An operational portfolio optimization model for a natural gas producer

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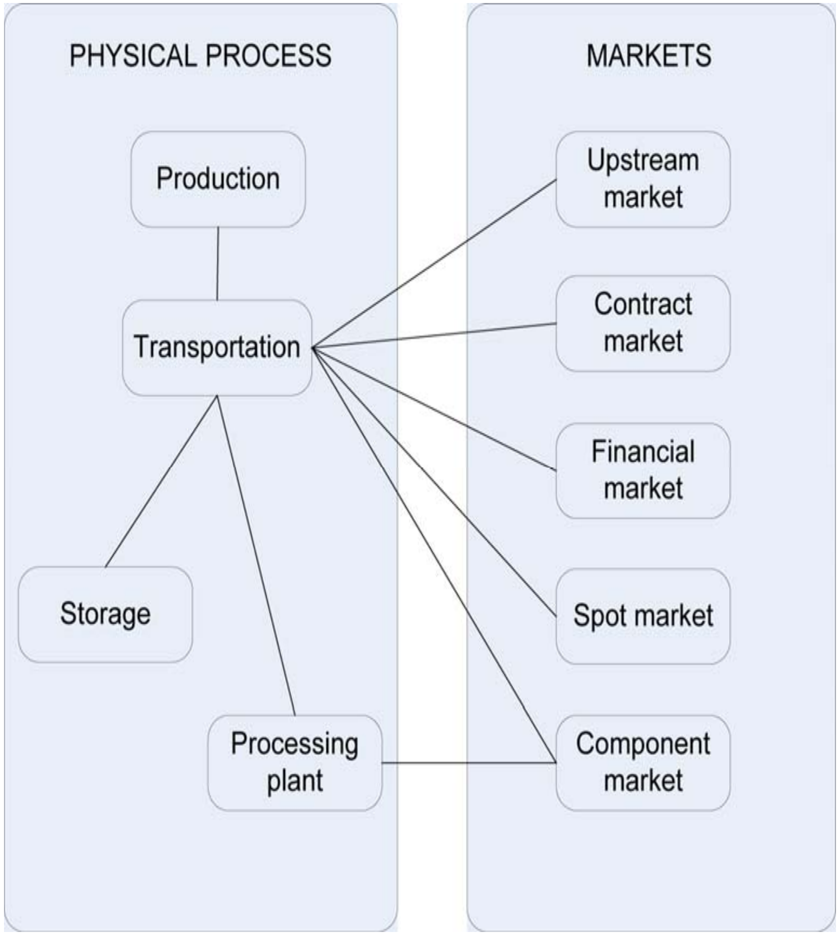
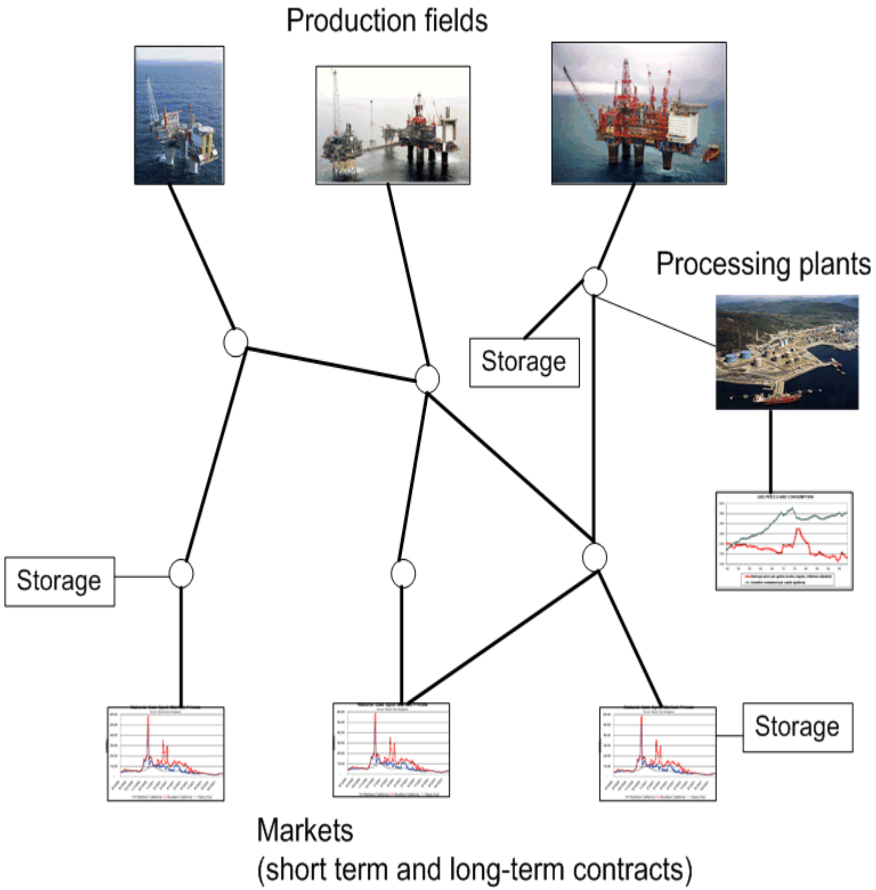
Outline

