Real Options in Energy Markets

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Overview

- Why real options?
- Why real options in energy markets?
  - ~ Selected applications
- Why use simulations?
  - ~ The least-squares Monte Carlo approach
- Case: gas storage

Real Options

What are real options?

- The Real Options approach is an extension of financial options theory to options on real (non financial) assets
  - ~ Options are contingent decisions
  - ~ Give the opportunity to take action after you see how events unfold
  - ~ Payoff is not linear
- Use financial market theories for investment decisions and strategy

Examples of real options

- Option to postpone / defer
- Option to expand
- Option to learn
- Option to abandon / disinvest / scale down
- Option to mothball
- Option to switch (inputs, outputs, country)

Problems with traditional NPV

- Require forecasts
  - ~ One single scenario analysed
  - ~ Difficulty for finding an appropriate discount rate when options are present
- Future actions are known
  - ~ No flexibility for taking action during the course of the investment project

History of real options

- Term introduced in 1977 by Stewart Myers (1973 = Black Scholes)
- In the 1980s literature primarily focused on the valuation of natural resources (exploration, mining, land use)
- In the 1990s theory applied in practice
- Last few years: applications in R&D, multi-national firms, drug development, internet companies, airlines, energy, ...
- Complexity still hampers widespread use

When is RO analysis appropriate?

- When the environment is uncertain: technical and/or economical:
  - ~ Average scenario does not work
- When the initial investment is relatively large
- When there is flexibility to respond to uncertainty:
  - ~ risk < uncertainty
  - ~ uncertainty (also) creates value

Applications of Real Options in Energy

Power plant

- A power plant may be treated as a call option (series) on the spark spread (= marginal revenue):

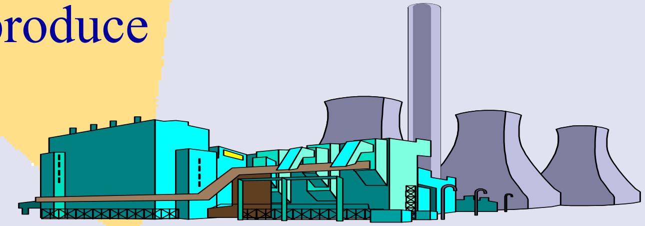
$$\text{Rev}_t = \max\{P_t - h \cdot G_t, 0\}$$

Power price → P_t

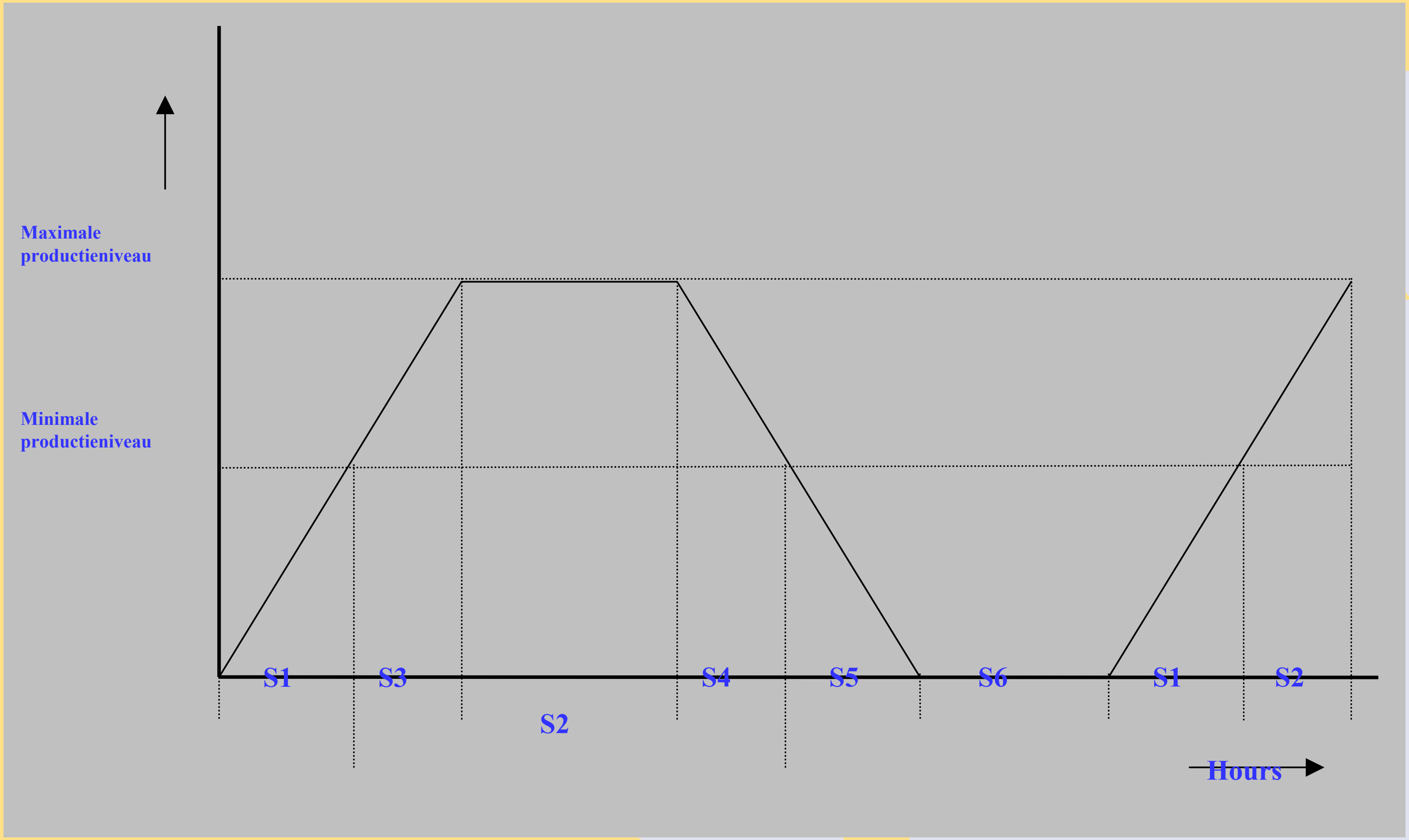
Heat rate → h

Fuel price → G_t

  ~ Positive spark spread: produce
  ~ Negative spark spread: do not produce



The states a power plant can be in



Swing option

- The flexibility in the quantity of energy which the holder of the option can receive
- Swing contracts have been engineered because of the uncertainty in the end user's energy consumption
- Traditionally in gas:
  - ~ swing delivery, take-or-pay, flexing, volumetric or interruptible contracts, storage
- Increasingly in power and coal

