**Univerzita Karlova v Praze**
**Fakulta sociálních věd**

**Institut ekonomických studií**

# Rigorózní práce

**2009** **David Zlámal**

**Univerzita Karlova v Praze**
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# RIGORÓZNÍ PRÁCE

# Option embedded in natural gas sales' contracts

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**Akademický rok:** **2008/2009**

**Prohlášení**

Prohlašuji, že jsem rigorózní práci vypracoval samostatně a použil pouze uvedené prameny a literaturu.

V Praze dne 4. 9. 2009 David Zlámal

**Poděkování**

Na tomto místě bych rád poděkoval panu Prof. Ing. Michalu Mejstříkovi CSc. za jeho odbornou pomoc a cenné rady při psaní této rigorózní práce.
Také bych chtěl poděkovat Mgr. Janě Strakové a Mgr. Janu Suchému za přínosné připomínky a návrhy. V neposlední řadě patří mé díky Petře a rodičům za podporu a trpělivost.

# ABSTRACT

The paper analyses the unexplored contractual relationship among sellers and buyers in the natural gas business. In the majority of European natural gas contracts the seller commits to deliver the stated quantity of gas during the year and the buyer is obliged to offtake the main part of the agreed quantity. The difference between these two volumes represents the offtaking flexibility that the seller grants to the buyer, the embedded option.

The paper focuses on the evaluation of this embedded option. Firstly the investigation is performed in the current market situation when the buyer doesn't have the access to the spot market with natural gas. Under this condition the buyer can't make a profit and he is using the option only to satisfy the changing demand of his consumers. Secondly, the option is evaluated in the future situation when the spot market with natural gas emerges. In this circumstance, the embedded option becomes a financial option with changing strike price and we can evaluate it using the spread option formulas.

# ABSTRAKT

Tato práce se zabývá neprozkoumanou částí smluvního vztahu mezi prodávajícím a kupujícím v odvětví zemního plynu. Ve většině kontraktů, týkajících se obchodu se zemním plynem v Evropě, se prodávající zavazuje dodat během jednoho roku určité množství plynu a kupující je povinen odebrat větší část z tohoto množství. Rozdíl mezi těmito dvěma objemy představuje odběrovou flexibilitu, kterou prodávající poskytuje kupujícímu, tj. opci zakotvenou ve smluvním ujednání.

Tato práce se zaměřuje na ohodnocení této vnořené opce. Ocenění je prováděno nejprve za současného stavu, kdy kupující nemá přístup na promptní trh se zemním plynem. V tomto případě opce slouží kupujícímu k tomu, aby mohl uspokojit poptávku svých zákazníků a nemůže ji využít k peněžnímu zisku. Poté je opce oceňována za pravděpodobné budoucí tržní situace, kdy kupující získá přístup na trh s plynem. Za těchto okolností se vnořená opce stává finanční opcí s měnící se uplatňovací cenou, umožňuje kupujícímu dosáhnout arbitrážního zisku a může být oceněna použitím modelů na spreadové opce.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| ACQ | Annual Contract Quantity |
| ADUQ | Average Daily Unused Quantity |
| AMQ | Annual Minimum Quantity |
| AOQ | Annual Option Quantity |
| DCQ | Daily Contract Quantity |
| DDR | Daily Delivered Rate |
| DQT | Downward Quantity Tolerances |
| DUQ | Daily Unused Quantity |
| LDC | Local Distributing Company |
| MDQ | Maximum Daily Quantity |
| NDC | National Distributing Company |

# CONTENT

# INTRODUCTION

The natural gas industry is unique in comparison with other classical areas of business. It is specific by monopoly character, high state regulation, high sunk costs and also lack of published information and papers. Recently, in the framework of the EU, it is undergoing major regulation changes such as obligatory unbundling to achieve a competitive market.

In this paper we are interested in the specific contractual relationship among sellers and buyers in the natural gas business. In the majority of European natural gas contracts the seller commits to deliver some stated quantity of gas during the year and the buyer is obliged to offtake a main part of the agreed quantity. The difference between these two volumes represents the offtaking flexibility that the seller grants to the buyer. The buyer has the possibility to offtake the option quantity for the contracted price or he can leave it untaken without any penalty. The motivation for the existence of the offtaking flexibility has source in the specificity of the gas business. The buyer is running the business in the market with the highly unpredictable total demand of his customers therefore he needs the flexibility to face it together with the certainty that he will get the gas to assure continuous deliveries.

The aim of the paper is to present the first venture into the interesting area of gas contractual relationship where by now the conducted research is almost none. The paper focuses on the evaluation of the buyer's option, which is embedded in the majority of gas sales contracts. The research can provide new important findings for the both parties of the contract and can be useful when the new contracts are arranged.

The investigation is performed in two different market situations. Firstly in the current market situation when the buyer doesn't have the access to the spot market with natural gas. Under this condition the buyer can't make a profit and he is using the option only to satisfy the changing demand of his consumers. The problem therefore reduces to the risk division between two negotiating parties and the seller's decision where and how to set the required compensation for the granted flexibility.

Secondly, we are trying to describe how to evaluate the option in the likely future situation when the spot market with natural gas emerges and the buyer will have the possibility to sell there the option gas. In this circumstance, the embedded option becomes a financial option with one distinction; it has a floating strike price. For that reason the classical option models can't be used and we have to move to the exotic, spread options models which include the assumption about the changing strike price. These highly sophisticated models are very complex but offer great possibilities where to use them. Furthermore, the natural gas price is not evolving randomly as is typical for shares but price changes are somehow related which add another difficulty in the option model.

The paper is organized as follows. Section one provides a presentation of the typical natural gas sales agreement. The specific features of gas sales contracts are analyzed as well as the gas pricing formula. In Section two, the embedded option is discussed in the situation of nonexistence of spot market with natural gas. Section three presents the possibilities of the emergence of liquid spot market in the European territory. Consequently, after the determination of the buyer's incentives and limitations of how to use the granted option the spread option models for the embedded option evaluation are analyzed. Finally, section four provides concluding remarks.

# 1. GAS SALES CONTRACTS

## 1.1. Basic definition

A gas sales and purchase agreement has the same basis as any other sales agreement. It is a binding mutual agreement to sell and purchase stated volumes of a defined product at agreed times and places and for an agreed price. The responsibilities of the two parties are specified, as are the methods in which a third party can enforce the agreement. Thus far no problem. However, there are some distinctive features resulting from the nature of the product and from the gas industry customs.

In the history, the gas contracts document envisaged a trade over many years, often starting with no infrastructure and attempting to deal with situations, which became increasingly uncertain over an uncertain future of maybe a 20-year duration. Such agreements had to be written in a flexible way in order to deal with and solve problems when they arose.

Nowadays, with developed infrastructure and matured markets it is possible to deal with some matters in a more commercial fashion. For example by establishing a price reference system to ensure that the pricing clauses maintain their relevance or by building a system of spot trading with standardized contracts. But the possibility of getting things fundamentally wrong still remains. It arises from a fact that we are trying to imagine what the world will be like in five, ten or fifteen years from now. So gas contracts are written with extreme caution and contain mechanisms to react to unanticipated events.

## 1.2. Specific features and concepts of gas contracts

Gas contracts are full of special terms and acronyms, making them difficult to read. Different contract writers also do not always use the terms in the same way. We will look at three main always-present concepts and their basic terminology.

### 1.2.1. Volume, capacity and tolerance

- The first set of numbers deals with true *Volumes*. There are often two volumes. The first is the amount of gas, which can be sold and purchased, for instance, in any year. This figure is often set higher than is the average purchase, to allow the buyer some flexibility in the manner in which he takes the gas. If we multiply this figure by the number of years of contract we will get a figure greater than the second figure - the total amount of gas, which can be taken over the life of the contract. Thus, the contract life volume acts as a cap on the sum of the yearly volumes.

- The second set of numbers results largely from the constraints of the pipelines. This set refers to *Capacity*, which is represented by the minimum rate at which the seller must offer gas and the maximum rate at which the buyer may take gas. The capacity is usually expressed as a daily quantity. In a perfect world the seller would offer and the buyer would take the same amount of gas each day such that at the end of the year, the yearly contract volume was achieved. In practice, fluctuating demand for gas and technological factors cause the daily offtake volume to vary from day to day, hence sufficient capacity must be built into the system to allow for it.

- The third set of numbers reflects the realities of life. It happens rarely that the gas offered or taken during a year will exactly equal the amount stated in the contract. Therefore, there are normally some *Tolerance clauses* to allow to some extent for the unforeseen. Such provisions we can understand as recognition of the inevitable surprises of business life but also as a non-intended "license to default". Tolerances affect the contract volumes only partially, but may affect any penalties due for failure to live up to the contract.

### 1.2.2. Functioning of the contract[1]

Whilst three concepts described above are easily understandable, the manner in which they are expressed in the contract can be very confusing, because the same term may often be used in different ways depending on how the contract is written.

The volume that should be sold and purchased in a year is normally called the *Annual Contract Quantity* (ACQ). It represents the maximum annual quantity the supplier is obligated deliver to the buyer. The ACQ may be stated as an independent figure in the contract or alternatively it can be sometimes expressed as the multiple of a Daily Contract Quantity (DCQ), which means: ACQ = 365*DCQ.

In some ways the *Daily Contract Quantity* is wrong notation, since nobody expects that the same amount of gas equal to DCQ will be taken each day during a year. That is why a straight figure ACQ is much clearer way of building the contract. However, DCQ is used to compute Daily Delivery Rate.

*Daily Delivered Rate*[2] (DDR) expresses the rate at which the seller's facilities must be capable of delivering gas. It is usually expressed as a multiple of the DCQ. The DCQ is multiplied by the fraction 1/load factor where load factor – "$l$" is coefficient form (0,1). The relation describes the equation 1.1. below.

$$DDR = \frac{ACQ}{365} * \frac{1}{l} = DDQ * \frac{1}{l} \qquad (1.1.)$$

As we see from the equation, DDR states maximum daily volume, which is the supplier obligated to deliver to the buyer when he request it. On the other side, the buyer's offtake rate must not exceed the DDR. In some defined period

[1] World Bank/ESMAP (1993)

[2] Also called the Maximum Daily Quantity (MDQ).

of the year, however, the seller is allowed to shut down or reduce the capacity in order to carry out annual maintenance.

Load factor is a very important component of the contract, because it determines buyer's flexibility. Lower load factor and therefore higher daily volume flexibility offers to the buyer the possibility to purchase more in the period, when he desires it. It can be in the winter period to satisfy higher demand for gas, but also in period with high spot prices of natural gas to make the profit from the difference between purchasing and selling price.

When the seller is a producer, then there is also the Minimum Offtake Rate, which states the daily minimum buyer's offtake. The introducing of this rate to the contract avoids seller's problems in maintaining optimum services.

Thus far, if all has gone well, the buyer, for its part, normally fulfils its side of the contract by taking and paying for the ACQ and the seller fulfils its side by delivering the ACQ, thus the contract has functioned without invoking tolerances. But we don't live in an ideal world. We must start to look at what happens when things go wrong, when one party has not fulfilled its ACQ responsibilities[3]. It is at this stage that Downward Quantity Tolerances (DQT) may be invoked to reduce any penalty.