- Background
- Optimization model
- Stochastic programming
  - Scenario generation
- Results
- Conclusions

The natural gas value chain





The portfolio perspective

- Several bottlenecks in the network makes residual analysis suboptimal
  - Transportation bottlenecks
  - Production bottlenecks
  - Quality
  - System effects
- The flexibility gained with a portfolio perspective is substantial
  - Utilization of short-term markets
    - Combination of short-term markets and contract delivery
  - Blending possibilities
- What is the value of optimal storage utilization in this perspective?
  - In particular, how can the network itself be utilized as a market-near storage?

The optimization model

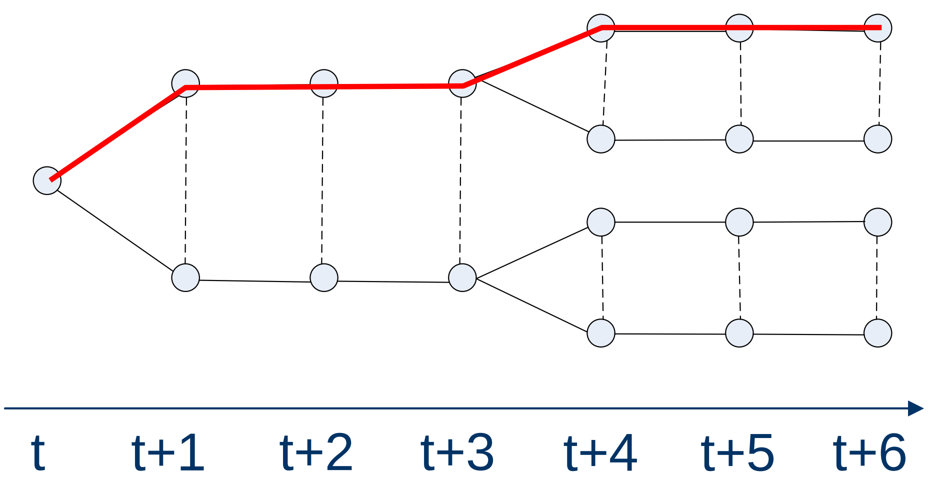
- Operational portfolio optimization model for a natural gas producer
- System perspective
- Multi-stage stochastic model
  - Stochasticity in gas prices and demand in long-term contracts
  - Resolution: days
  - Time-horizon: one week
- Linear programming model
  - Linearization of pressure constraints
  - Linearization of compressor costs
  - Linearization of line-pack relationship with pressure in pipelines
- Assume perfect competition in the market nodes
- Storage in pipelines (line-pack)
  - Commercial value of actively using the line-pack for maximizing profits
- Benchmarked on real market prices