Simulations:
Least-squares Monte Carlo

Traditional solution methods

- Diffusion models
- Black-Scholes type models
- Price and decision trees

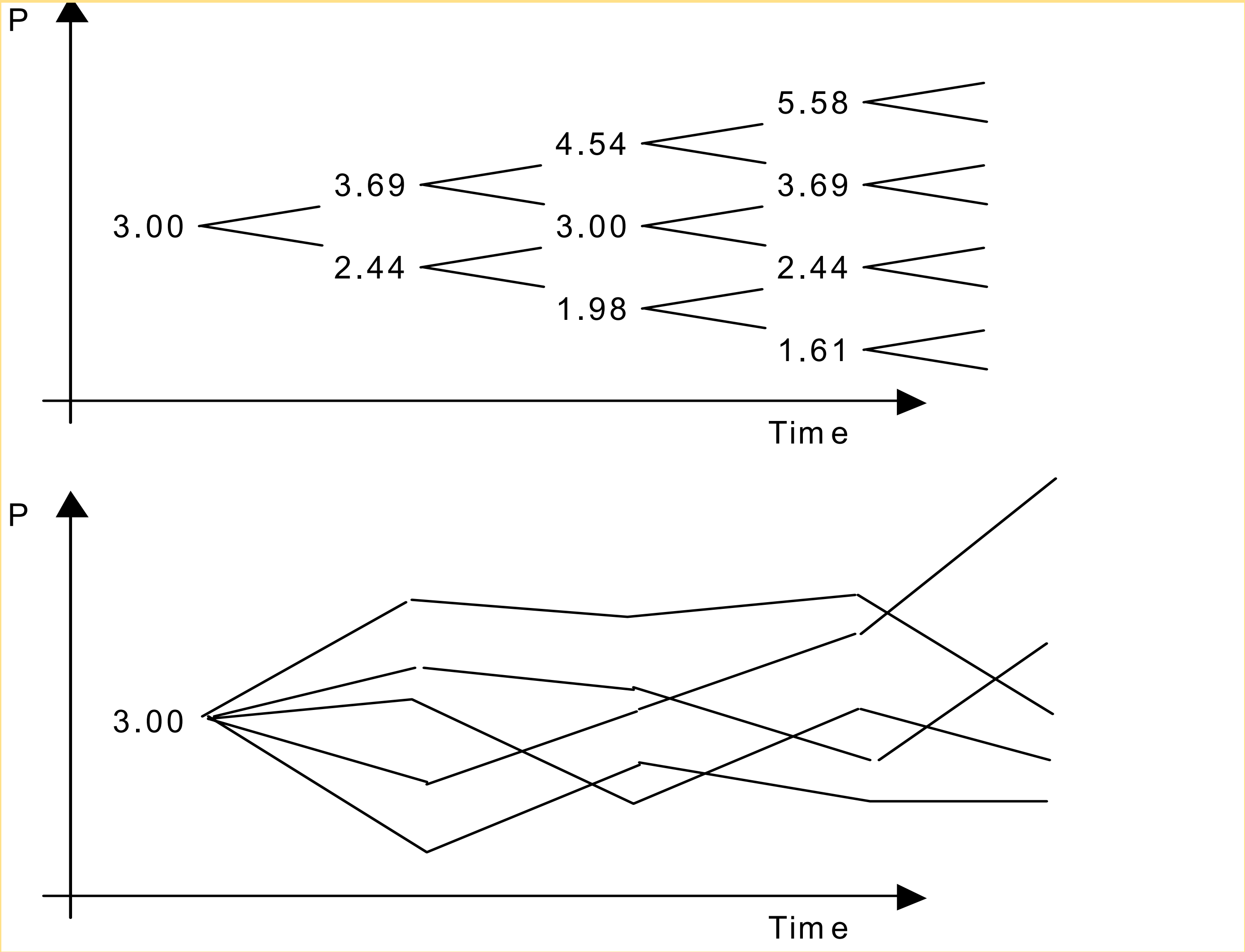
Problems:

- Energy prices do not fit models
- Asset flexibility hard to capture

Least-squares Monte Carlo

- Carriere (IME, 1996), Longstaff and Schwartz (RFS 2001, Risklab 2001 presentation)
- Breakthrough in convergence speed
- Applied to American-style financial options
- Idea:
  - ~ Avoid the problem of forward-looking nature of simulations
  - ~ OLS regressions to calculate ‘expected continuation value’ and thus the optimal exercise strategy

Tree or simulations?



Example

- Suppose we have an American style option:
  - ~ Exercise price € 20
  - ~ Time-to-maturity 2 days
  - ~ No dividends, no interest
- We compare a ‘traditional’ tree to ‘LSMC’
- Central to both valuation is the comparison at time t=0 and t=1 of the:
  - ~ Direct pay-off = P(t) – 20
  - ~ Expected continuation value = E[CV]
    - * Tree approach: E[CV(t)] = (CV(t+1,up) + CV(t+1,down))/2
    - * Simulation approach: E[CV(t)] = fitted value of regression

TREE APPROACH

Market price

26.00
24.20
22.00 22.00
20.00
18.00

Direct pay-off

6.00
4.20
2.00 2.00
0.00
-2.00

Expected continuation value

0.00
4.00
2.60 0.00
1.00
0.00

Option value = maximum of
a) direct pay-off OR 0
b) exp. cont. value

6.00
4.20
2.60 2.00
1.00
0.00

Strategy

exerc
exerc
wait exerc
wait
none

SIMULATION APPROACH

Market price

22.00	25.00	24.00
22.00	23.00	26.00
22.00	22.00	19.00
22.00	21.00	21.00
22.00	19.00	17.50

Direct pay-off

2.00	5.00	4.00
2.00	3.00	6.00
2.00	2.00	-1.00
2.00	1.00	1.00
2.00	-1.00	-2.50

Regression at t = 1:
Regress CV(2) on P(1)
CV = -16.5 + 0.85*P + e

Expected continuation value

2.32	4.75	0.00
2.32	3.05	0.00
2.32	2.20	0.00
2.32	1.35	0.00
2.32	0.00	0.00

Option value = maximum of
a) direct pay-off OR 0
b) exp. cont. value

2.32	5.00	4.00
2.32	3.05	6.00
2.32	2.20	0.00
2.32	1.35	1.00
2.32	0.00	0.00
	2.32	

Strategy

wait	exerc	exerc
wait	wait	exerc
wait	wait	none
wait	wait	exerc
wait	wait	none

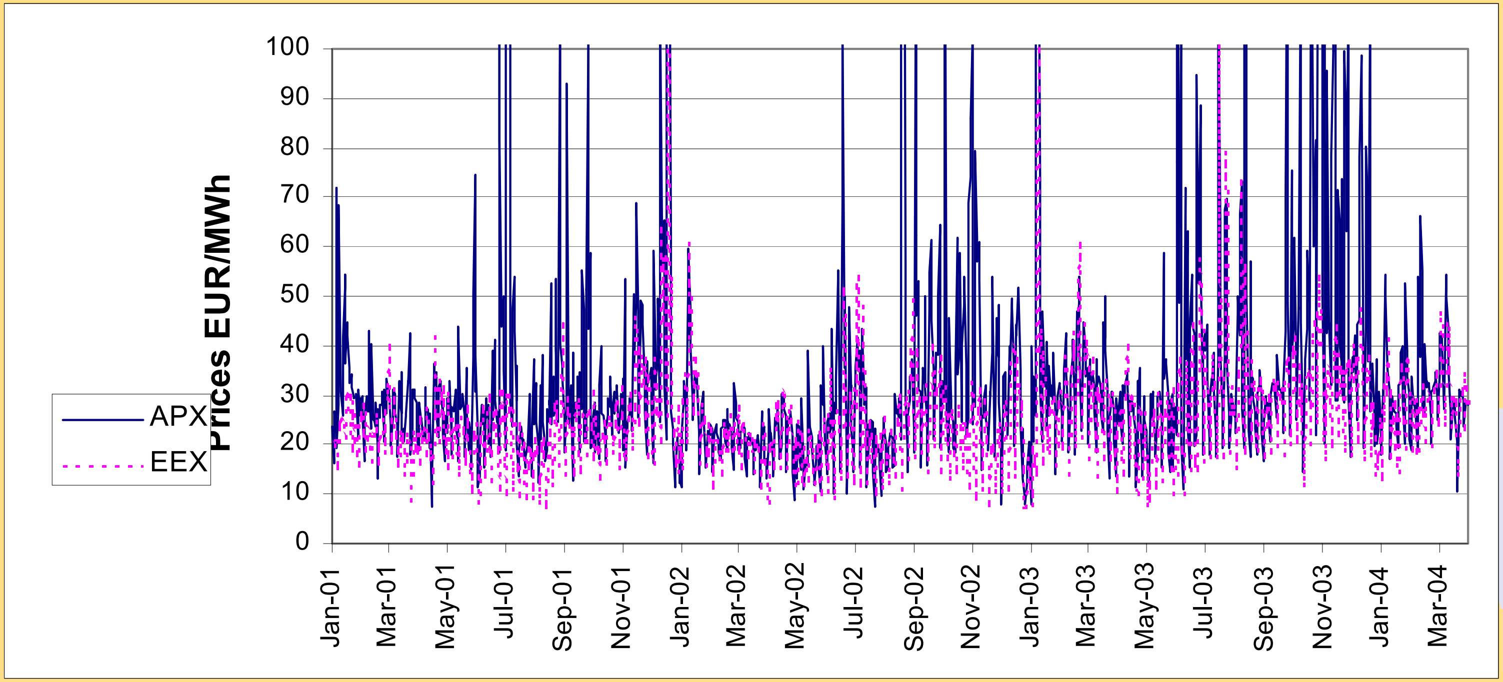
Does LSMC work well?

