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Quantitative analysis of gas supply strategies from a German plant operator’s perspective

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Introduction

Methods

Results

Conclusion
There have been profound changes in the German energy industry within the last two decades

1 Modification of the Regulatory Framework
   - Liberalization of the gas market
     ➔ Unbundling: Network operation and gas sales now operating independently
     ➔ Federal Network Agency as the new supervisor of the German gas network
     ➔ Free choice for the customers between newly competing suppliers
   - Increase of eco-friendly and renewable energy sources

2 Specific Gas Market Changes
   - Stimulate competition in gas sales and in gas trading by reducing market entry-barriers
     (e.g. consolidation of market areas, network access via an easy-entry-exit system, adjustments to the balancing system)
   - Formation of wholesale markets for gas

3 Technological Advancements
   - Technical advancements in production and transportation
     ➔ Decoupling of gas prices from oil prices
Introduction

Basically two strategic options for plant operators to buy gas

**Full Supply Contract**
- One single supplier
- Long term contracts
- Paying a fixed capacity charge
- Paying an additional variable energy charge for each MW of consumed gas at spot prices for natural gas
- Quantity risk lies with the supplier, who imposes a flexibility-premium per MWh

**Trading at Wholesale Markets**
- In addition to OTC-trading, EEX has been offering gas trading since July 2007
- Booking of capacity charge
- Managing Balancing Energy units and units being bought on an hourly and daily basis
- Quantity risk lies with the plant operator
## Introduction

### Comparison of Cost Structures: Full Supply Contracts vs. Wholesale Market Supply Strategy

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<th>Full Supply Contracts</th>
<th>Wholesale Market Supply</th>
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<tr>
<td><strong>Fixed costs</strong></td>
<td>capacity charge</td>
<td>booking of the exit capacity</td>
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| **Variable costs**  | gas procurement costs per MWh + fixed structuring charge per MWh  
example: NCG-price/MWh + 2 €/MWh | gas procurement costs per MWh + structuring charge  
charge determined by balancing system including hourly and daily gas deviations |

- What influence do hourly and daily balancing costs have on the gas supply costs?
- **Aim:**
  - Development of a model to calculate the demand-dependent costs (raw materials, balancing energy costs and structuring charge)
  - Stochastic optimization is used in order to take into account the option of capacity-storing and the different requirements
Methods

Methodological Approach/Roadmap

Conduction of semi-structured interviews with power plant operators
- Balancing costs incur as a result of uncertainty in gas demand within three hours caused by two events: unscheduled outages and spontaneous electricity trades in the control power market
- Determination of a basic portfolio consisting of two gas and steam cogeneration plants, two heating plants and a natural gas pipe array (gas storage facility)
- Determination of technical restrictions

Design of Stochastic Optimization Model & Calculations (GAMS / IBM ILOG)
- Calculation of total balancing costs in different scenarios and sensitivity analyses

Simulation of Gas Demand Scenarios (@Risk)
- Analysis of the two particular events in historical data of the plant operators
- Generation of basic gas demand scenarios using existing Real Option Model approach of the plant operators
- Simulation of unscheduled outages and spontaneous electricity trades
Methods

Stochastic optimization model

Input
- DGFC NCG and Gaspool market area
- DGFC reference prices (TTF, ZTP)
- Hourly demand scenarios of the power plant portfolio (Compensation Model)
- Technical Parameters of Gas pipe arrays

Assumption
- Firmly reserved capacities available in sufficient quantities
- One accounting grid per market area
- No cross-market area gas transport
- No transaction costs

Optimization

Output
- Costs for gas, structuring fee and balancing energy

Conditions
- Gas prices
- Balancing costs
- Structuring fee
- Utilization of gas pipe arrays
- 3 hour period for renomination
Results

Dominant Strategy: Managing gas supply for a portfolio of gas-fueled power plants by using wholesale markets

Reason

Expected value of quantity risk is far lower than the premium in offered contracts

- Even calculations without storage capacities show lower balancing costs per MWh than the quantity risk premium in full supply contracts
- Proportionalized balancing costs do not exceed 18 ct/MWh in all calculations and scenarios, whereas supply contracts include a risk premium multiplied approximately by 10

Note: A flexible gas supply contract can be added profitably to the supply strategy

- Contract has to contain a very low take or pay quantity of only about 1-5% of total annual fuel demand
- Contracts helps to reduce balancing costs for positive balancing energy in the event that the operator sells energy in control power market
Conclusion

- German Gas-fueled power plant operators should consider managing supply on their own by trading in wholesale market, but they have to anticipate further costs incurred by additional expenditures for extra labour and enhanced IT system requirements to manage the gas supply.