*Downward Quantity Tolerances* states the amount by which a buyer may fall short of its full Annual Contract Quantity (in a Take or Pay gas sales contract) without incurring sanctions. If there is no provision requiring the buyer to take supplementary volumes in subsequent years to make good for the deficiency, the ACQ becomes in effect the ACQ minus the DQT which we call Annual Minimum Quantity (AMQ).

[3] We should also mention that the ACQ may be adjusted against Force Majeure circumstances on either side.

## 1.3. Breach of contract

Contracts can of course be breached in many different ways but it is failure to take or supply gas that is most interesting and important.

### 1.3.1. Buyer's breach of contract

The buyer can potentially be in breach of contract if he has taken less gas than he should have done according to ACQ. In this case, the buyer applies at first the two following factors:

- First of all, the buyer claims Downward Quantity Tolerance, which may either excuse or at least limit penalties, which will be due.
- Then, he looks if the contract allows for Carry Forward provision[4]. It is the provision, which allows a buyer that has taken more than its ACQ in an earlier year to offset the additional volume against any shortfall in a later year.

If there still remains a shortfall after these adjustments, the buyer is in breach of contract and the seller may request the penalties for sustained damage at the court. However there is also a third route, frequently encountered in gas (and electricity) contracts, which is called "Take-or-Pay".

**Take - or – Pay mechanism**

Take-or-Pay is a common provision in gas contracts, which says that that if the buyer fails to take the agreed quantity in a given year (assuming that the seller was able to deliver the gas) for reasons other than force majeure, it shall pay the seller for that quantity as if the gas had been taken. Thus, when the buyer's annual purchased volume is less than the ACQ minus any shortfall in the seller's deliveries, minus any DQT, the buyer pays for such shortfall as if the gas had been received.

The contract usually allows the buyer to take the volume of gas paid for, but not taken, in subsequent years. This gas refunded in later years is known as a *Make Up Gas*. Make up gas can be free or charged at the difference in gas

[4] Sometimes called Advance Make Good provision.

price between the time the shortfall occurred and the time the gas was taken, depending on the contract.

However the buyer can receive make up gas only when in certain subsequent year after the shortfall he has taken his agreed threshold volume for that year, which can be ACQ or AMQ depending on different contracts.

Advantages of Take-or-Pay

- clear and simple mechanism avoiding going to court
- discourages the buyer from over-contracting for gas which, if not taken, the seller has problems of disposing elsewhere
- effective protection against the risk of the buyer "shopping the market" (up to the threshold level)
- the seller needs to have some guarantee of its cash flow, since over 90 % of gas production and transportation costs are fixed sunk costs
- lenders financing big gas projects insist on the Take-or-Pay provision in the contracts to lower the risk that loans won't be repaid

Arguments against Take-or-Pay

- gas is not so special good as to need a specific "simple mechanism"
- the seller should either accept lost sales as a normal business risk or sue through the courts if necessary
- experience[5] suggests that it doesn't protect the seller against the risk of a structural change in the industry which can cause the buyer to lose or give up its market as a result of a structural change in demand or if the buyer changes roles as a result of regulatory changes
- transfer of the risk from seller to buyer resulting from the dominant position of the supplier
- it is legally unenforceable

[5] This is what occurred in the U.S. when interstate pipelines discontinued their merchant function under FERC Order 636. It also occurred in Canada after deregulation in 1985 when industrial and commercial end-users elected to purchase gas directly from producer/marketers rather than from the traditional demand aggregators, such as LDCs (Long-term Canadian Natural Gas Contracts: an Update, 1997).

The debate about validity of Take-or-Pay provision has been continuing for many years. The main argument, which usually solves it, is the reluctance of banks to lend money to a seller who does not have Take-or-Pay in its contract for as long as interest and repayment is due[6]. It means that if the construction of a new pipeline system together with the exploration of new gas fields is necessary (and it would be the case of Europe where new and expensive long distance projects will be needed to meet the growing demand) then take-or-pay provision will very probably remain a part of the gas contracts in future years.

Long-term contracts with take-or-pay also provide better assurance of the security of supplies, which is, according to the EU the most important point[7], more than short-term contracts where the producer has the possibility to change gas deliveries between the world regions depending on the actual gas demand and the price, e.g. Russia may change the direction of gas deliveries from Europe to China where the demand together with the price is rising sharply.

### 1.3.2. Seller's breach of contract

The seller must be able to deliver the gas on any occasion the buyer requires it. His part of the contract doesn't include downward quantity tolerances, carry forward or Take-or-Pay provision. The seller knows that he can't afford any delay with deliveries, because he would immediately breach the contract.

For that case of breaching, contracts do sometimes have clauses which penalize the seller, who is obliged to sell quantities of gas at reduced prices to compensate for its failure. But in most cases the chosen route for redress is damages through the court.

In the situation when the buyer wants to offtake the gas but the seller isn't able to provide it, the buyer won't have taken ACQ and it isn't his fault. For that reason the buyer's ACQ must therefore be reduced by the seller's shortfall.

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[6] In the U.S. and Cananada, the *Deficiency charges* have evolved from the take-or-pay mechanism since 1991 and have a similar effect without creating an unacceptable risk for the buyer. However the major part of gas in Europe in the period 1990-1998 was sold on long term take-or-pay contracts (Brautaset et al., 1998).

[7] For a deeper insight into the problematic of the security of European natural gas supplies, nowadays heavily discussed topic, see Stern (2002).

## 1.4. Gas pricing

The majority of gas sales in the EU-area are regulated by long-term gas sales contracts. Since there is no regional, let alone global, liquid traded market price for natural gas as there is for oil, the market value for natural gas in each sector is typically determined relative to the price of the principal competing fuel.

The pricing of natural gas, under the long-term sales agreement, is usually arrived at through a process of negotiation between the seller and the buyer. The negotiation is based on the relative bargaining powers of both parties and several other factors[8].

### 1.4.1. General gas price formula

The price of the gas delivered according to the long-term take-or-pay contracts is determined by a gas price formula[9]. The formula links the current gas price to the price of relevant energy substitutes, thus continuously securing the buyer competitive terms[10]. The price formula consists of two parts, a constant basis price (fixed term) and an escalation supplement linking the gas price to alternative forms of energy (variable term)[11]. Examples of alternative energy commodities used in pricing formulas for natural gas are light fuel oil, heavy fuel oil, coal, and electricity. Usually not a single but a combination of alternatives is used (weighted average of energy prices) to reflect the markets for substitutes[12]. Different techniques are used, e.g., using different types of price lags in the price formulas (for example see Box 1.). The basis price reflects the parties' evaluation of the value of the gas at the time of entering into the contract. Each of the alternative energy commodities is assigned a certain

[8] Factors affecting gas pricing provision are for example: the flexibility of deliveries, reliability of the gas and market conditions as shares of competing fuels and their changes over time, changes in the market structure or changes in specific marketing costs due to changes in the market structure.

[9] Asche et al., (2000a)

[10] Adjustments in the gas price are not imposed automatically, but by monthly (or quarterly) recalculations of the contract price by using the price formula and updated prices on substitutes.

[11] This is the basic structure of most gas contracts in Europe.

[12] Some contracts may also contain adjustments for inflation.

weight reflecting the competitive situation between natural gas and the substitute.

The price change of each energy commodity is multiplied by an energy conversion factor in order to make the substitute and natural gas commensurable. Thereafter, the individual escalation terms are multiplied by the pass through factors, i.e., the change in the price of the substitute is not fully reflected in the gas price. A general price formula[13] is given by the equation 1.2.

$$P_t = P_0 + \sum_j \alpha_j \left(AE_j - AE_{j0}\right) EK_{AEj} . \lambda_j + \gamma . P_{t-1} \qquad (1.2.)$$

where: $P_t$ is the gas price paid to the seller's company,

$P_0$ is the basis price,

$\alpha_j$ is the weight in the escalation element for substitute *j* (often with $\sum_j \alpha_j = 1$),

$\left(AE_j - AE_0\right)$ is the price change for substitute *j* (actual minus reference price),

$EK_{AEj}$ is an energy conversion factor,

$\lambda_j$ is the pass through factor for price changes in substitute *j, and*

$\gamma$ is an intertemporal price escalation coefficient ($\gamma = 0$, except in those periods when a price adjustment is made)

The pass through factors are typically high, e.g., 0.85 or 0.90. Thus, natural gas prices in these contracts are highly responsive to price changes in substitutes, and exhibit a high volatility. This implies that the exporters are carrying a large fraction of the price risk. Price adjustments for substitutes are based on the difference between current and historic prices. Current prices are calculated as average prices for a reference period, ranging usually from three to nine months. This gives reliable price data and implies a certain lag in the price adjustments, both upwards and downwards.

[13] Asche et al., (2000b)

The previous equation formulation comprises the basic issues underlying the gas market:

- recognition of the price risk inherent in the business and the need to provide the sharing of the risk between the buyer and the seller in the long-term agreement
- provision for the price to reflect developments in the market for substitute fuels
- provision for intertemporal price adjustment if and when it is considered necessary

With the base price and the pass through coefficient the seller is protected against price swings below a predetermined level, while the buyer benefits from the link between the gas price and the price of competing substitutes.

Even if the gas price formula provides high flexibility it can't react on all possible eventualities that may happen during the long life of the contract. For that reason the sale and purchase agreement often includes the price reopener clause. The clause can be used only in the time and situation that is clearly stated and defined in the contract[14] and a final settlement must be possible even if the parties are unable to agree with each other on a solution.

[14] For all elements of the price reopener clause see World Bank/ESMAP (1993), page 88.

## Box 1.: Real gas price formula

The exact contents of the gas sales contracts are secret and the gas price formula is one of the most guarded parts. Fortunately one real example has emerged. It is the price formula with the fuel indexation (equation 1.3.), which the German company Ruhrgas has published for a gas auction held in 2004[15].

$$P = P_0 + 0{,}0035.(GO - GO_0) + 0{,}00175.(FO - FO_0) \qquad (1.3.)$$

where: $P_0$ is determined as 95 % * 1.2232, BAFA value 01.01.2003 which is equal to 1,16204

*GO* is the arithmetic average of the eight values of the product GASOIL multiplied by USD for the eight months ending one month prior to each Recalculation Date for GO which is the first day of January, April, July and October of each calendar year. $GO_0$ is stated as 223.757 Euro per ton.

*GASOIL* is the monthly average of the daily quotations high and low for Gasoil 0.2 PCT FOB Barge Rotterdam in USD per ton as published in the "Platt`s Oilgram Price Report", New York.

*USD* is equal to the monthly average of the reciprocal of the exchange rate of the US Dollar against the Euro as published by ECB.