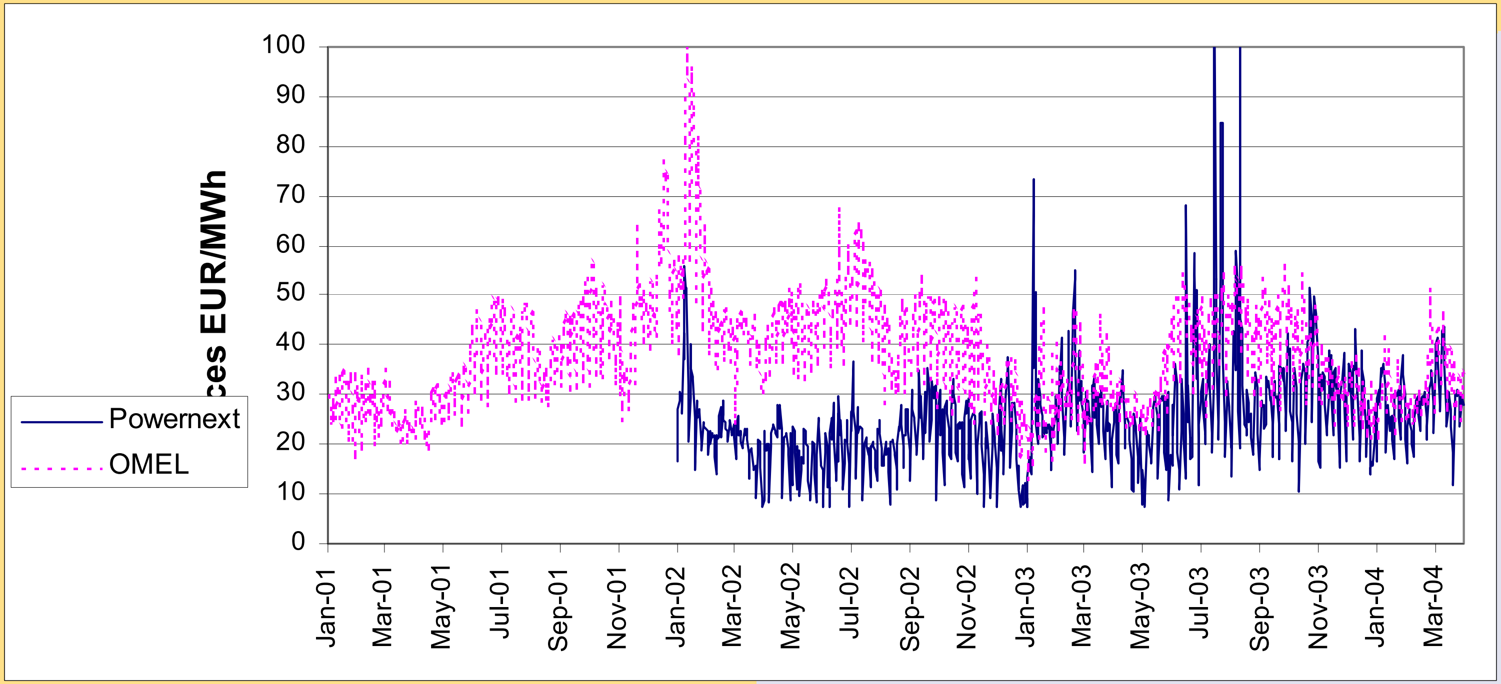
- Regressions carried out fast
- Depending on the problem we need higher order regression
- Convergence results verified and good
- We always use two sets of simulations:
  - ~ To determine exercise strategy (run regression)
  - ~ To evaluate strategy and calculate option value

  → Avoids any potential over-fitting

Complex distributions in energy

- General characteristics of spot prices, especially electricity, but also gas:
  - ~ Mean-reverting
  - ~ High and time-varying volatility
  - ~ Jumps, regime switches
- General characteristics of forward prices:
  - ~ Volatility decreases with maturity
  - ~ Strongly correlated, seasonal, etc


Prices EUR/MWh
APX
EEX
100
90
80
70
60
50
40
30
20
10
0
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04


ces EUR/MWh
Powernext
OMEL
100
90
80
70
60
50
40
30
20
10
0
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
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Nov-02
Jan-03
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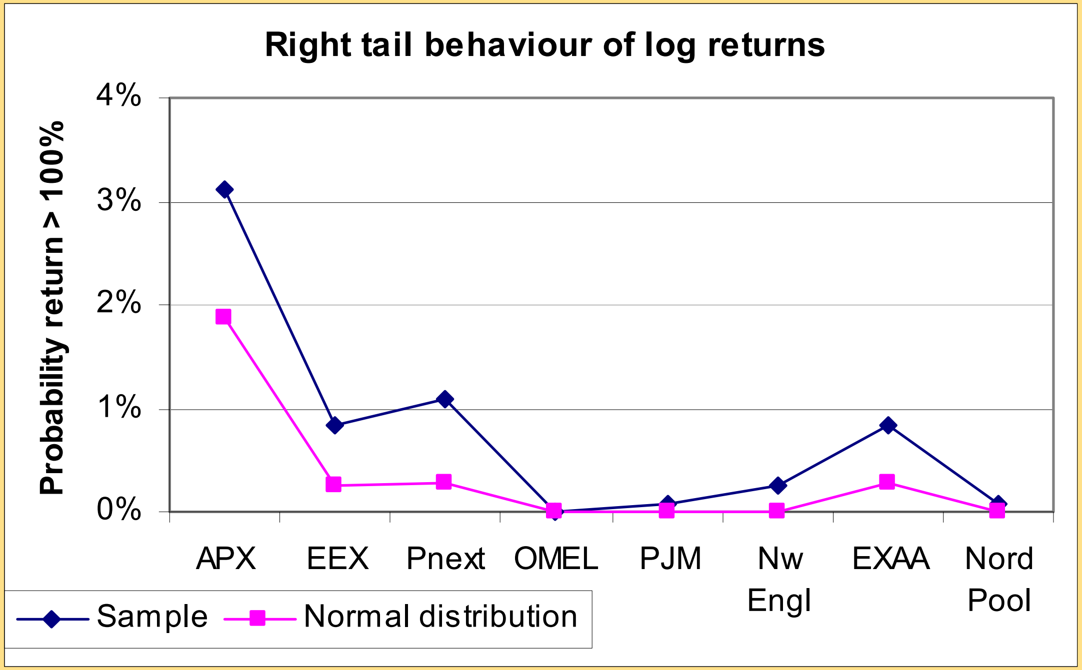
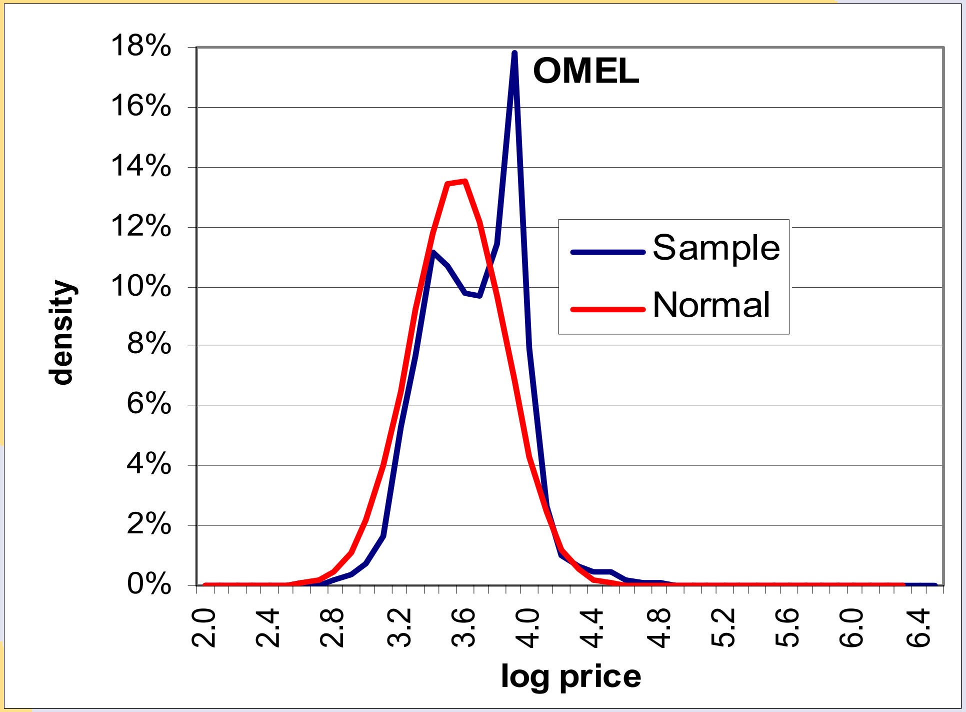
Nov-03
Jan-04
Mar-04



Right tail behaviour of log returns
Probability return > 100%
4%
3%
2%
1%
0%
APX
EEX
Pnext
OMEL
PJM
Nw Engl
EXAA
Nord Pool
Sample
Normal distribution



OMEL
density
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Sample
Normal
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
6.0
6.4
log price

Risk neutral simulations or Real world simulations?