- Gas suppliers selling full supply contracts will probably not be able to offer lower priced quantity risk premiums than those accruing by trading in wholesale markets as there is an information asymmetry between the operator and the supplier concerning actual gas demands of a plant.

- Gas storage capacities lost value from a plant operator’s perspective as gas demand declined and intraday trading at EEX was established in March 2010.

- The overall analysis shows that savings exist, but the core problem is not primarily the optimization of the balancing cost but the low CO2 costs with low residual load.
Many thanks for your attention!

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References


Birge, John; Louveaux, Francois (1997): Introduction to Stochastic Programming


European Energy Exchange AG (2012): EEX Product Brochure Natural Gas (Release 0001D),

Scholl, Armin (2001): Robuste Planung und Optimierung (Robust Planning and Optimization)


Backup
Backup – German Gas Market: Entry/Exit Model, Market areas

**market area:**

cooperation of single gas network operators, that enables transmission customers to only need one entry and one exit contract
Backup – Regulator stimulating competition: Reduction of number of market areas

![Bar chart showing the reduction of number of market areas over time.]

- L-Gas
- H-Gas

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Backup – Products in Gas trading

- **Full Supply Contracts** (Take or Pay contracts)

- **Fixed Flow Contracts**: 12 months, 6 months, 3 months, 1 month
  - Assumption: no further gas demand → highly flexible and unpredictable demand

- **Spot market**:
  - Day-Ahead Contracts, Within-Day Trading
Backup – Merit Order: Gas-fueled Power Plants

Price / costs [Eur/MWh]

Market Price

Demand

~ Supply

Quantity [MWh]

Wind  Water  Nuclear  Brown Coal  Black Coal  CCGT  Gas
Backup – Gas Demand of a Power Plant (2 days in Dec 2012)
Backup – Balancing System

- Customers need to ensure a balance of entry (bought at VHP) and exit (consumed at power plants) volumes

- **Balancing costs:**
  - Imbalances are penalized at the end of each day
    - Former Tolerance of 5% which may be balanced within the next two days disestablished (currently discussed)
    - Penalty depends on reference prices, appr. 10-20% loss of value of imbalanced volume
  - Imbalances within an hour are penalized
    - Tolerance of 2%
    - Penalty: 15% of daily reference price multiplied by imbalanced volume, penalties may vary within different hours of a day
Backup – Analysis of relevant events and simulation of gas demand scenarios

- **Simulation in two steps** as outages (physical) and spot market sales (market) occur independently

- **Simulation of outages:**
  - Hourly Gas demand vector modification:
    - Outage yes/no? Binomial distribution of total outages / Simulation: Bernoulli Process (event of outage independent of previous outages)
    - Amount of unavailable capacity regarding historical data

- **Simulation of spot market sales:**
  - Hourly Gas demand vector after simulation of outages:
    - No spot market sales, positive or negative sale
    - Amount of gas sales according to historical data
## Backup – Simulation of Outages

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### Backup – Simulation of Spot Market Sales

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Backup – Example: Analysis and Simulation of Quantity of power sold in intraday spot market
## Backup – Simulation of Gas Demand Scenarios

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<tr>
<td>P(keine RL</td>
<td>Produktion=0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verteilung RL-Höhe</td>
<td>Beta(0,52;9;30;0,362)</td>
<td>Log-Logistisch (-192;200;16)</td>
<td>Beta(0,25;0,25;0;557)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Backup – Optimization Model: (non-linearised, deterministic) Objective function

\[
\begin{align*}
\text{min } g_k &= \sum_{j=1}^{365} P_j \cdot x_j + \sum_{j=1}^{365} PA_j \cdot (\Delta d_j - 0.05 \cdot (x_j + \Delta d_j)) \cdot \chi\{\Delta d_j > 0.05 \cdot (x_j + \Delta d_j)\} \\
&- \sum_{j=1}^{365} NA_j \cdot (\Delta d_j + 0.05 \cdot (x_j + \Delta d_j)) \cdot \chi\{\Delta d_j < -0.05 \cdot (x_j + \Delta d_j)\} \\
&+ \sum_{j=1}^{365} \sum_{i=(j-1) \cdot 24+1}^{j \cdot 24} PS_i \cdot (\Delta h_i - 0.02 \cdot (x_i + \Delta h_i)) \cdot \chi\{\Delta h_i > 0.02 \cdot (x_i + \Delta h_i)\} \\
&+ \sum_{j=1}^{365} \sum_{i=(j-1) \cdot 24+1}^{j \cdot 24} NS_i \cdot (\Delta h_i + 0.02 \cdot (x_i + \Delta h_i)) \cdot \chi\{\Delta h_i < -0.02 \cdot (x_i + \Delta h_i)\}
\end{align*}
\]
Backup – Optimization Model: Objective function (Spot market only)

\[
\min g_k = \sum_{i=1}^{24} (P_i \cdot x_i) \\
+ \sum_{s=1}^{SZ} \frac{1}{SZ} \left( \sum_{j=1}^{J} \left( \sum_{i=(j-1) \cdot 24+1}^{j \cdot 24} \right) (P_i + 3) \cdot (x_{v_i,s} + x_{v_i,h,s}) + PS_i \cdot u_{i,s} + NS_i \cdot w_{i,s} \right) \\
+ PA_j \cdot n_{j,s} - NA_j \cdot q_{j,s} \right)
\]