[15] During 2002, the German Federal Minister of Economics and Labor approved the acquisition of sole control by E.ON AG over Ruhrgas. The approval placed a number of obligations on E.ON as set out in the Minister's decisions of 5 July and 18 September 2002 respectively. The Approval obliges E.ON, inter alia, to ensure that Ruhrgas establishes a Gas Release Program under which Ruhrgas has to release certain quantities of gas from its portfolio of long-term import contracts. In accordance with the Approval, Ruhrgas has to make six separate annual auctions. For the second auction Ruhrgas has introduced a price formula with fuel oil indexation as an alternative to the BAFA-based price formula (the average import price of gas delivered to Germany) laid down in the Approval.

| | |
|---|---|
| *FO* | is the arithmetic average of the four values of the product FUELOIL multiplied by USD for the four months ending immediately prior to each Recalculation Date for FO which is the first day of each delivery month. $FO_0$ is stated as 168.404 Euro per ton. |
| *FUELOIL* | is the monthly average of the daily quotations high and low for fuel oil 1 PCT FOB Barge Rotterdam in USD per ton as published in the "Platt's Oilgram Price Report", New York edition. |

After the substitution of the known parameters to the previous equation we get the final equation:

$$P = 1{,}16204 + 0{,}0035.(GO - 223{,}557) + 0{,}00175.(FO - 168{,}404)$$

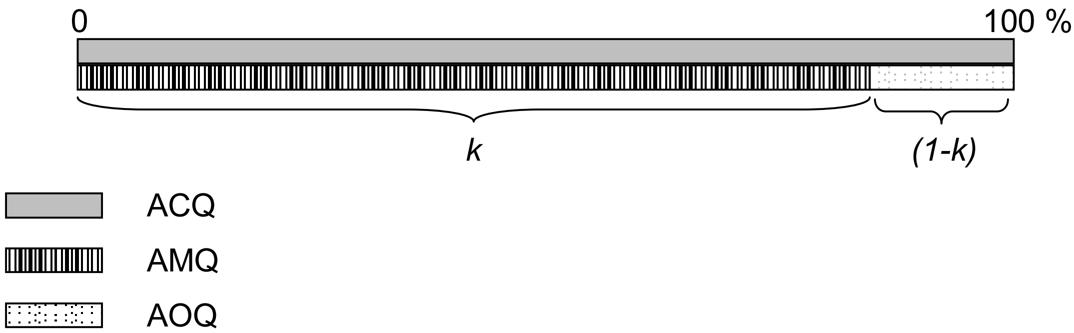
Overall, the take-or-pay gas contracts are complex, containing a number of detailed regulations of contingencies related to quantities and prices. Still, there are a number of feasible contingencies that are not explicitly covered by the contracts, e.g. the contractual response to deregulation. The contracts must therefore be considered as incomplete, and revisions and renegotiations may take place. According to Hart (1995), an incomplete contract is best seen as providing a suitable backdrop or starting point for such renegotiations rather than specifying the final outcome. The contract should be designed to ensure that, whatever happens, each party has some protection against bad luck and opportunistic behavior by the other party.

## *1.5. The embedded option*

In majority of gas contracts there is included an offtaking flexibility, i.e. the option to offtake some quantity of gas for the price agreed in the contract. The motivation for its existence is the volatility of the total annual gas quantity that the buyer needs to satisfy the customers. The volatility is caused by the uncertain demand of buyer's customers whose gas consumption depends on the weather conditions from the substantial part, i.e. on temperatures during the winter[15]. More weather dependent customers the buyer has, the higher flexibility he needs to react on the cold or hot winter. As the weather is highly unpredictable, the buyer can face the volatility by having the offtaking flexibility in the contract with the seller or by using the weather derivatives, which are unfortunately still immature and can't provide for an appropriate hedging.

The embedded option arises from different positions of buyer and seller in the contract. It corresponds to the take-or-pay provision in the sales agreement. The seller guaranties to deliver the amount equal to ACQ. On the other hand the buyer is obliged to offtake (or pay for) only "*k*" percent of ACQ, i.e. $k \cdot ACQ = AMQ$, where $k \in (0,1\rangle$ is a coefficient of take-or-pay quantity. The difference between ACQ and AMQ or $(1-k) \cdot ACQ$ represents the buyer's offtaking flexibility, i.e. *Annual Option Quantity* (AOQ) (see Scheme 1.1.). The buyer has an option to offtake this AOQ or to not offtake it without any penalties. The option is not tradable as it is embedded in the contract, which doesn't make it possible to sell to the third party.

**Scheme 1.1.:** The embedded option




Source: Author

[15] In the regions with hot summer temperatures where the air conditioning is widely used the summer period also plays the important role.

# 2. OPTION IN THE SITUATION WITH NONEXISTENCE OF THE SPOT MARKET

In this market situation, the local distributing company (the buyer) has not any access to the spot market with natural gas. He can buy the natural gas only from the national distributing company (the seller). He has usually a long-term take-or-pay contract with the seller, which covers all natural gas the buyer needs during the year.

There exists also the possibility that the buyer could buy the gas from a foreign distributing company. However, this situation is not usual, because the foreign gas trading companies have limited access to the Czech market[16]. Since this situation is not common, we won't consider it in the option analysis.

## *2.1. The position of the buyer*

Without the access to the spot market, the buyer can use the option only to cover the fluctuating demand of his customers. He can't exercise the option in order to sell the gas at higher price to someone else and make a cash profit. He can't even sell the gas at lower price. The only advantage following from the granted option is the offtaking volume flexibility, which enables him to react on uncertain future gas demand. Thus, we can see that it is not possible to look at the option as a financial option and evaluate it using formulas for options derivatives.

We mustn't forget to mention that the buyer could also have the possibility to sell the gas he doesn't need to other local distributing companies. On the other hand he could have an opportunity to buy the gas from local distributing company (LDC). However, this trading among LDCs is very unlikely and if it happens the trading volume will be relatively small, thus we will assume

[16] This situation will change after the unbundling in 2006 when the foreign gas distributing companies gain access to the Czech market. But as the development and characteristics of the future trading situation are not known at the present time, we won't consider it in the current analysis.

the non-existence of such a trading. The reason for this assumption is based on the following argumentation.

Let's suppose that all LDCs in the country (rational and maximizing their profit) are offtaking the gas for the same price from the national distributing company, which owns the pipeline system. We have to mention that there are shipping costs related to the gas transportation from one LDC to another and also uncertainty about the free capacity in the pipeline system. Let's look what can be the LDC motivations for gas trading.

Any LDC has a reason to sell the gas only in two cases. The first case is when its annual offtake is less then AMQ, because it can avoid an application of take-or-pay obligation by a national distributing company. The second case is when it could sell the gas more expensively than it bought it from national distributing company and at the same time it knows that after this trading operation its annual offtake won't exceed its ACQ.

Any LDC has a reason to buy the gas also only in two cases. The first case is when its annual offtake is greater than its ACQ. The second case is when it could buy the gas cheaper than from the national distributing company and at the same time it knows that its annual offtake will exceed its AMQ.

Taken together, from these two paragraphs we can see that trading could occur only when the annual offtake quantity of some LDC is smaller than AMQ or bigger than ACQ. We can expect that such a situation could happen only when there are: big changes in the demand profile of customers; too hot or too cold year; some big catastrophe like for example floods or bad decision making of the LDC management. The first two scenarios (changes in demand profile and weather conditions) would affect all LDC in the country, therefore all of them will have the same difficulties (too high or to small offtaken quantity) and so no trading would take place. The third scenario could affect only a part of LDCs or only one, but in this situation the force majeure provision is applied and so the annual offtake quantity of involved LDC is no more under AMQ, because the AMQ was decreased for the influence of the catastrophe.

Thus, trading could only occur when the management of LDC for some reason underestimated or overestimated the future gas demand of their customers. However this misestimating is very expensive. In the case of overestimating, the LDC has to sell the gas for a lower price than it bought it and in addition it has to pay shipping costs and hope for the free capacity in the system. The second possibility is that the LDC would pay for the non-offtaken gas to the seller according to the take-or-pay agreement, but in this situation no trading would occur. In the case of underestimating, the LDC could buy the gas from other LDCs, if they could spare it and there is free capacity, but for the higher price than is the formula price (the price they would pay to the seller if this gas would be contracted) plus the shipping costs. The second possibility is to buy the needed gas from the seller, but he will also probably demand some surcharge to the price.

Overall, the trading among LDCs is unlikely and if it happens the trading volume would be relatively small, thus we will assume non-existence of such trading.

## 2.2. The position of the seller

The seller has to be prepared to deliver the whole annual option quantity (AOQ), which he has granted in the sale agreement. In order to meet this obligation, his contracts with producers have to cover all ACQ belonging to the buyer. However, the seller doesn't know if the buyer will take whole ACQ. The seller only knows, that the buyer will offtake or pay the major part of the contracted gas (corresponding to the percentage value of take-or-pay clause in the contract), but whether the buyer would offtake also the remaining part is uncertain. Thus, the seller has to offtake the entire option volume of gas and wait to see, whether the buyer will need it or not.

The seller has also the option quantity in the contracts with the producers. If the option quantity were greater or equal to the sum of all AOQ that the seller granted to its buyers then the seller wouldn't face any problems and the following analysis would be needless. However the option quantity granted by the producers is not usually back to back, but much smaller. Therefore, as a simplifying assumption, we won't take into account the seller option flexibility in contract with the producer in the following part but at the end of the chapter.

Taken together, the best situation for the seller is when the buyer offtakes the whole option quantity. Then the seller has not any problems of disposing the gas elsewhere and any risks following form difference between the purchasing and selling price[17].

Unfortunately from the seller's point of view, this situation happens very rarely. It is more likely, that the buyer will offtake only part of the option volume. The reason for this statement is based on buyer's behavior when he is deciding about the size of ACQ in the contract.

## Optimal buyer's determination of the ACQ value

The buyer's optimal behavior about the setting of the ACQ size in order to profit the most from the granted option is following.

The rational buyer should firstly state the quantity of gas (let's denote it "X") which he anticipates to offtake according to the estimation of the expected demand of his customers. Then he should set the ACQ volume in such a way that his estimated volume "X" will be equal to the ToP volume (AMQ) plus half of the option volume (equation 2.1.).

$$X = AMQ + \frac{AOQ}{2} \qquad (2.1)$$

Under this condition, his expected offtaken volume (X) has the most favorable possibility to fluctuate to both directions, because it is situated in the middle of the option volume and can move up or down for AOQ/2 without any penalties for the buyer. The right half of the option volume (blanc part in the scheme 2.1.) provides the insurance against an increase in the gas consumption (colder winter then in average[18]) and the left half of the option

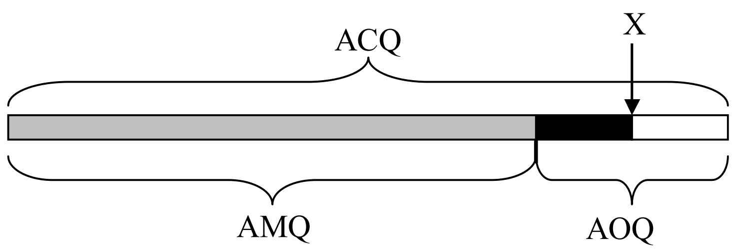
[17] Under the condition that either selling price formula is back-to-back to purchasing price formula or when he is hedged against the differences in these two formulas.