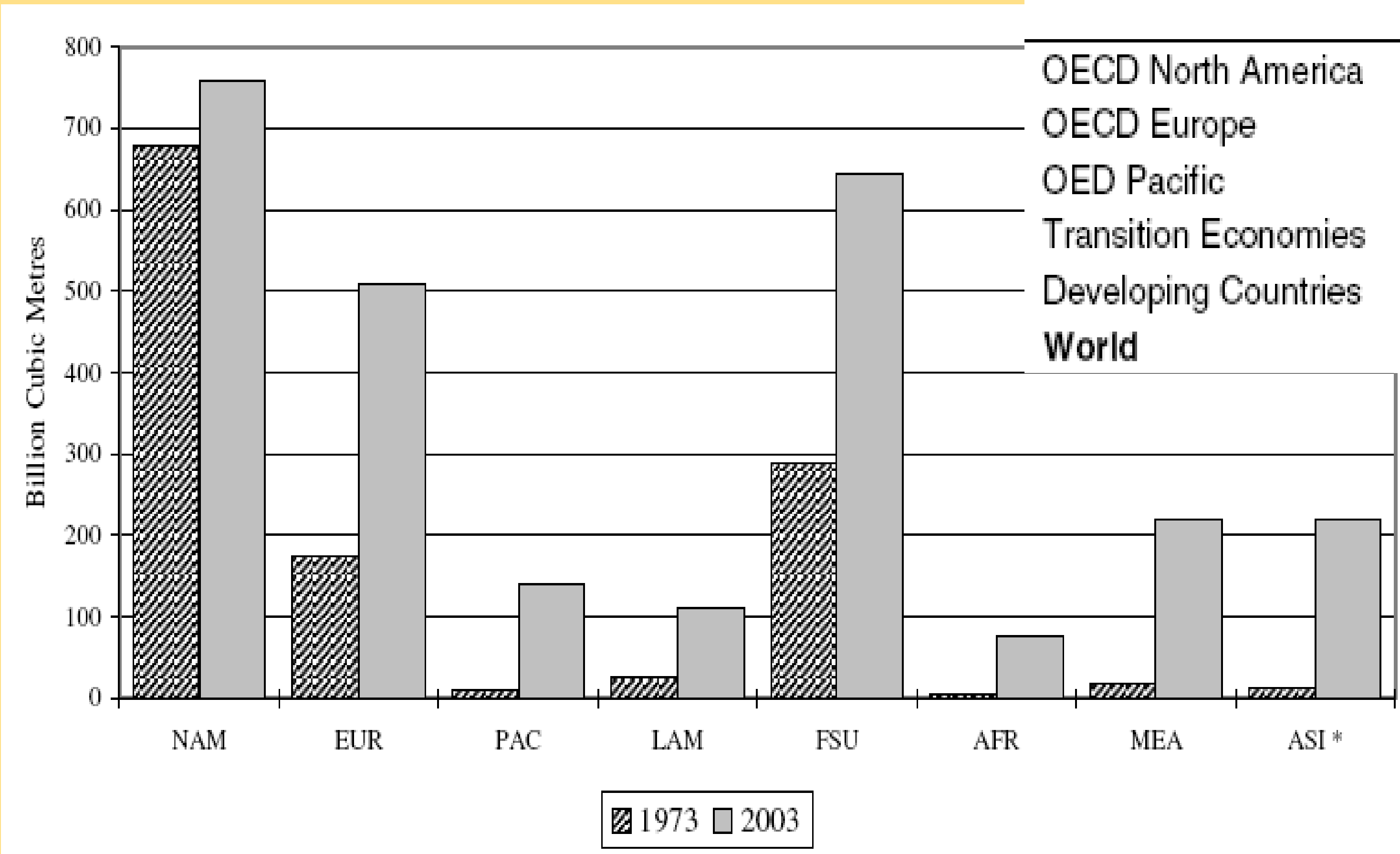
- Option theory: if the option can be replicated with tradable instruments, then:
  - ~ Use risk-neutral simulations, i.e. drift of simulations equals drift of tradable instruments
  - ~ Discount pay-offs with riskfree rate
- In many energy real option applications the asset canNOT be replicated, so we use real-world simulations and higher discount rate

Case: gas storage

Storage Needs

	Working Volume 2000	Working Volume 2030
OECD North America	129	215
OECD Europe	61	138
OED Pacific	2	14
Transition Economies	132	266
Developing Countries	4	51
World	**328**	**685**