- Gas bought in same amounts in all scenarios as relevant events occur after nomination
- Variabilities in different gas demand scenarios are being handled using storage facilities, using two full supply contracts or causing balancing costs (on hourly and daily basis)
Backup – Optimization Model - Constraints

- Constraints for linearizing objective function
  (using binary variables, Big-M)
- Gas storage facility: hourly entry and exit, total capacity
  (using currently stored gas volume and hourly change in currently stored gas)
- Link between hourly change in currently stored gas, gas demand, bought gas
  (spot market or using contract), and balancing energy
- Flexible Full Supply Contract specification (ToP, hourly exit flexibilities)
- *(Balancing of volumes within two days)*
Backup – Results: Table Examples

5% tolerance, no storage facilities

<table>
<thead>
<tr>
<th></th>
<th>2012</th>
<th>Menge</th>
<th>Ausgaben</th>
<th>2013</th>
<th>Menge</th>
<th>Ausgaben</th>
</tr>
</thead>
<tbody>
<tr>
<td>in MWh bzw. Euro</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Börsenbezug</td>
<td>9.117.307</td>
<td>253.908.741</td>
<td></td>
<td>7.262.056</td>
<td>206.047.462</td>
<td></td>
</tr>
<tr>
<td>Vertrag</td>
<td>118.717</td>
<td>3.680.224</td>
<td></td>
<td>94.874</td>
<td>2.981.079</td>
<td></td>
</tr>
<tr>
<td>SB</td>
<td>151.856</td>
<td>656.177</td>
<td></td>
<td>193.077</td>
<td>852.657</td>
<td></td>
</tr>
<tr>
<td>positive AE</td>
<td>272</td>
<td>8836</td>
<td></td>
<td>682</td>
<td>23.214</td>
<td></td>
</tr>
<tr>
<td>negative AE</td>
<td>-58.598</td>
<td>-1.451.911</td>
<td></td>
<td>-58.790</td>
<td>-1.487.627</td>
<td></td>
</tr>
<tr>
<td>SUMME</td>
<td>9.177.698</td>
<td>256.802.067</td>
<td></td>
<td>7.298.822</td>
<td>208.416.785</td>
<td></td>
</tr>
</tbody>
</table>

- Comparison with calculations with storage facilities show lower costs of appr. 2 million Euros per year
  - price-deterministic model uses different buying prices
  - AE and SB can be avoided
### Backup – Results: Flex Contract – Take or Pay Volumes

#### 5% tolerance, storage facilities

<table>
<thead>
<tr>
<th></th>
<th>ohne Vertrag</th>
<th>Vertrag flexibel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>in MWh bzw. Euro</strong></td>
<td>Menge</td>
<td>Ausgaben</td>
</tr>
<tr>
<td>Vertrag</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>SB</td>
<td>75</td>
<td>333</td>
</tr>
<tr>
<td>positive AE</td>
<td>3.674</td>
<td>120.368</td>
</tr>
<tr>
<td>negative AE</td>
<td>-16.484</td>
<td>-419.603</td>
</tr>
<tr>
<td><strong>SUMME</strong></td>
<td>9.177.687</td>
<td>254.557.436</td>
</tr>
</tbody>
</table>

- Take or Pay volume has to be very low to be added profitable to supply portfolio
- Calculations without tolerance in daily imbalances show a volume of about 1-3% depending of structuring charge
Backup – Critical Appreciation of the Model

1. Realistic Key assumptions of the model:
   - all exit points with consumption metering RLMoT
   - option to use a daily band, but it is more expensive in terms of structuring charges because of the highly fluctuating gas demand within one day
   - capacity at the exit points firmly booked ➔ sufficient to supply the power plants at full load with gas

2. Calculation of the gas supply costs are market area specific

3. Managing the exit points within one market area in one balancing group ➔ balancing deviations in the gas consumption

4. The use of the DPFC and the uncertainty regarding the required Gas demand refers to the period between nomination and exit-point
   ➔ implies that the desired amount of gas can be bought at daily market price

5. Neglecting transaction costs