[18] The average winter temperature is important determinant of the customers' demand. However it is not possible to forecast the weather more then some days in advance with sufficient reliability. Therefore it plays the biggest uncertainty in the future gas demand.

volume (black part) provides the insurance against a decrease in the gas consumption (hotter winter than on average).

If the buyer's anticipations of the demand are correct, he will offtake only one half of the option volume. In reality, the expected demand would be different from the real demand and so the buyer will offtake very probably more or less gas than is "X". However, the possibility that he will need more gas than ACQ (or less then AMQ) is less probable and would happen only in the case of extremely hot or cold year[19].

**Scheme 2.1.:** Setting the ACQ with respect to estimated demand of customers




Source: Author

From the above description it follows, that the situation when the buyer doesn't offtake the whole option quantity of gas but only a part of it, is very likely. Then the seller who has already purchased the gas from the producer has to store it and try to sell it to someone else. The resulting seller's risks are difficulties to sell the gas, storage costs and the difference between the purchasing and selling price.

[19] It can also happen in a situation of a sudden great change in the customers' demand behavior caused by government decision about preferential treatment of one kind of energy, by changes in the energy taxation or by other big market changes. In such cases we can suppose that the contract would be renegotiated e.g. using price reopener clause or other.

## 2.3. Option evaluation

As we have seen before, we can't evaluate the embedded option using formulas for financial options, because the option provides only the offtaking flexibility to the buyer so that he can react on the changes in demand of his customers. For that reason we will use another approach which can be called costs evaluation method. We will look at the option from the seller's point of view. Firstly, we will evaluate the costs connected with the not offtaken option gas quantity. In the following part of this chapter we will show what are the seller's possibilities of how to implement these expected costs into the gas sales contract.

### 2.3.1. Approximation of seller's costs for not offtaken gas

For the option evaluation, we have to first approximate, what are the seller's costs for not offtaken gas. Let's denote "C" as the total costs per one unit of gas (for example one thousand $m^3$). We will also assume that the seller will sell the whole not-offtaken option gas at one specific time to one subject for the same price. Then, for the costs approximation we can use the following equation 2.2.:

$$C = T_{storage} \cdot C_{storage} + \left[ P_{purchasing} \cdot (1+r)^t - P_{selling} \right] + C_{shipping} + C_{transaction}$$

(2.2.)

Where: $T_{storage}$ represents storage time in days

$C_{storage}$ represents the costs of storage of one unit of gas for one day

$P_{purchasing}$ represents the purchasing price of one unit of gas

$P_{selling}$ represents the selling price of one unit of gas

$r$ represents annual rate of return of alternative using of employed capital

$t$ represents time in years between the gas purchasing and selling

$C_{shipping}$ represents the shipping costs of one gas unit to the new buyer

$C_{transaction}$ represents transaction costs

From the equation 2.2, we can see that we can decompose the total costs of one gas unit into four parts. The first part corresponds to storage costs for the period from the option gas purchase to the option gas sale. The second part includes the costs related to the difference between the purchasing and selling price. Here, we have to also take into account that the seller's company has already paid some capital for the gas in the time of purchasing and couldn't dispose with this capital till the time when the gas is sold. For that purpose, we have to include the lost profit from the employed capital, which could be invested somewhere else for the rate of return "r". The third part represents the shipping costs to the new founded buyer. The last part of costs comprises transaction costs related to the selling procedure (costs to find the new buyer).

We can replace the purchasing price by the price for which the seller has expected to sell the gas to the buyer. It means by the price depending on the gas price formula, which is stated in the sale contract between these to parties. As we know, this price is not fixed, but it is changing every month, so there are twelve different prices during a year. For our costs evaluation, we will take the December price, since the option gas is the last amount of gas the seller expects to sell.

## 2.4. Costs implementation into the gas sale contract

Let's suppose that we have been able to estimate average costs per one gas unit. The next logical step is how to implement these seller's costs to the gas sale contract so that both parties would be satisfied.

Definition of the terminology for the further equations:

O Option gas quantity expressed in gas units

$N_o$ Number of gas units in the option gas quantity

T Offtaken quantity from the option quantity expressed in gas units

C Seller's costs for one not-offtaken unit of gas (option quantity and offtaken quantity is dividable by the unit of gas)

P Price per one unit of gas (determined by December's gas price formula)

$P_f$ Final price per one gas unit paid by the buyer for each unit of gas offtaken from the option gas quantity

### 2.4.1. Take-or-pay provision

The simplest way how the seller could retrieve the costs from the buyer, is to include another take-or-pay provision in the sale agreement. This provision would be related to the option quantity of gas and would mean that the buyer has to pay price "C" for every not offtaken gas unit from the option volume. It means that his payment would correspond to the quantity of gas he has not offtaken (less of the option gas he offtakes more he would pay). The payment day could be sometime in the January in the following year.

The amount of the payment is equal to:

$$C*(O-T) \qquad (2.2.)$$

Consequently, for all offtaken gas from the option quantity the buyer would pay the price equal to:

$$P*T+C*(O-T) \qquad (2.3.)$$

From this result, we can derive final price per one gas unit taken from the option gas quantity:

$$P_f = P + C*\frac{(O-T)}{T} \qquad (2.4.)$$

where the second part represents the surcharge per one gas unit.

From the last expression, we can see that the buyer pays the same price that is obtained by the gas price formula only when he offtakes the whole option quantity. In all other situations the buyer pays a higher price than is the price obtained by the price formula.

This approach is advantageous to the seller. He doesn't undergo any risks (except the bad estimation of the "C") and moreover the used method forces the buyer to sell the whole amount of annual contracted gas which is in seller's interest, because it raises his profit. However, the disadvantage of this method from the seller's view is the buyer's refusal of such a proposal, because he would likely be against another take-or-pay provision, when he already has one on the main part of his ACQ.

### 2.4.2. Surcharge

The second way how the seller could retrieve the costs from the buyer, is to include a surcharge for the gas option quantity in the sale agreement. The question is in what manner it should be paid and how big should the surcharge be?

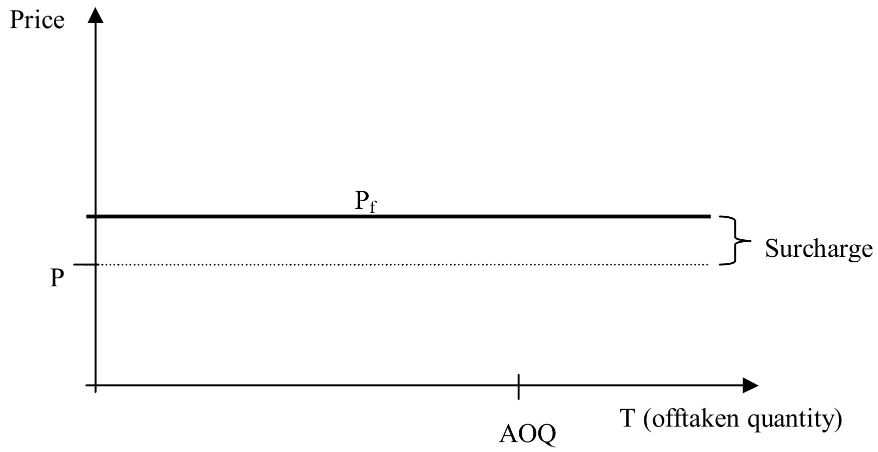
#### 2.4.2.1. Surcharge included in the gas price formula

There exist at least two possibilities how the buyer could pay the surcharge. One is that the surcharge would be included in the price of the option gas. It means that after the buyer offtakes the AMQ, the price of gas wouldn't be determined only by the agreed gas price formula, but the price of gas option quantity would be composed of two elements: the price determined by the gas price formula and the surcharge, which amount would be constant and settled in advance.

$$P_f = P + surcharge \qquad (2.5)$$

Under this surcharge approach the price of one gas unit of the option quantity would be higher than the price of one gas unit of the take-or-pay quantity (figure 2.1.). The buyer shouldn't protest against such a pricing because he should understand that he has to pay for the obtained flexibility.

**Figure 2.1.:** The final price of one unit of gas



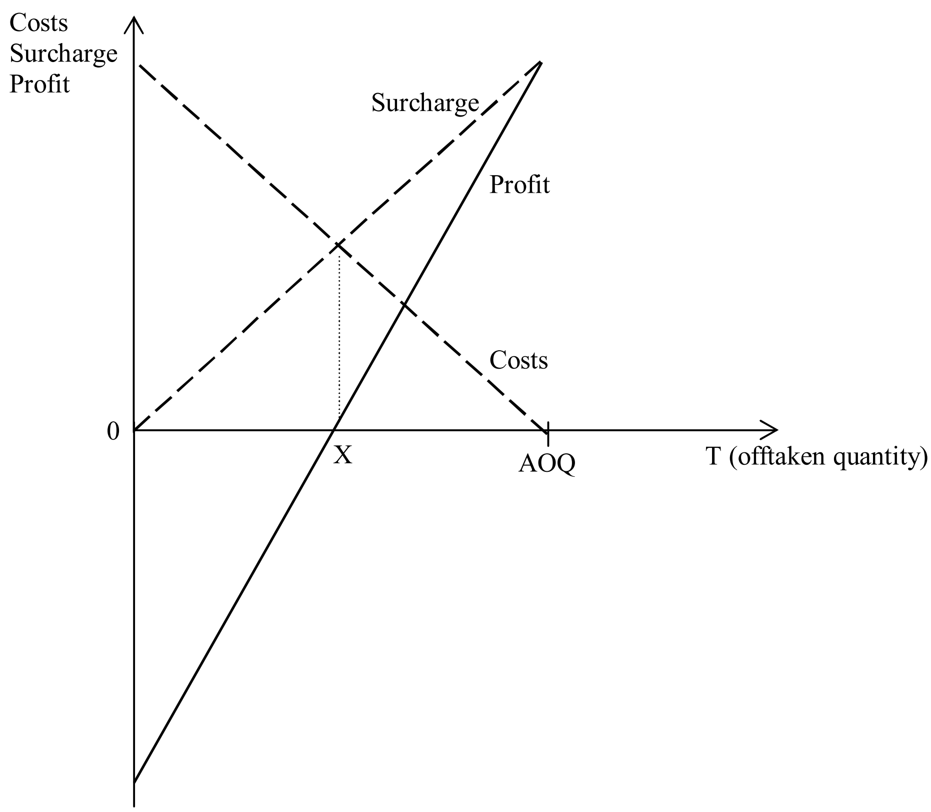

Source: Author

The inconvenience is that the buyer won't be motivated to sell as much gas of the option quantity as possible, because the marginal price of gas would be higher than the average price of gas.

Another disadvantage is that the seller would get the surcharge only for the offtaken amount of the option gas quantity. However, the seller's costs come from the not-offtaken part of the option quantity. Thus, the flows of the costs and the surcharge would be unbalanced (figure 2.2.).