Natural Gas Consumption

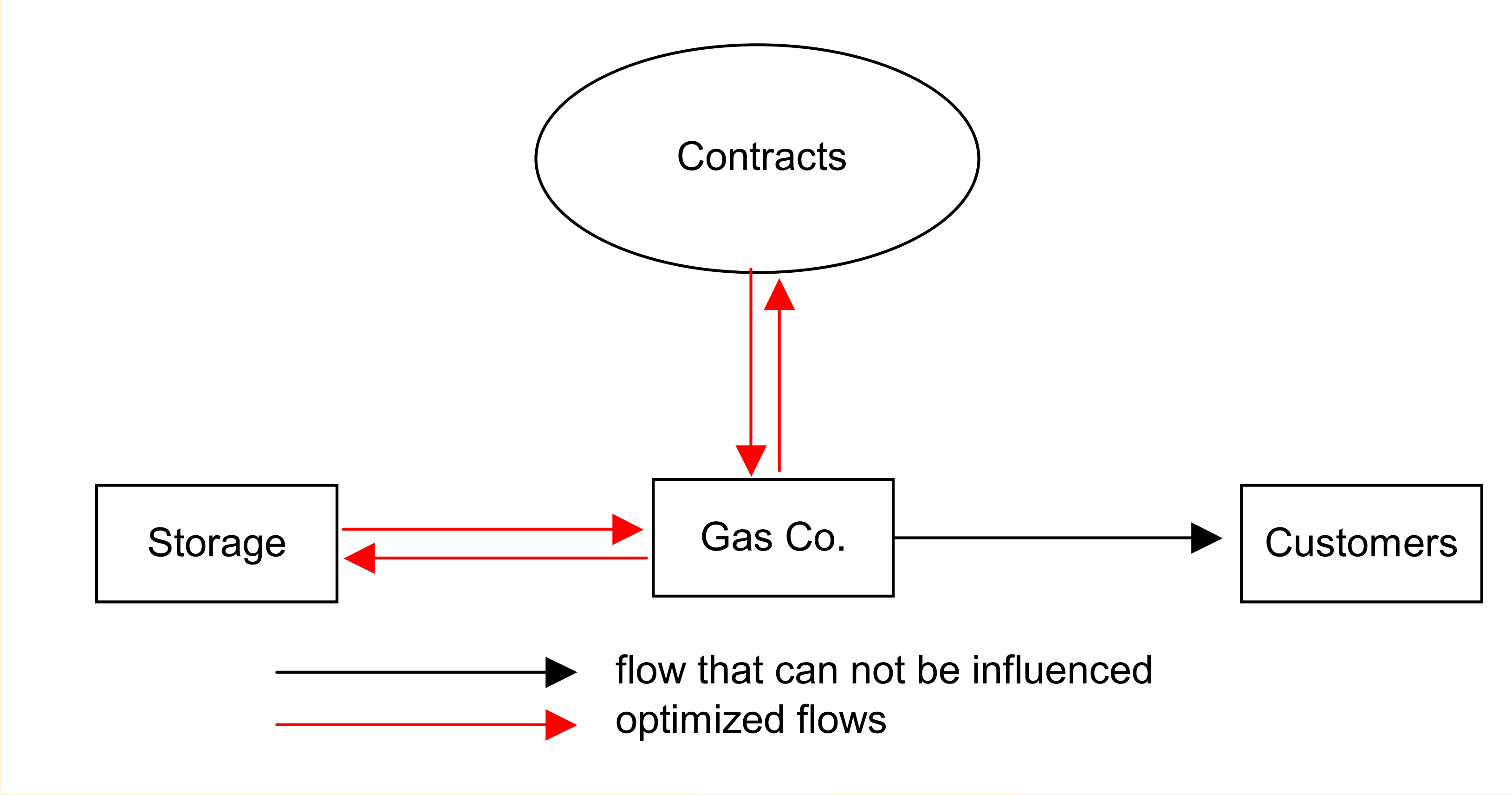


Source: IEA Gas Information 2004

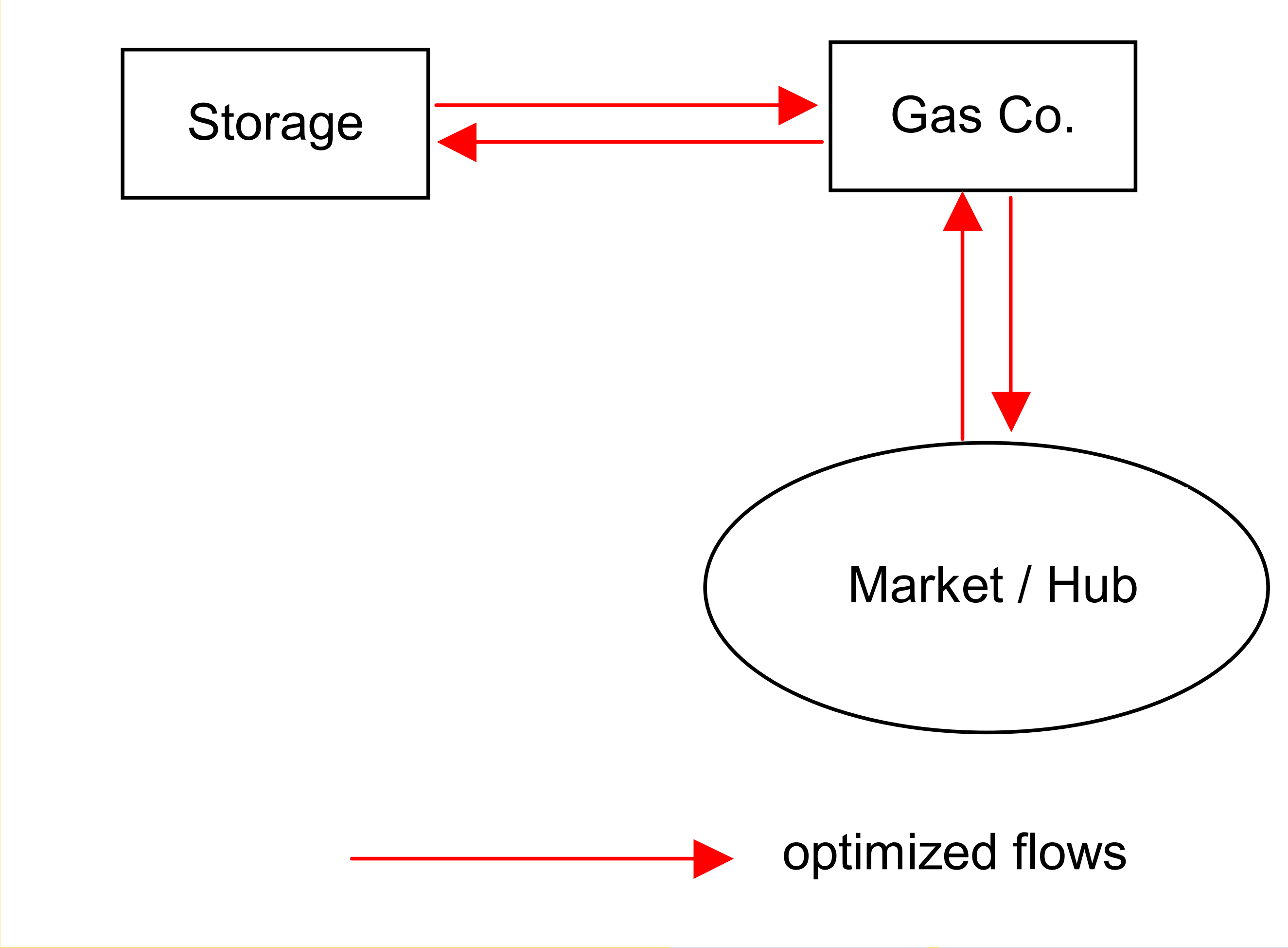
Purpose of storage

- Storage is a flexibility instrument:
  - ~ Balance supply with demand
  - ~ Compare to other flexibility instruments and market prices to derive value
- The general idea of storage is that it:
  - ~ allows the owner with an end-user portfolio to meet fluctuations in demand, thus being a substitute for other contracts with flexibility (***internal optimization***)
  - ~ allows any owner to benefit from market movements (***external optimization***)

Internal optimization



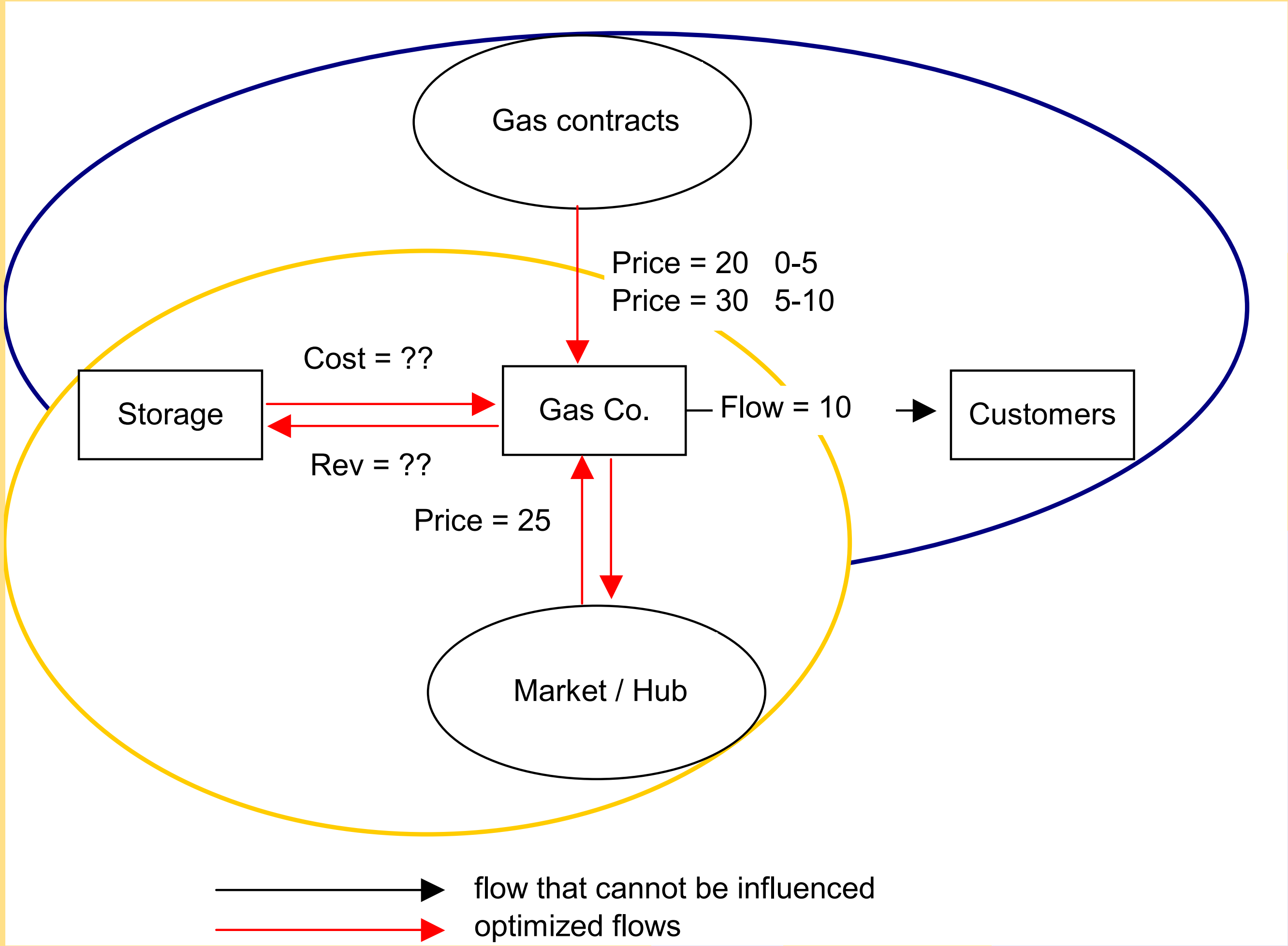
External optimization



External optimization

- Increasingly possible
- Optimal operation depends on the development of market prices and the ability to trade
- A user can benefit from:
  - ~ Predictable price movements:
    - * Summarized in the forward curve
    - * Yielding an intrinsic value
  - ~ Unpredictable price movements:
    - * Summarized in spot dynamics
    - * Adding an extra option value and yielding an extrinsic value

Integrated storage management



Q: What is the “cost” and “revenue” of using gas from storage?