Recourse decisions

- Consider a problem with two stages. The following sequence of events occurs:
  1. We make a decisions now (first-stage decision)
  2. Nature makes a random decision (high/low, wet/dry, etc…)
  3. We make a second stage decision that attempts to correct some of the problems caused by (2)
  4. (in a multi-stage problem, nature makes another decision, we make another corrective action, and so on…)
- The second stage decision are called recourse decisions

- The goal of a two-stage model is to identify a first-stage decision that is well positioned against all possible realizations of the random variables

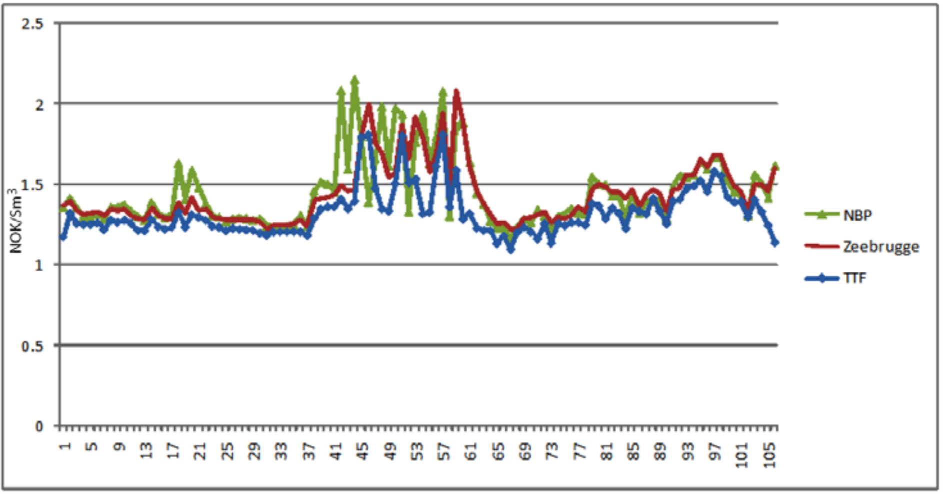
Scenario tree

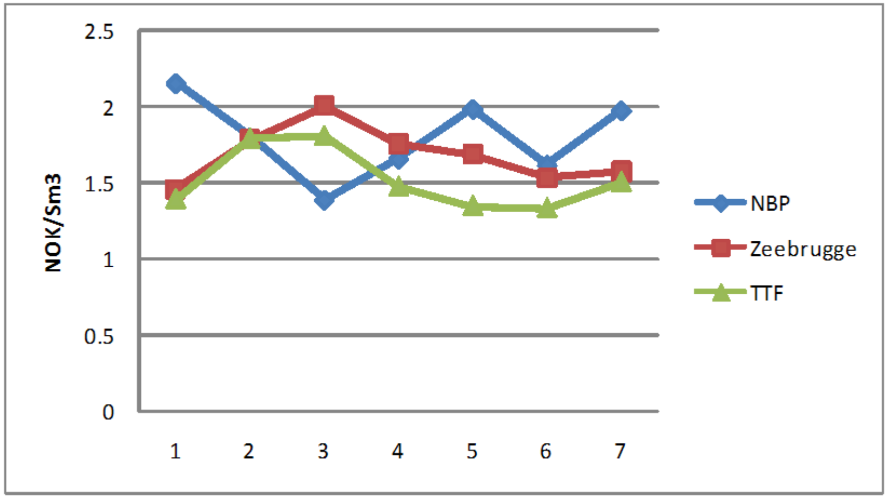


- Each path through the tree gives a scenario
- A stage is a point in time where it makes sense to make a new decisions
  - New information is available
- The number of stages is determined based on problem characteristics
  - Must capture all the important consequences of the first stage decisions

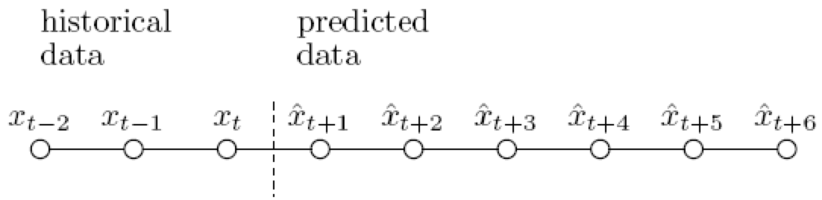
Natural gas prices

- Seasonal patterns (high price in winter, low in summer)
- Mean reversion
- Large spikes (mainly upward spikes)
- High volatility