For example, the total amount of the surcharge will be small when the buyer offtakes only a small amount of the option quantity of gas, whereas the seller's costs would be high, because the large part of the option quantity will remain to him and he will have to dispose it elsewhere. In the opposite situation when the buyer offtakes almost the whole amount of the option quantity, the seller's costs would be low while the received surcharge would be high. In general, the seller's profit will be negative up to some amount quantity "X" and positive after this point as shows the curve "profit" in the figure 2.2.

**Figure 2.2:** Unbalanced surcharge and costs




Source: Author

Overall, although this approach initially seems good and easy to implement, it doesn't look appropriate for our objectives.

#### 2.4.2.2. Fixed surcharge

The second possibility is to state the fixed surcharge for the whole option quantity. The buyer will pay the surcharge to the seller whatever his offtaken quantity would be[20]. Then the price of one gas unit of the option quantity would be:

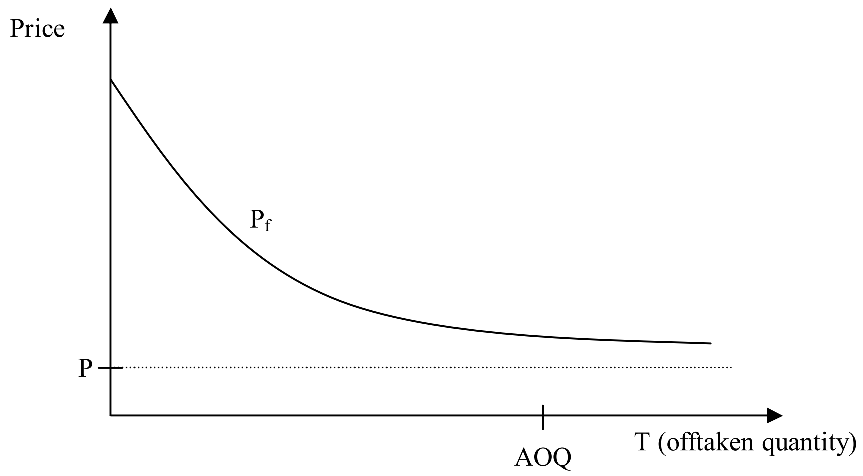
$$P_f = P + surcharge/T \qquad (2.6.)$$

[20] There exist a lot of methods of payment for which the parties can agree to (e.g. monthly installments). We don't need to consider this subject in the analysis since it doesn't depend on which one they choose.

This equation would be the same as the equation (2.4.) if the surcharge were C*(O-T), which means depending on the offtaken quantity. However, in this case it is different, because the surcharge is not floating, but fixed.

From the equation 2.6., we can derive that the price of one unit of gas is decreasing when the offtaken quantity of the option gas quantity increases. It is because the surcharge is divided by more and more units of gas. However, the price of one gas unit would be still higher than the price determined only by the gas price formula, even if the buyer offtakes the whole option quantity (picture 3.2.).

**Figure 2.3.**: The final price of one unit of gas in the situation of the fixed surcharge




Source: Author

The above picture 3 and the statement derived from it are valid no matter how big the surcharge would be. The only differences resulting from the changes of the surcharge value will be the size of the curvature and the starting point of the "$P_f$" curve.

This approach together with the suitable chosen amount of the surcharge is convenient to the seller. It provides the positive cash flow which would cover the possible costs and it motivates the buyer to offtake as much of the option quantity of gas as he can. The problem is whether the buyer would accept such a proposal. He may require that he should pay the same price as is obtained by the gas price formula when he offtakes the whole option quantity. Consequently, the corresponding price equation would be:

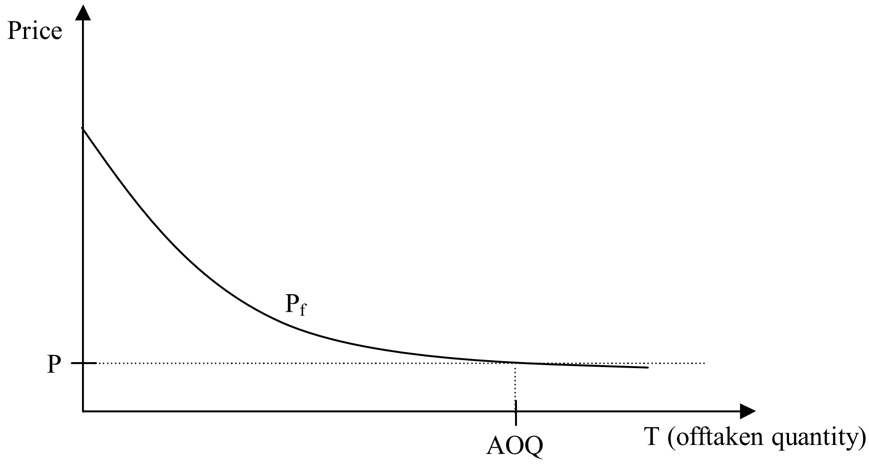
$$P_f = P' + surcharge/T$$

where $$P' = P - surcharge/O$$

after the substitution we get $$P_f = P - surcharge/O + surcharge/T$$

From the last equation it follows that if the offtaken quantity is equal to the option quantity (T = O) then the price per one unit of gas is equal to the price determined by the gas price formula ($P_f$ = P). The only change between this and the previous method is that the "$P_f$" curve has moved a little lower (figure 2.4.).

**Figure 2.4.:** The final price of one unit of gas




Source: Author

In this approach the buyer pays the surcharge in advance and thereafter he offtakes the gas for the lower price than is obtained by the gas price formula, which motivates him to increase his offtaken quantity. Once the buyer has paid the surcharge he decides only by the price of gas, because the surcharge payment is the sunk costs for him.

Analogically as in the previous example, (in the case when the seller has weaker negotiating position) the seller can set the price of the option gas in such a way that the "$P_f$" curve will move even lower. Then for example, the price of the first half of AOQ will be above the formula price and the price of the second half of AOQ will be lower then the formula price. Such a price setting would be more acceptable for the buyer and it will motivate him to offtake more then half of the AOQ in order to profit from the quantity discount.

#### 2.4.2.3. Fixed "hidden" surcharge

In the previous examples we have supposed that the seller claims the surcharge payment for the granted option from the buyer who pays it in several instalments. However from the seller's practical point of view it can be better to implement the surcharge into the gas price formula which applies on the take-or-pay gas and then to use surcharge unaffected price formula on the option gas (Figure 2.5.a).

If the seller has a strong dominant position then he can manage either to completely hide the existence of the surcharge or more probably not to disclose the true full value of the surcharge to the buyer (conceal the part of it).

This approach is very advantageous from the seller's angle. In both cases it would improve the seller's bargaining position, because he won't be requiring any surcharge or lesser part than he would be requesting in reality. It also assures that he will collect the whole surcharge value. By the separation of the surcharge from the option gas quantity, the price of the AOQ will be lower than is the price of the AMQ. Implementation of this quantity discount[21] will motivate the buyer to offtake more gas and it will help him to offer higher quantity discounts to the customers. The buyer may also rather accept the agreement in which he is getting the quantity discount than the contract where he has to pay more for the marginal offtaken gas then for the average gas.

Moreover this approach would help the seller to maintain a dominant position after the opening of the gas market. As the main part of the gas trading is subject to the take-or-pay clause and will remain for a long time after the Czech market opening, the first emerged competitive trading will concern the optional gas. The seller in a dominant position will be able to cross-subsidize the price of the optional gas from the price of the take-or-pay gas. Consequently he will be able to offer a better price then other market participants. Hence he will maintain his dominant position in the market with the marginal gas.

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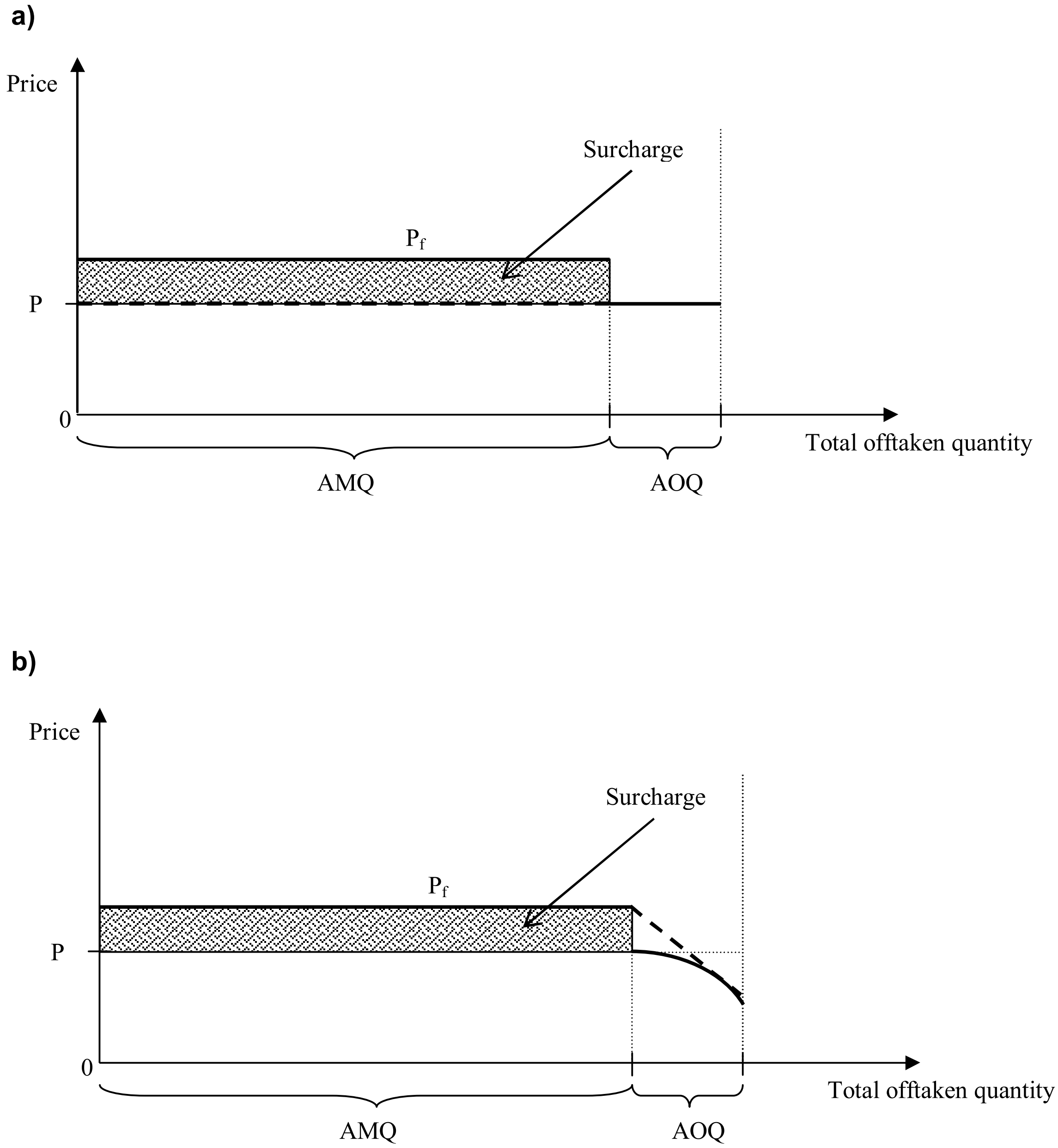
[21] The quantity discount can take various forms (figure 2.5.b) depending on how much the seller needs to motivate the buyer.