Opportunity cost = option value

The storage model

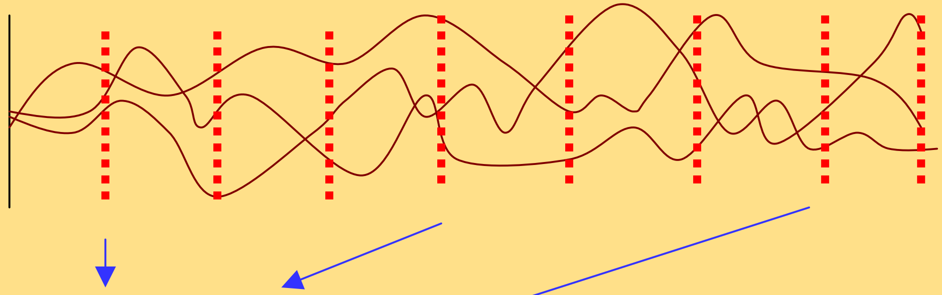
Value future flexibility

- Situation:
  - ~ Current storage level 5 mln GJ
  - ~ Injection rate 0.06 mln, Withdrawal rate 0.25 mln GJ
  - ~ Current spot price 3.00 €/GJ
- Problem: inject, withdraw or do nothing:
  - ~ Do nothing: Value of 5 mln GJ next day
  - ~ Inject: Value of 5.06 mln GJ next day – €180,000
  - ~ Withdraw: Value of 4.75 mln GJ next day + €750,000

Derive the expected future (= next day's) value of different storage levels using the market as a benchmark

Least-squares Monte Carlo

1. Simulation set A

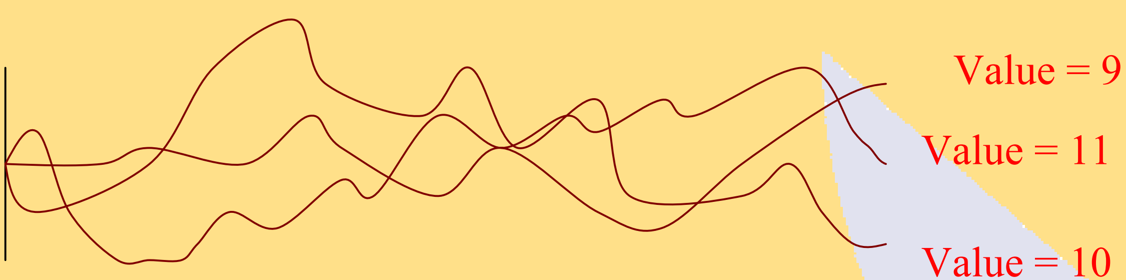


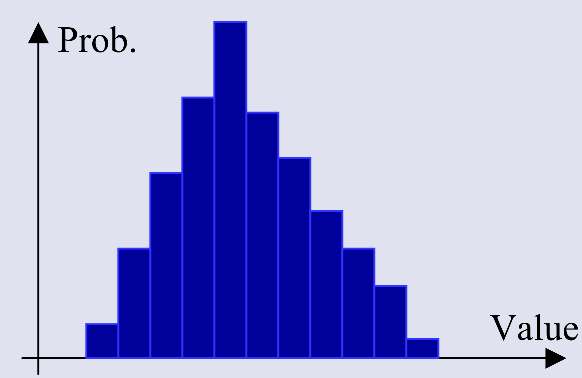
2. Regressions

3. Exercise strategy

Day t Inv. level L Price P	Inject? Do nothing? Withdraw?