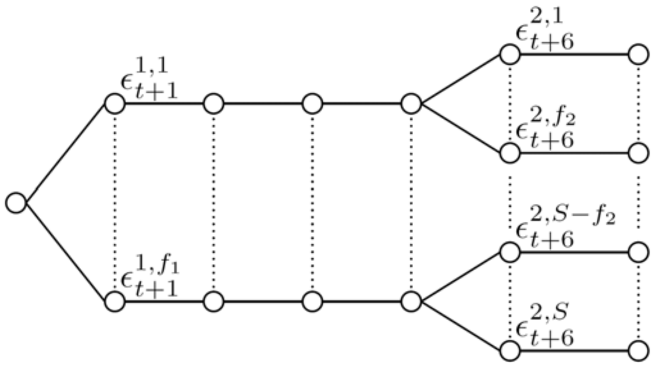


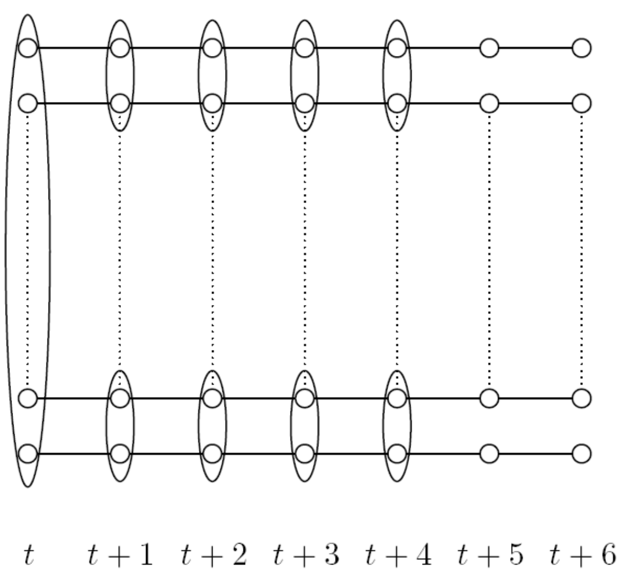


Scenario generation



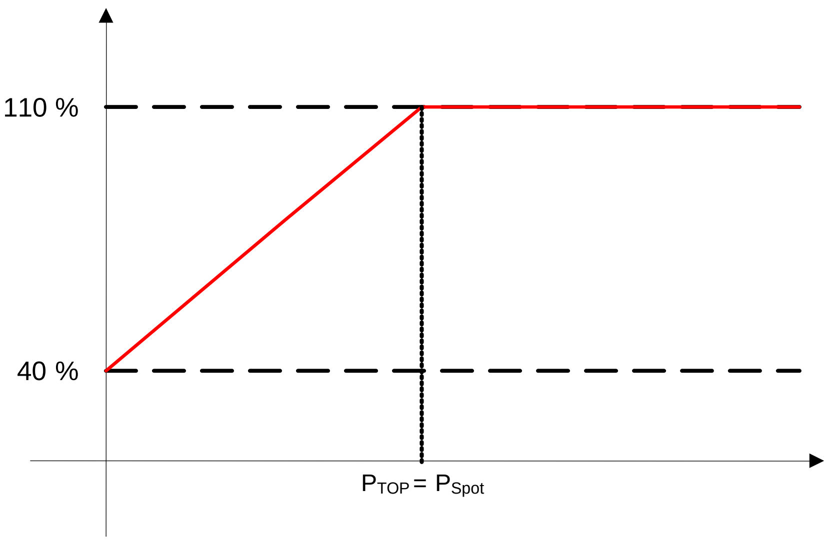
$$\hat{x}_{t+j} = \begin{cases} \alpha + \sum_{i=1}^{2} \beta_i x_{t+j-i} & \text{if } j = 1 \\ \alpha + \beta_1 \hat{x}_{t+j-1} + \beta_2 x_{t+j-2} & \text{if } j = 2 \\ \alpha + \sum_{i=1}^{2} \beta_i \hat{x}_{t+j-i} & \text{if } j > 2 \end{cases}$$