**Figure 2.5.:** Surcharge implemented into the price of the take-or-pay gas




Source: Author

#### 2.4.2.4. Surcharge value

The important point is the value of the surcharge. It is obvious that the seller would like to obtain as high surcharge as possible and on the other hand the buyer would like to pay the lowest possible amount. The final value of the surcharge will be the result of tough bargaining between these two parties[22]. Therefore, the final amount will depend on which of these two parties has a stronger position in the negotiation.

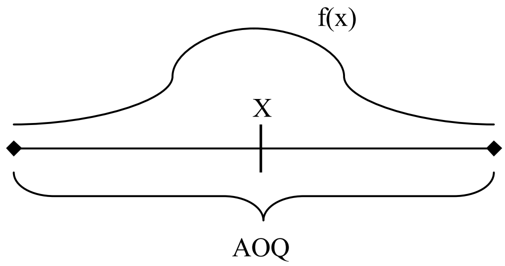
For the purpose of our analysis it is sufficient to propose a value of the surcharge that would be the lowest feasible for the seller. It means such a value of the surcharge, which ensures that the seller won't have any losses or any profit related to the option granting.

In order to state such a surcharge the seller would need to know the exact future buyers demand of gas, which is not possible. He can try to estimate it and set the surcharge according to the forecasted value of the total offtaken quantity. However the forecasting is very difficult, because he doesn't have the access to all needed information about the buyer's customers so his estimations would be more inexact then the buyer one's.

The second possibility is to choose such a value of the surcharge so as it will assure that the seller's balance will be neutral in the long-term. For that purpose, we can start with the argument about the optimal buyer's determination of ACQ in the beginning of this chapter and suppose that the buyer's estimated future consumption is equal to "X" which is equal to AMQ plus half of the option quantity (as is described in the scheme 2.2.). It is certain that his real offtaken quantity won't be equal to his estimated quantity, but it is more likely that it will be close to "X" than far from "X". Moreover, we can expect that the final offtaken quantity would have the same probability to be on the left or on the right side from the point "X". Based on these facts we may approximate the probability distribution of the final offtaken quantity as is described in the figure 2.6.

[22] The outcome of the negotiations typically follows the two party bargaining model with non-unique equilibrium. The exact equilibrium depends on the relative bargaining strengths of the parties including the ability to hold out and deploy bluffs and counter-bluffs. For a more complex interpretation of the two party bargaining model see, e.g., Layard (1978).

**Figure 2.6.**: The probability distribution of the offtaken quantity




Source: Author

In the situation when the seller has several buyers (N), we can expect that some of them ($n_1$) will offtake more than is their "X"s and some of them ($N-n_1$) will offtake less than is their value of "X"s. But taken together, we expect that the total offtaken quantity of all buyers will be equal to the sum of their X. It means that the sum of the quantity that the buyers ($n_1$) will exceed their "X"s by, will be equal to the sum of the quantity that will remain to the buyers ($N- n_1$) to reach their "X"s.

Since, we have found that the average offtaken quantity will be equal to "X", we can deduct the minimal value of the surcharge, which is equal to the costs of disposing of half of the option quantity (i.e. C*(O/2)).

As we have mentioned before the seller has also some optional quantity granted him by the producer. The impact of the seller's flexibility in the analysis is obvious. The seller should imply all his AOQ into the surcharge calculations. It would mean that sum of all AOQ of the LDCs would be decreased by the seller's flexibility and the surcharge would be applied at a smaller quantity than before. More precisely, the quantity of each individual AOQ should be decreased proportionally to its size on the total optional quantity granted by the seller to all of his buyers. Consequently the value of the surcharge required by the buyer will be less than before. Another seller's possibility is to keep his AOQ out of the surcharge calculations to have some free space to react on an unexpected development.

# 3. OPTION IN THE SITUATION WITH THE EXISTENCE OF THE SPOT MARKET

## 3.1. The emergence of European gas trading

The main premise of the second part of this paper is the existence of liquid gas market in EU. Future gas trading should occur around the hub or a system of hubs[23] at which gas can be traded at spot markets. A precondition for a hub is that natural gas supplies coming from different sources meet each other at the hub. Within continental Europe the primary candidate for such a hub would be Zeebrugge, where supplies from Norway, the United Kingdom and LNG meet each other. Other future 'would be hubs' could be located anywhere in Europe (figure 3.1.), provided that several independent supplies and pipelines meet at one point. The liquid hub will offer contractual diversification, price discovery, balancing opportunities and risk-management capability connected with the derivatives trading. Experience with a hub-based system in the United States indicate that such a system significantly reduces the disadvantages of regulated TPA combined with full unbundling, while at the same time retaining the advantages of competition (Oostvoorn, 1999).

However, creating such a gas market may be a slow process. The institutional conditions stated in European Directive 98/30 are developing slowly but favorably. At the access rules level, we are moving towards a regulated third party access consolidated by the legal separation of transport networks and storage capacities in all countries. The integration of national markets will be realized by the harmonization of the various tariffs for transportation and the laying down of rules for cross-border exchanges.

[23] The joint valuation problem in a hub-based system is solved by jointly allocating property rights of gas and transport capacity. Sellers transport gas to the hub, buyers from the hub. Gas trade occurs at the hub. The main advantage of a hub-based system is that it decreases the complementary nature of gas and its transportation: it solves the matching problem between gas and transportation. In a hub-based system, gas without the capacity to transport does not exist, since prices would go up. This would reduce the demand for gas and hence the need for transportation capacity.

The shady side is that in fact the gas industry and its institutions are shaped, and will remain to be, by the basic conditions of the production. Upstream from the national wholesale markets, gas supply sources are directly international in most European countries (5 major supplier countries, only two of which are European Union Member States). The existence of major producers and major sellers limits the evolution of spot trading for several reasons:

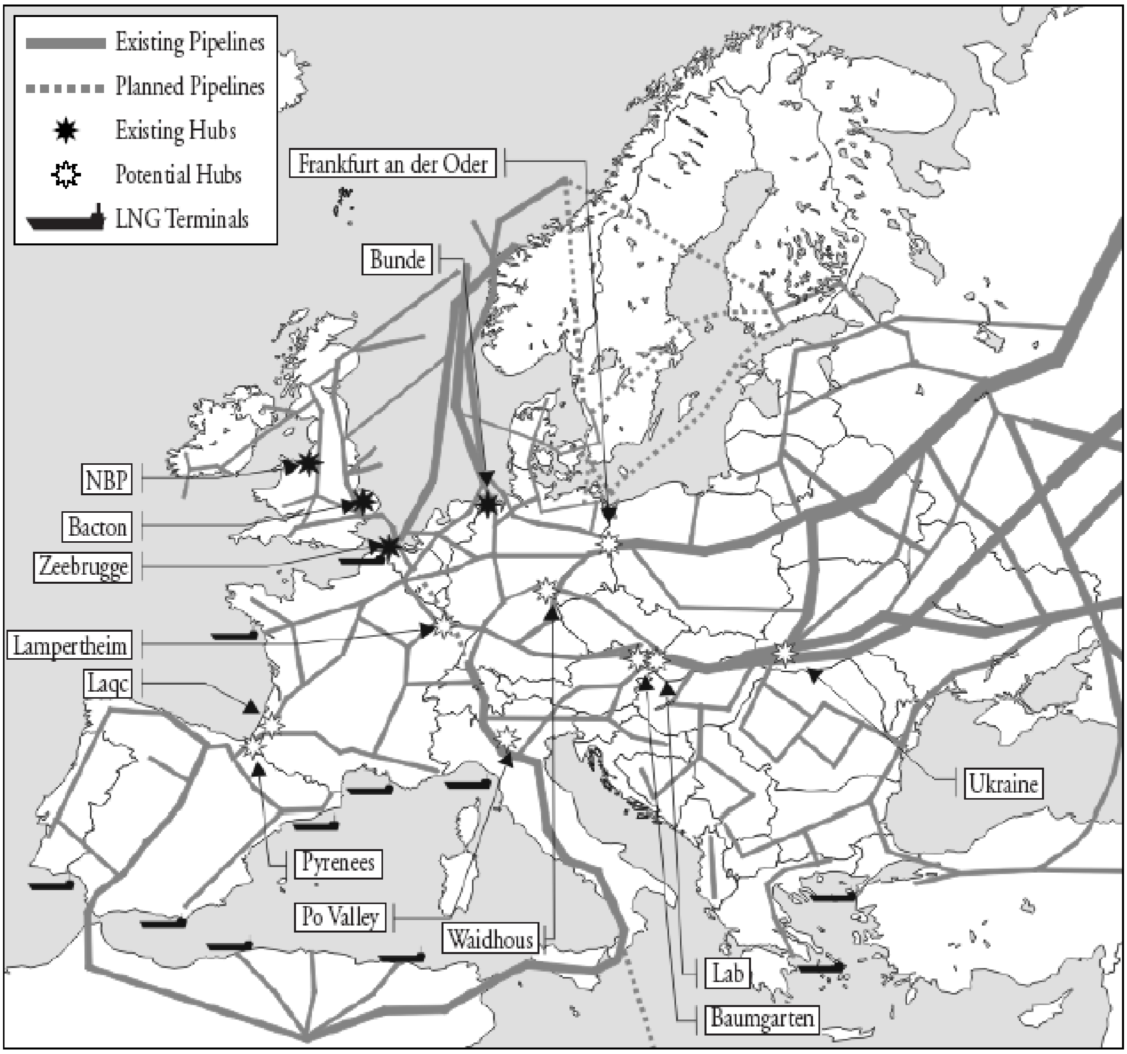
- Firstly, the suppliers have huge long term contracts to defend. They will be hesitant to trigger a price war, and they may be reluctant to stimulate spot trading that may undermine their vested interests in the long-term *take-or-pay* contracts.
- Secondly, the existing contracts do not let sufficient field for "free gas" which is not "contractualized" and allow a sufficient liquidity on the continental marketplaces. In order for the multi-hub European market to establish itself, alongside the British NBP spot market, at least two of the continental hubs should reach a certain level of liquidity.
- During the gradual phasing out of existing contracts over the next fifteen years, internal competition in each country will remain limited, with a wholesale price based on the contractual reference to oil prices for most of the major suppliers' purchases.
- The territorial restriction clause in existing contracts for Algerian and Russian exports limits changes in trade between Member States because it restricts the possibility of buyers' reselling gas outside their respective territories. However, the first breakthrough in this area has already happened[24].