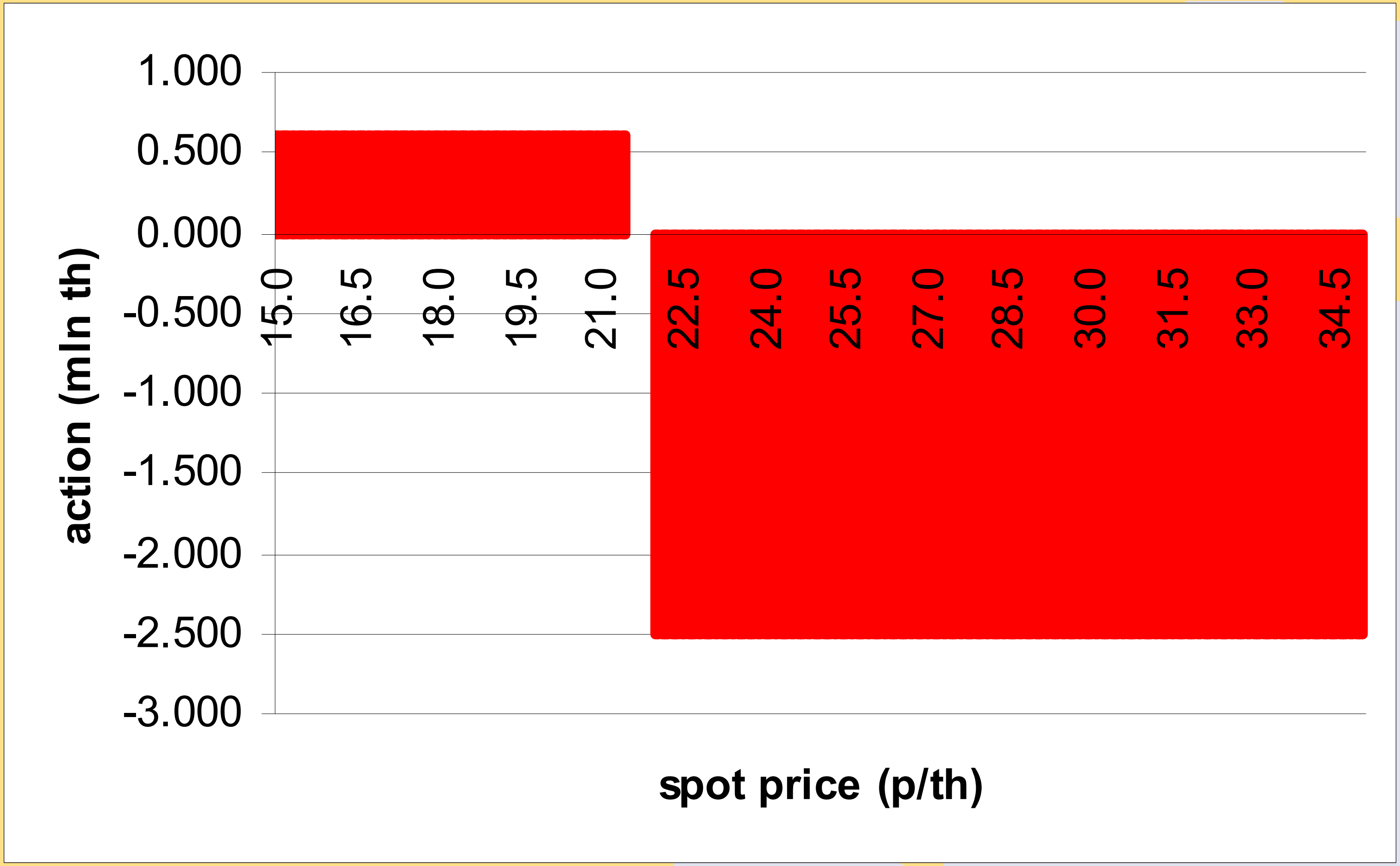
4. Simulation set B: Evaluate strategy



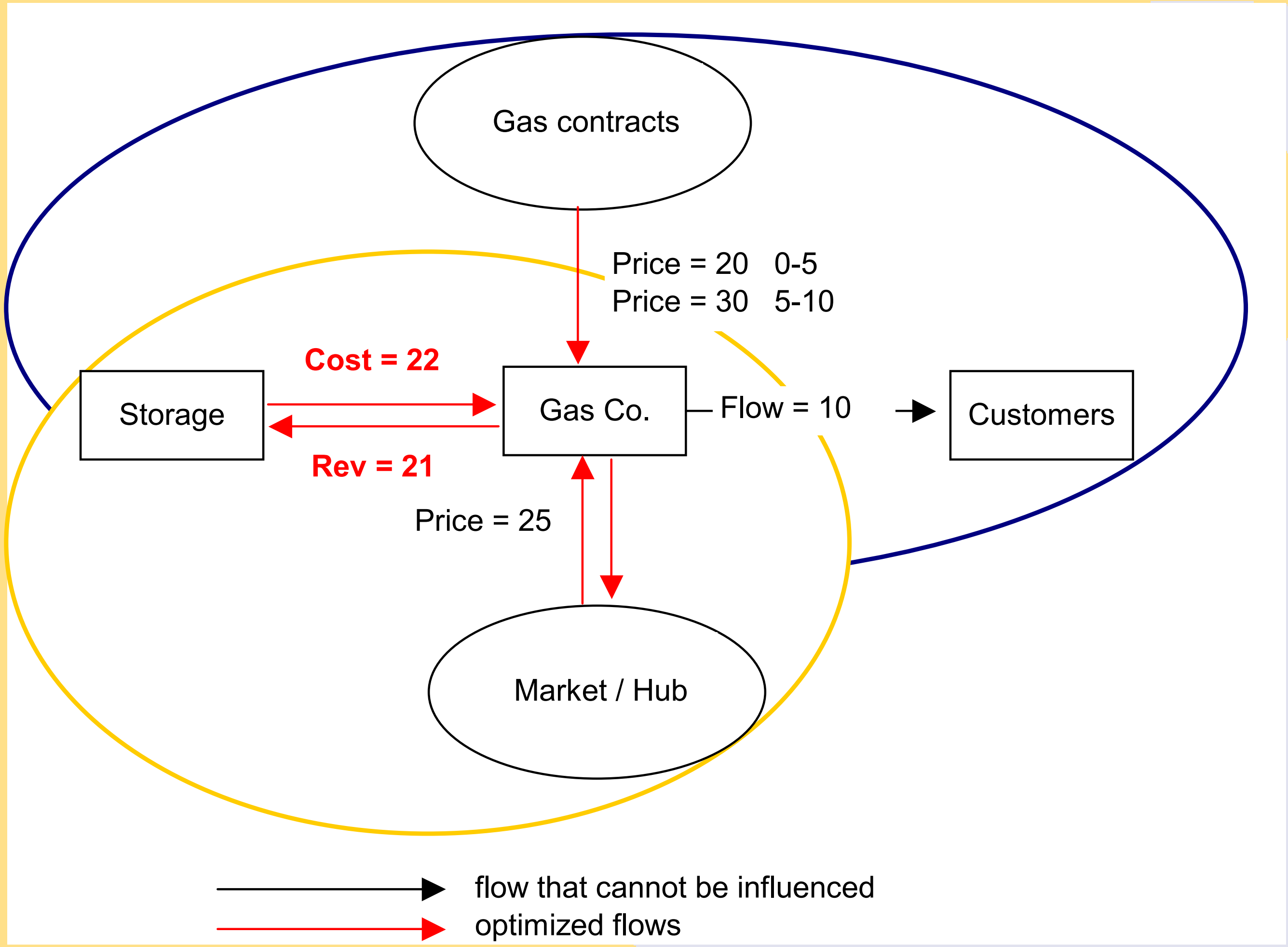


Exercise frontier example

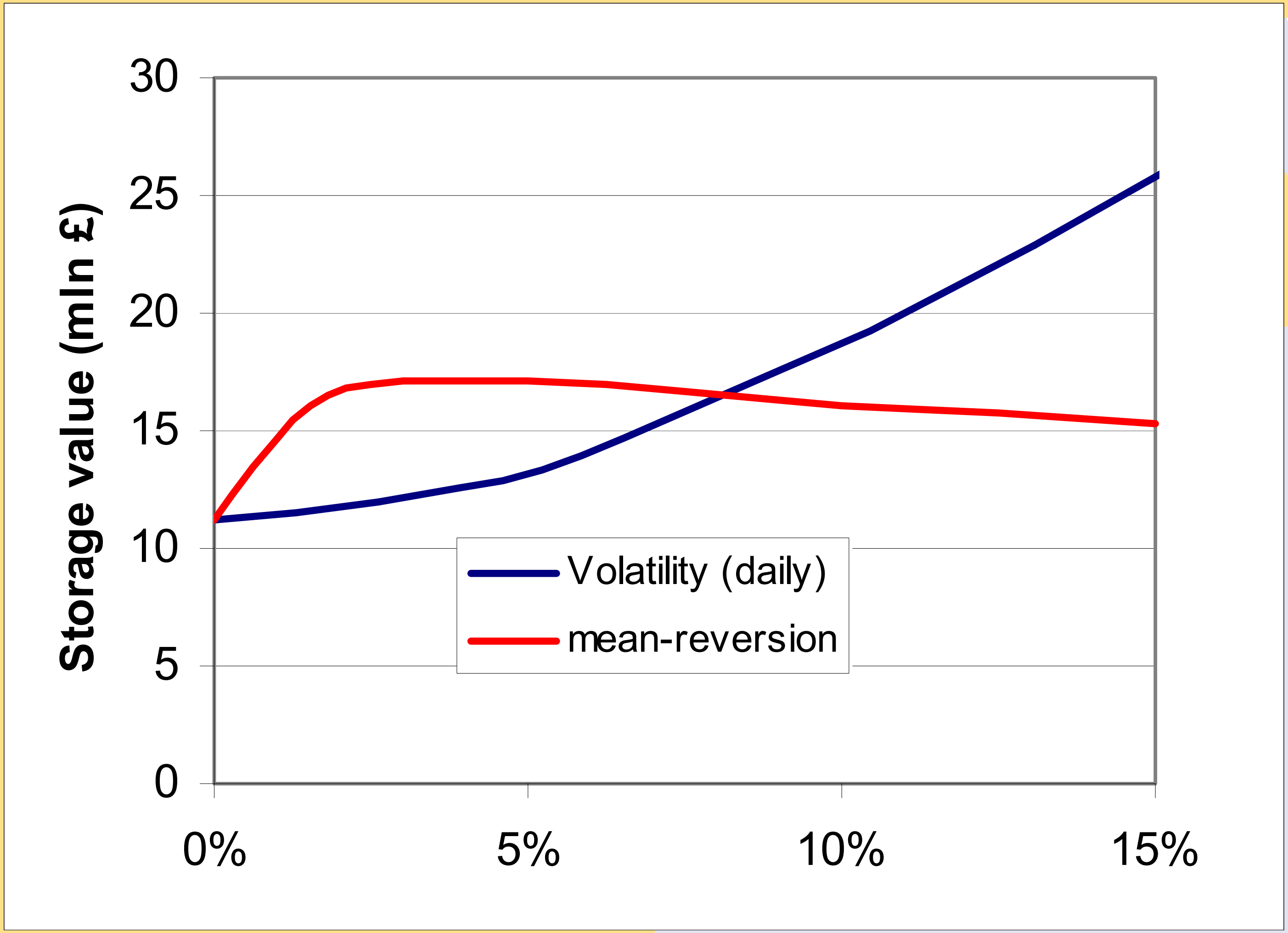
(for a day t and inventory level L)

