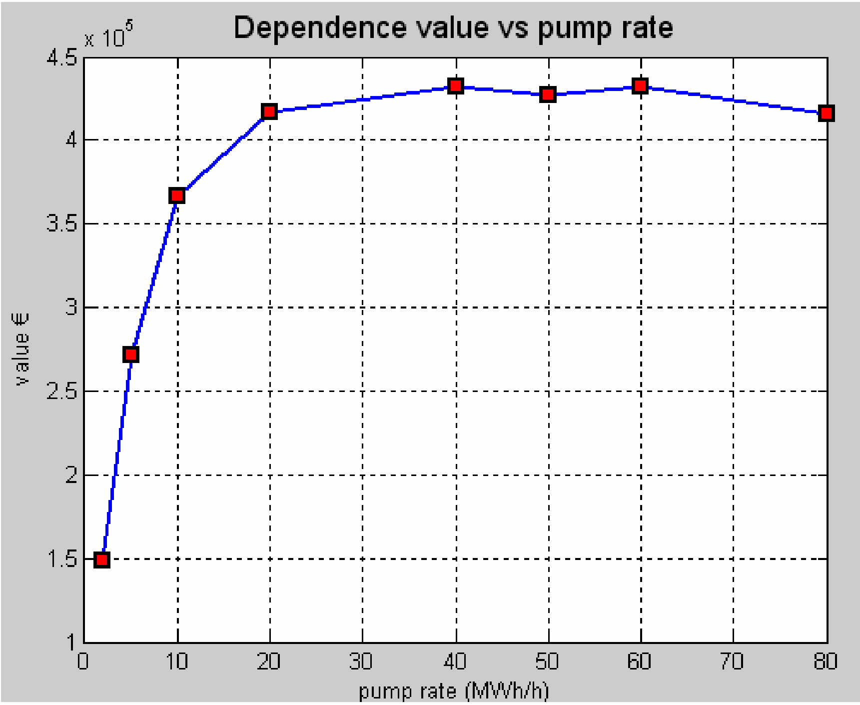
Other impacts on a Virtual Asset value

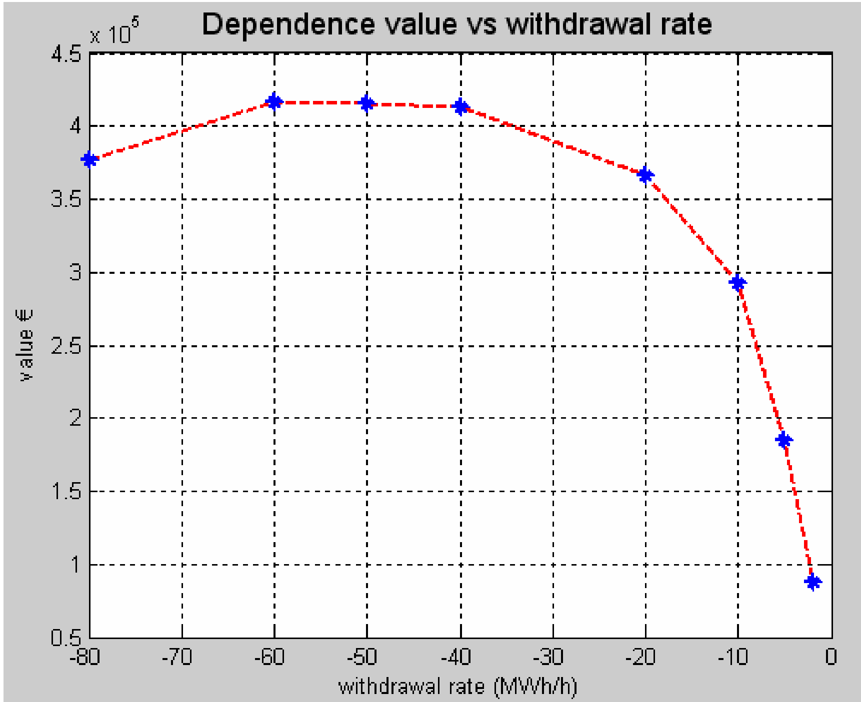
- **Impact of mean reversion**: with respect to mean-reversion two effects play a role in opposite directions:
    1. a higher mean-reversion makes price movements more predictable and the successful timing of purchases and sales easier; this effect raises storage value;
    2. a higher mean-reversion ensures that prices are pulled back to an average level faster; this limits the possibility of large price swings and decreases storage value.
- **Impact of operational characteristics**: besides the market dynamics, the operational characteristics can change the value of storage dramatically.

  We show a sensitivity analysis of the working volume, injection and withdrawal rates, changing one parameter at the time.



Other impacts on a Virtual Asset value





- The general pattern is that storage value increases fastest if flexibility (injection or withdrawal) is raised from very low levels, but less so if it is raised from higher levels.

- **Impact of regression settings:** different mathematical techniques can be used to evaluate a strucutrated product:

  - Analytical methods based on PDE solution
  - Ordinal Optimization
  - Least Squares Monte Carlo

Which kind of basis functions should we choose?

Thank you for your attention

Enzo Fanone is responsible for Pricing and Structuring at Edison Trading where he develops quantitative models for pricing complex commodity derivative instruments. He holds a degree in Quantitative methods for finance from University of Verona and he is a Phd candidate in Finance at the University of Trieste. His research interests mainly deal with optimization methods for valuing real and virtual assets, structured financial products and real options.

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