Under these conditions, the emergence of a European gas market will be a slow process, which needn't be ever accomplished if the number of producers will fall. Only in the situation with new sources of upstream gas can we hope for

[24] The Italian oil and gas company ENI managed in 2003 renegotiate number of restrictive clauses in their existing contracts with the Russian gas producer Gazprom. Under the new settlement, ENI is no longer prevented from reselling, outside Italy, the gas it buys from Gazprom. The latter is free to sell to other customers in Italy without having to seek ENI's consent.

a gradual development of spot trading. Spot market existence is supposed in the remaining part of the paper.

**Figure 3.1.**: Existing and Possible Gas Hubs in Europe




Source: Cornot-Gandolphe (2002)

## 3.2. The option's characteristics

When both parties of a gas sale contract have access to the spot market with natural gas, the situation that was described in the previous part is no longer valid. With the spot market existence the granted option no more represents only some offtaken quantity flexibility offered to the buyer. In this new situation the buyer has an opportunity to exercise the option. He can sell the gas at higher price in the spot market and make a cash profit. Thus, we can see that it is possible to look at the option as a financial option and evaluate it using formulas for options' derivatives.

### 3.2.1. Definition of the option

An option is a derivative instrument, meaning that its price is derived from the price of another security. More specifically, an option price is derived from the price of an underlying asset. Every option represents a contract between a buyer and a seller. The seller (writer) has the obligation to either buy or sell an underlying asset (depending on what type of option he sold[25]) to the buyer at a specified price by a specified date. Meanwhile, the buyer of an options contract has the right, but not the obligation, to complete the transaction by a specified date. When an option expires, if it is not in the buyer's best interest to exercise the option, then he or she is not obligated to do anything. Hence, the buyer has purchased the option or the possibility to carry out a certain transaction in the future.

In our case the seller grants an option to the buyer. This option is a call option and gives to the buyer the right, but not the obligation, to purchase the option quantity of gas for the agreed price. Before the specification of the option characteristics I will show that the granted option is not one call option, but the series of call options with the same characteristics.

### 3.2.2. Number of the options

The total amount of the option, which the seller grants to the buyer, is equal to AOQ. However, the buyer, holder of the option, doesn't have to exercise the whole option quantity at one time. He can exercise any part of the option at any time he wants up to its expiration date. He can also exercise only a part of the total option quantity and the rest would remain unexercised. According to these findings, we can look at the embedded option as a portfolio of many small options with the same characteristics.

The concrete number of the options would be equal to the amount of the quantity expressed in the lowest traded unit. For example: if the lowest trading unit is expressed in MWh, then some hypothetic AOQ equal to 1000 MWh would mean that the seller grants 1000 options of 1 MWh to the buyer. Since the value of AOQ is usually equal to millions of MWh, we would have millions of

[25] either a call option or a put option

the small options. Fortunately, there is a way we can decrease the number of options to a reasonable amount.

We have to take into account that in the spot market there is stated a minimum tradable quantity of gas (MTQ). Therefore the buyer has to sell at least that minimum quantity, in order to exercise the option. Consequently, the quantity of one option is equal to the minimum tradable quantity of gas. So, we can assume that the number of the options included in the embedded option (let's denote it N) is equal to AOQ/MTQ.

### 3.2.3. Type of the option

The style or family of a financial option is a general term denoting the class into which the option falls, usually defined by the manner in which the option may be exercised. The two great families are European and American. An European option may be exercised only at the maturity of the option, i.e. at a single point in time. American options give the holder the right to exercise the option at or before the expiry date. This characteristic of American options renders solutions to value them difficult and somehow almost impossible. On the other hand the evaluation of European style option is much easier.

In our case it is difficult to assess if we should look at the embedded option as the American or European type. In the sale contract, it is stated that the first delivered gas corresponds to the quantity where the take-or-pay provision applies. After the buyer offtakes the whole take-or-pay quantity (AMQ) he can start offtaking the option quantity and thereby take advantage of the embedded option. Therefore the last gas, which the seller is delivering to a buyer during a year, is the option gas quantity. It would mean that the buyer is exercising the option in the last months, which can be the truth from the seller's view but not from the buyer's view, which we will show later in this chapter.

### 3.2.4. General characteristics

- *Maturity of the option* - the maturity or the expiration date of the embedded option depends on the sale contract specificity and it is usually the end of the calendar year. As we will show later the set of options will have different maturities

- *Strike price* - the exercise price of the option is determined by the gas price formula (for example: $P = P_0 + \alpha*(GO-GO_0) + \beta*(FO-FO_0)$). The value of the strike price changes at the start of every month. Therefore, there are twelve different strike prices during a year: $S_{Ti}$ where i = 1, 2, …, 12.

- *Spot price* – The spot price is determined by the supply and demand of natural gas in the concrete spot market. It is influenced by the surplus or lack of free gas available to trading (example: gas hub Zeebrugge). The spot price changes every trading day. The important point is that the spot price does not strictly depend on the strike price. There is a different dynamics of price movement. The spot price is determined by the offer and the demand of gas at a specific time, while the strike price is determined by the average of the different oil prices for several previous months.

### 3.2.5. The option's payoff

The buyer will exercise the option and make a profit if the spot price is bigger then the strike price. In order to exercise the option the buyer has to transport the gas to the spot market (to the corresponding hub). Thus, the shipping costs associated with this transmission lower the buyer's profit from the option's exercising. Taken together the buyer's payoff is:

$$Payoff = P_{spot} – P_{strike} – C_{shipping}$$

## *3.3. Factors influencing the option's exercising*

### 3.3.1. The buyers possibilities to exercise the option

In order to decide about the style of the option and to set the right expiration dates for the (N) options that are embedded in the contract we should look closer at the buyers' offtaking characteristics and also study how and when the buyer could exercise the embedded option.

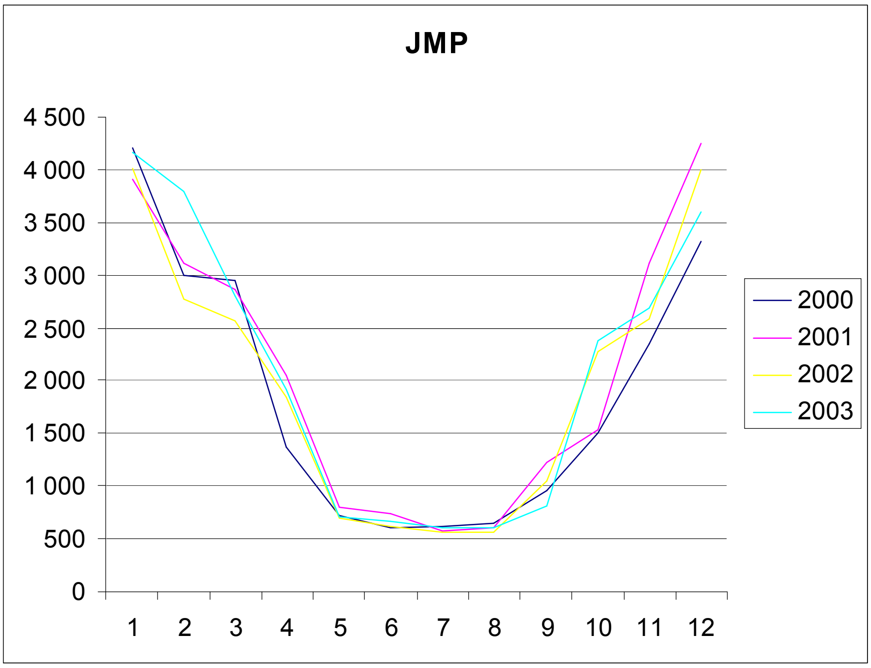
#### 3.3.1.1. The buyer's offtaking characteristics

As an example of buyers we have chosen two local distributing companies: Jihomoravská plynárenská (JMP) and Severomoravská plynárenská (SMP). The reason to choose these two companies was the difference in the structure of their customers. If we divide the customers into two groups: households and industry, we can say that the part of households of the total number of the customers is bigger at JMP than at SMP. Therefore, the industry customers play a more important role at SMP.

**JMP**

In the graph 3.1. we can see that in the case of JMP the pattern of the offtake is U-shaped and is quite similar every year. JMP is offtaking the highest quantity of gas in the winter period (January, February, March, November and December). In the summer period (May, June, July, August and September) the offtaken quantity is about six times smaller and in April and October the offtaken quantity is somewhere in between.

**Graph 3.1.:** Monthly offtaken quantity of JMP in the period 2000 – 2003 (in million kWh)

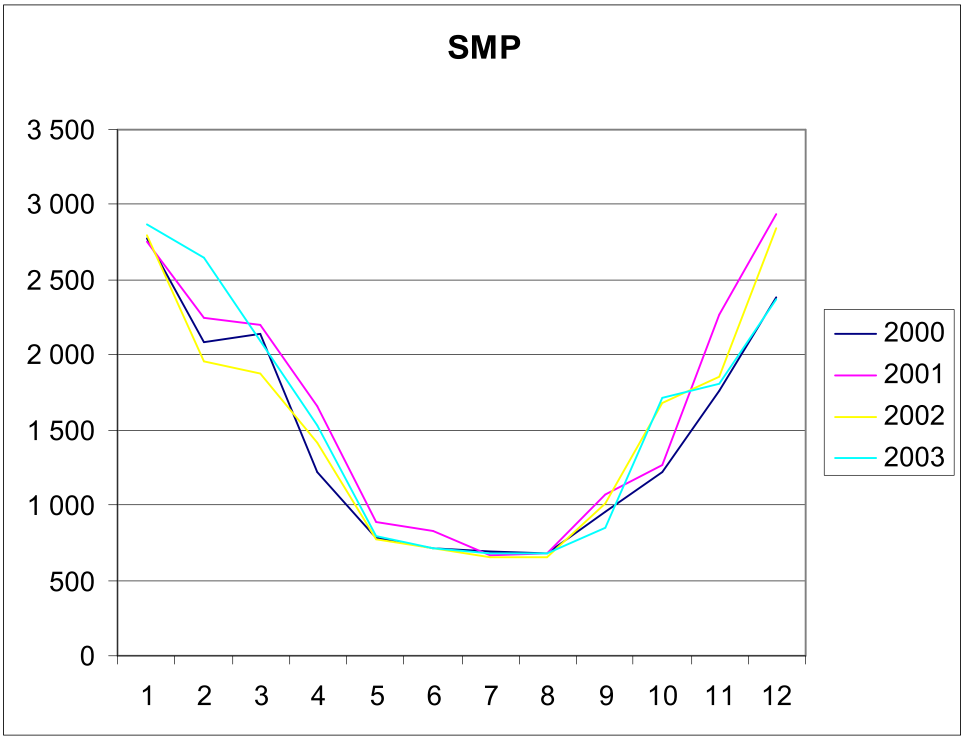



Source: Transgas a.s.

**SMP**

In the following graph 3.2. we see that the offtaking characteristics of the SMP are similar to the JMP. Monthly offtaken quantity is U-shaped with the peak period in the winter and off-peak period in the summer. However the contrast between the peak period and the summer period is not as big as was the case of the JMP. The reason could be explained by the fact that the households' consumption varies more during the year than the consumption of industry customers. Thus, the household consumption is more weather dependent.