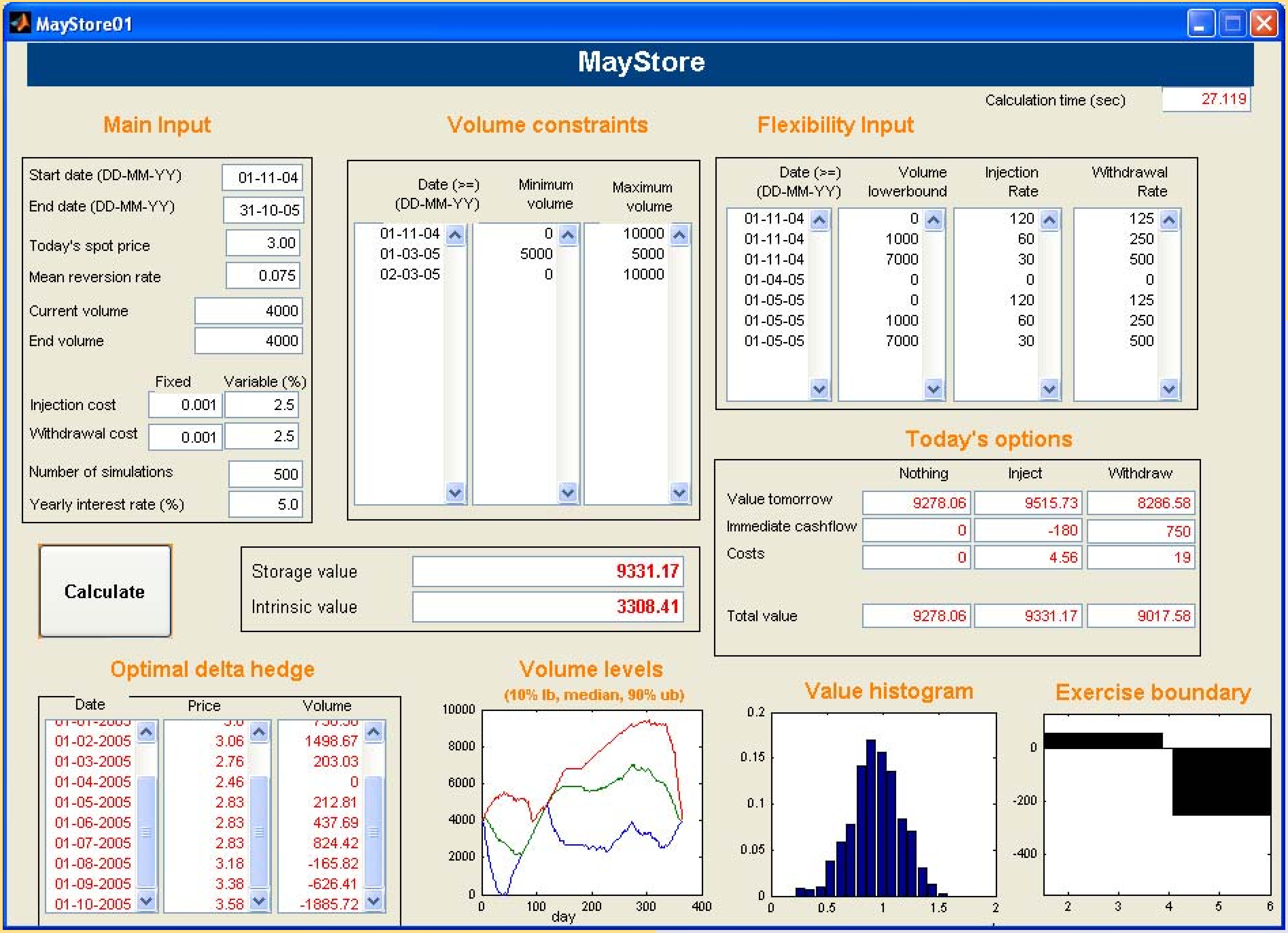


Storage cost & revenue



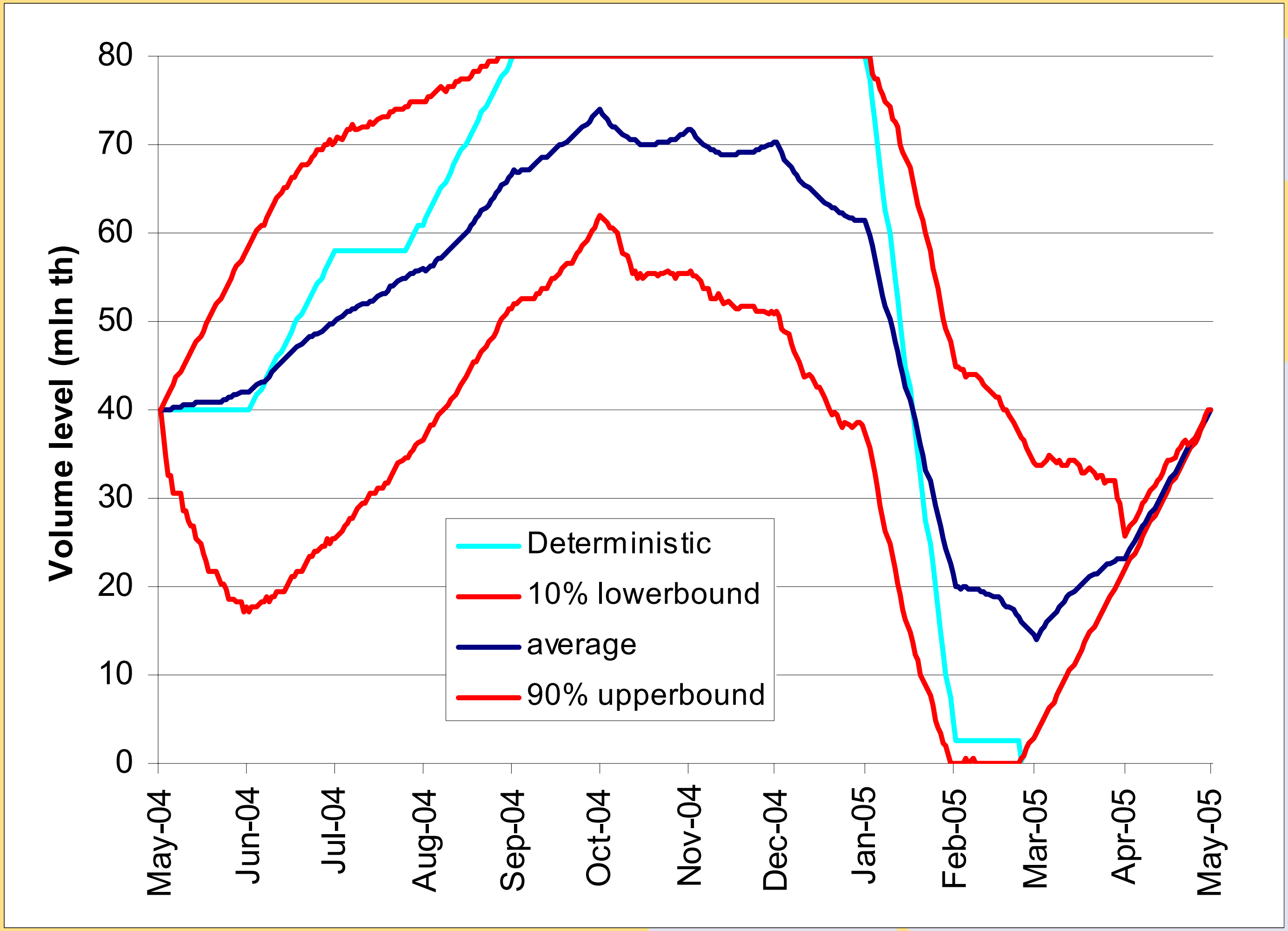
Value drivers





MayStore01
MayStore
Calculation time (sec) 27.119
Main Input
Start date (DD-MM-YY) 01-11-04
End date (DD-MM-YY) 31-10-05
Today's spot price 3.00
Mean reversion rate 0.075
Current volume 4000
End volume 4000
Fixed Variable (%)
Injection cost 0.001 2.5
Withdrawal cost 0.001 2.5
Number of simulations 500
Yearly interest rate (%) 5.0
Volume constraints
Date (>=) (DD-MM-YY) Minimum volume Maximum volume
01-11-04 0 10000
01-03-05 5000 5000
02-03-05 0 10000
Flexibility Input
Date (>=) (DD-MM-YY) Volume lowerbound Injection Rate Withdrawal Rate
01-11-04 0 120 125
01-11-04 1000 60 250
01-11-04 7000 30 500
01-04-05 0 0 0
01-05-05 0 120 125
01-05-05 1000 60 250
01-05-05 7000 30 500
Today's options
Nothing Inject Withdraw
Value tomorrow 9278.06 9515.73 8286.58
Immediate cashflow 0 -180 750
Costs 0 4.56 19
Total value 9278.06 9331.17 9017.58
Calculate
Storage value 9331.17
Intrinsic value 3308.41
Optimal delta hedge
Date Price Volume
01-02-2005 3.06 1498.67
01-03-2005 2.76 203.03
01-04-2005 2.46 0
01-05-2005 2.83 212.81
01-06-2005 2.83 437.69
01-07-2005 2.83 824.42
01-08-2005 3.18 -165.82
01-09-2005 3.38 -626.41
01-10-2005 3.58 -1885.72
Volume levels
(10% lb, median, 90% ub)
10000
8000
6000
4000
2000
0
0 100 200 300 400
day
Value histogram
0.2
0.15
0.1
0.05
0
0 0.5 1 1.5 2
Exercise boundary
0
-200
-400
2 3 4 5 6

Unrestricted inventory developments



Portfolio management

- Integration of market with portfolio:
  - ~ Reserve some capacity for portfolio, some for trading.
  - ~ Determine optimal allocation by calculating opportunity costs

Conclusion

- Energy markets ideal environment to apply real option analysis:
  - ~ To make investment decisions
  - ~ To make trading profits
  - ~ To optimize portfolio management
- Simulations often needed:
  - ~ Non-normality
  - ~ Joint model for several commodities or contracts