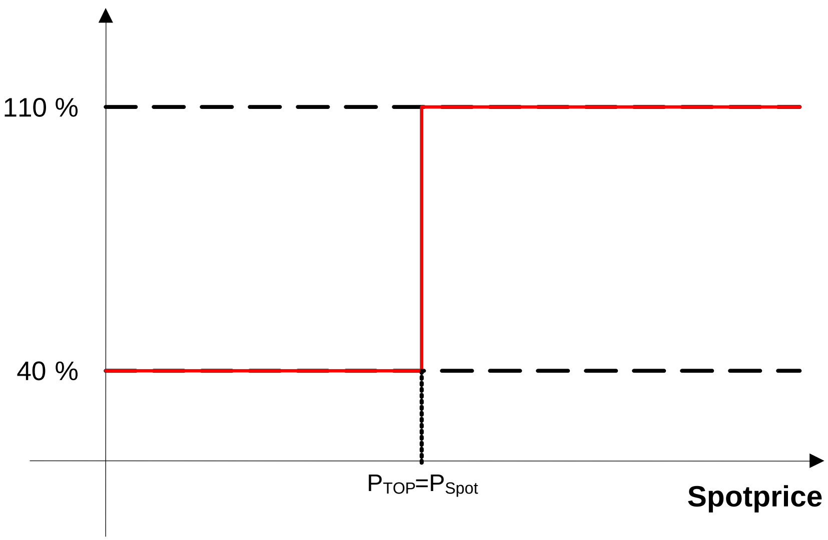




$$\hat{x}_{t+j}^{s} = \begin{cases} \alpha + \sum_{i=1}^{2} \beta_i x_{t+j-i}^{s} + \epsilon_{t+j}^{s} & \text{if } j = 1 \\ \alpha + \beta_1 \hat{x}_{t+j-1}^{s} + \beta_2 x_{t+j-2}^{s} + \epsilon_{t+j}^{s} & \text{if } j = 2 \\ \alpha + \sum_{i=1}^{2} \beta_i \hat{x}_{t+j-i}^{s} + \epsilon_{t+j}^{s} & \text{if } j > 2 \end{cases}$$

Modeling of TOP volume



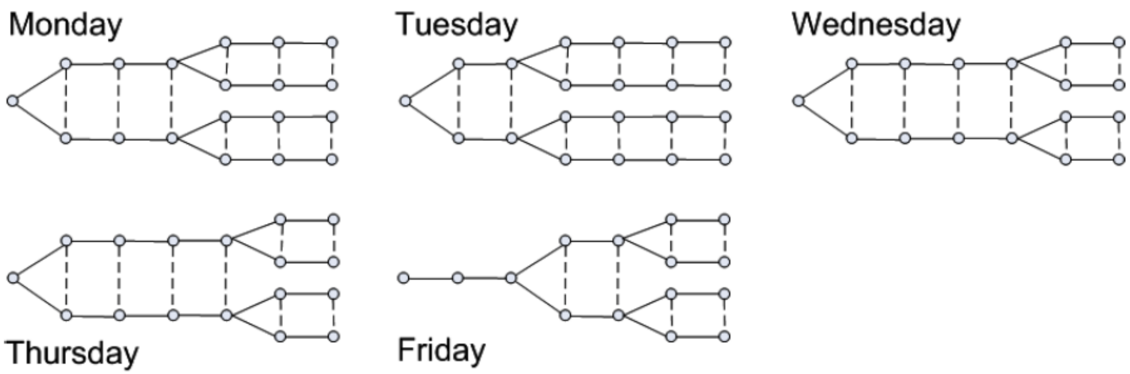


- Large customer
- Can not buy all needed gas in the spot market
- Assume that demand in customers portfolio is correlated with the spot price

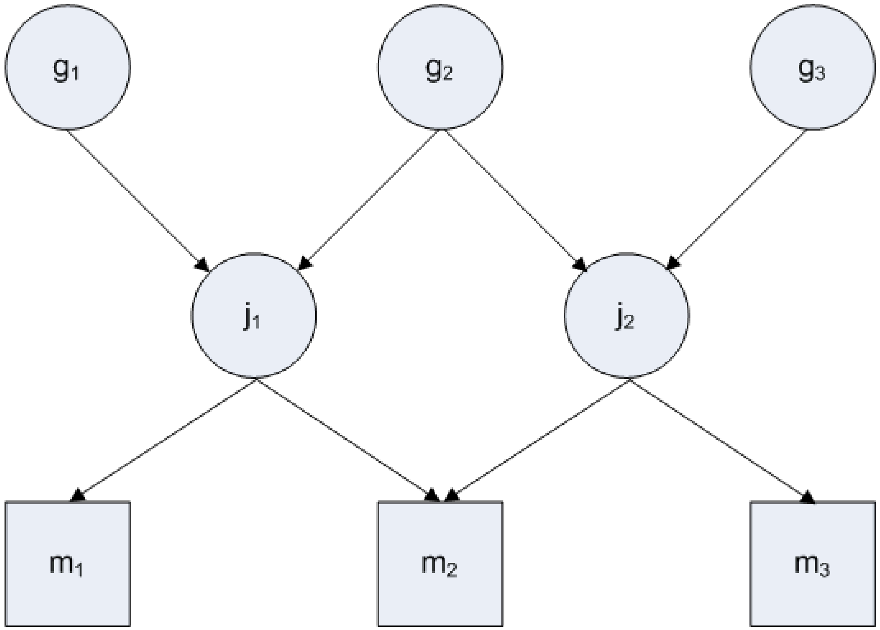
- Smaller customer
- If spot price is higher than TOP – takes maximum delivery
- If it is lower than TOP – takes minimum delivery

Rolling horizon and price models

- Run the model for a given week, implement the first stage decisions
  - Update parameters (production limits, line-pack, scenarios)
  - Run the model again on the next weekday



Case used in the numerical examples



- Simplified network
  - Contains an aggregated view of the most important nodes in the North-Sea
- Accounts for approximately 60% of total transportation in the North-Sea
- Demand in long-term contracts accounts for approximately 60% of total production
- Starting line-pack equal to ending line-pack
  - Business constraint

Results with perfect information

- Assumes that the producer has perfect information of the price development and TOP-demand

	Case 1	Case 2
Time period	T	T
Model type	With line-pack	Without line-pack
Spot market income	14573.94	14205.71
Average price	2.388	2.388
Average obtained price	2.927	2.833
Adjusted with average price	14450.40	14205.71

	Case 3	Case 4
Time period	$T+1$	$T+1$
Model type	With line-pack	Without line-pack
Spot market income	18806.26	15994.74
Average price	2.927	2.927
Average obtained price	3.777	3.344
Adjusted with average price	18228.61	15994.74

Stochastic model versus deterministic model

- In the stochastic model we have 3 stages and 900 scenarios

	Case 5	Case 6
Price model	PM1	PM1
Model type	With line-pack	With line-pack
Uncertainty	Stochastic	Deterministic
Spot market income	30317.06	30199.84
Average obtained price	3.022	2.882
Average price	2.658	2.658
Adjusted with average price	29408.23	28104.57

	Case 7	Case 8
Price model	PM1	PM1
Model type	Without line-pack	Without line-pack
Uncertainty	Stochastic	Deterministic
Spot market income	28566.24	28450.87
Average obtained price	2.946	2.934

Conclusions

- Optimal utilization of the line-pack in pipelines as storage has a large commercial value
  - Depends on the quality of the forecasting method
  - With perfect information, the profitability increased with 13.97%
- Stochastic models give more robust results compared to deterministic models
  - In terms of forecasting parameters
  - In addition, the deterministic model was infeasible for some test runs on the rolling horizon