**Graph 3.2**.: Monthly offtaken quantity of SMP in the period 2000 – 2003 (in million kWh)




Source: Transgas a.s

The following table 3.1. is illustrating the volatility of the total annual offtaken quantity. We can see that the annual consumption of LDCs' customers varies substantially from year to year. The source of the volatility is mainly the weather, because the gas is consumed by the main part for heating during the winter. This proposition is valid more for the households than for the industry where the gas is mainly used for technological purposes as a part of inputs. As the weather is highly unpredictable, the buyers can face the volatility by having the offtaking flexibility in the contract with the seller or by using the weather derivatives, which are unfortunately still immature and can't provide for an appropriate hedging.

**Table 3.1.**: Annual offtaken quantity of JMP and SMP (in mil. kWh)

| | 2000 | 2001 | 2002 | 2003 | average |
|---|---|---|---|---|---|
| **JMP** | 22 257 | 24 773 | 23 537 | 24 722 | 23 822 |
| **SMP** | 17 432 | 19 456 | 18 229 | 18 759 | 18 469 |

Source: data - Transgas a.s.

From the development of the monthly offtake quantity we can derive that at the beginning of the year the buyer can't estimate the annual demand of his customers' very accurately. Moreover, even at the end of September he can't be sure about the total demanded quantity, because the large part of his demand still remains unknown.

Note that the both above examples are from the market situation when the buyer doesn't have the access to the spot market. It means that all the offtaken quantity is used to satisfy the demand of the customers, which is his primary obligation. Therefore, we can suppose that the above monthly offtake quantity is equal to the demand of buyer's customers.

The implication for our option analysis is as follows. The buyer has two reasons to offtake the gas from the seller. His first motive is to satisfy the demand of his customers that he has to fulfill every day. His second reason is to sell the gas in the spot market. Therefore we can state that any time the buyer offtakes more gas than is the demand quantity of his customers he is offtaking the option gas. This situation can occur whenever during a year. It implies that each from "N" options, which are embedded in the sale's contract, can be exercised any time up to its maturity. Thus we have identified that the option is the American style option.

#### 3.3.1.2. <u>The daily unused quantity</u>

As the buyer's offtaken rate is limited by the daily maximum offtaken quantity, it takes him some time to offtake and sell all the option quantity of gas. In order to estimate the needed time, we have to look closer at the buyer's daily offtaken quantity.

We need to know what quantity of gas the buyer could offtake to sell in the spot market. This amount of gas corresponds to the daily quantity for which the buyer has the right to offtake, but he doesn't use. The daily unused offtaking quantity (DUQ) is equal to the maximum daily quantity (MDQ) which the buyer can offtake from the seller without any penalty minus the daily demanded quantity of his customers (DDQ).

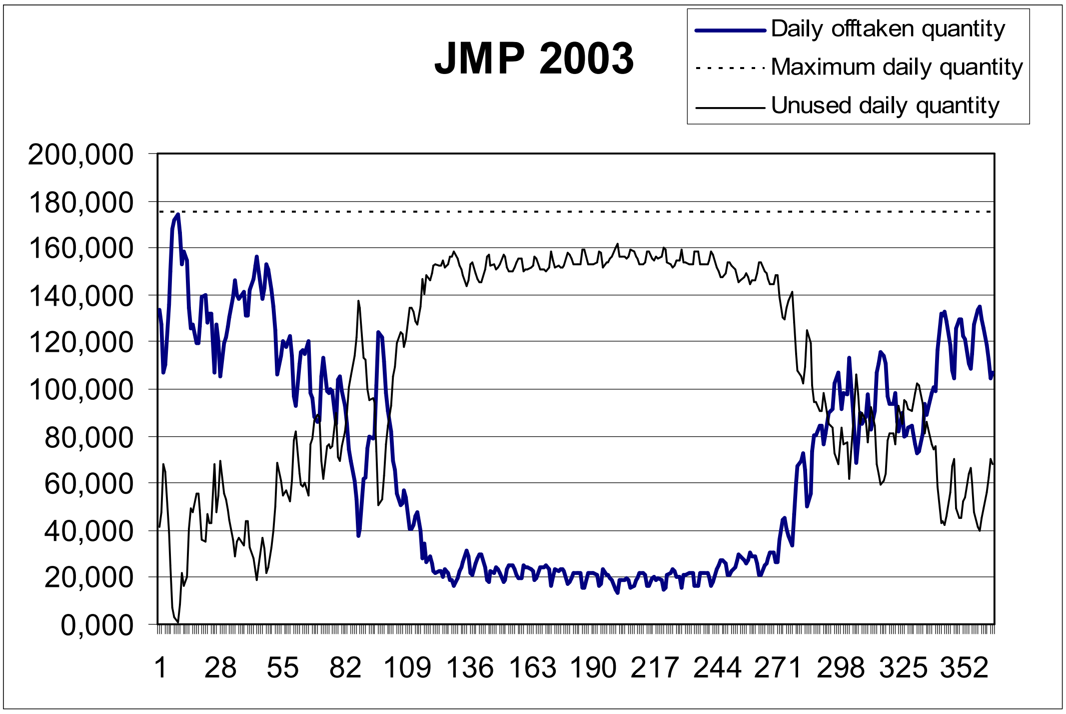
$$DUQ = MDQ - DDQ \qquad (3.2.)$$

The daily unused quantity is a very important factor for the option exercising. It determines how much gas the buyer can daily buy from the seller in order to sell it in the spot market. It sets the maximal quantity of gas that can be exercised in the specific day. Also it determines how long it takes for the buyer to exercise the whole option amount (AOQ). The bigger the daily unused quantity, the faster the buyer can exercise the embedded option.

As an example, we can focus on the JMP in 2003. Because the daily maximum quantity (MDQ) is not publicly available, we suppose that it is equal to the highest daily quantity, which was offtaken by the JMP during the year 2003 (174,5 mil. kWh). To determine the daily demanded quantity of the customers we can suppose that it is equal to the daily offtaken quantity in the year 2003, because JMP didn't have access to the spot market and so it has no other reasons to offtake the gas than to sell it to its customers. Then we compute the daily unused quantity (DUQ) as a difference between the MDQ and daily offtaken quantity.

In the graph 3.3., we can see that the daily offtaken quantity is volatile, but the look is similar to the monthly offtaken quantity. The DUQ is also volatile and looks as an upside-down daily offtaken quantity.

**Graph 3.3.:** Daily offtaken quantity of JMP in 2003 (in million kWh)




Source: data - Transgas a.s., (own calculations)

Because the daily unused quantity varies a lot, it would be better to compute monthly averages of the DUQ. The following table 3.2. shows the average daily unused quantity (ADUQ) in different months for JMP and SMP.

**Table 3.2.**: JMP and SMP average daily unused quantity (in mil. kWh)

| | JMP | | | | | SMP | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2000** | **2001** | **2002** | **2003** | **average** | **2000** | **2001** | **2002** | **2003** | **average** |
| **Jan** | 35 | 52 | 47 | 40 | 44 | 15 | 36 | 30 | 33 | 28 |
| **Feb** | 62 | 67 | 77 | 39 | 61 | 29 | 44 | 50 | 31 | 39 |
| **Mar** | 76 | 86 | 94 | 84 | 85 | 36 | 54 | 59 | 58 | 52 |
| **Apr** | 125 | 110 | 114 | 111 | 115 | 64 | 69 | 73 | 74 | 70 |
| **May** | 148 | 152 | 154 | 152 | 151 | 80 | 96 | 95 | 100 | 93 |
| **Jun** | 151 | 154 | 155 | 152 | 153 | 81 | 97 | 96 | 102 | 94 |
| **Jul** | 151 | 160 | 158 | 155 | 156 | 83 | 103 | 99 | 104 | 97 |
| **Aug** | 150 | 159 | 158 | 155 | 155 | 83 | 103 | 99 | 104 | 97 |
| **Sep** | 139 | 137 | 141 | 147 | 141 | 73 | 89 | 86 | 97 | 86 |
| **Oct** | 122 | 129 | 103 | 98 | 113 | 65 | 84 | 66 | 70 | 71 |
| **Nov** | 93 | 75 | 90 | 85 | 86 | 46 | 49 | 58 | 65 | 55 |
| **Dec** | 64 | 42 | 47 | 58 | 53 | 28 | 30 | 28 | 49 | 34 |

Source: data - Transgas a.s., (own calculations)

According to the monthly average of the daily unused quantity we can divide the year into three periods:

1. From January till the middle of April, the buyer can't sell a lot of gas in the spot market, because the buyer uses a large part of the maximum daily quantity to satisfy the demand of his customers.
2. From the middle of April till the middle of October, the unused quantity is two to three times greater than in the previous period.
3. From the middle of October to the end of December, the unused quantity is smaller than in the second period, but greater than in the first period.

#### 3.3.1.3. The time of the option exercising

Let's suppose that the buyer wants to sell the whole AOQ at the end of the year. As the buyer's offtaken rate is limited, he is not able to complete the transaction in one day. He has to start to offtake the option gas in advance of some "D" days to be able to sell all the AOQ in the spot market till the end of the year. The number of days "D" necessary to sell the annual option quantity is in average equal to AOQ/ADUQ. In each of the "D" days the buyer offtakes the daily maximum quantity and sells the unused quantity in the spot market.

The reason to compute the number of "D" days is that it directly influences the maturity of the embedded option. As the buyer is not able to exercise the whole option amount in one day, the maturity of the "N" options must differ one from the other. Some of the options should have the maturity at 31.12., some of them 30.12. etc. The number of different maturities is equal to the number of "D" days.

In the following table 3.3., there is presented the number of days "D" needed when the buyer wants to exercise the option as late as possible. We have set the annual offtaken quantity is equal to 100 % and compute the option quantity as 5 %, 10 % and 15 % from that amount. Then we computed how many days it would take to offtake the whole option quantity using the average daily unused quantity from the table 3.2.

We can see that the number of days "D" varies a lot from year to year and also between the two explored distributing companies. When the option quantity represents a five percent option of the offtaken quantity, it would take on average 24 days for JMP and 29 days for SMP to offtake the whole option quantity. In the case of the 10 % option, the number of days increases to 43 and

**Table 3.3.:** Number of days "D" for different size of take-or-pay (in mil. kWh)

| JMP | 2000 | 2001 | 2002 | 2003 | Average |
|---|---|---|---|---|---|
| Annual offtaken quantity | 22 257 | 24 773 | 23 537 | 24 723 | 23 822 |
| 5 % option (ToP = 95 %) | 1 113 | 1 239 | 1 177 | 1 236 | 1 191 |
| Number of days ("D") | 18 | 30 | 25 | 22 | 24 |
| 10 % option (ToP = 90 %) | 2 226 | 2 477 | 2 354 | 2 472 | 2 382 |
| Number of days ("D") | 34 | 47 | 49 | 39 | 43 |
| 15 % option (TOP = 85 %) | 3339 | 3716 | 3531 | 3708 | 3573 |
| Number of days ("D") | 46 | 62 | 54 | 54 | 54 |

| SMP | 2000 | 2001 | 2002 | 2003 | Average |
|---|---|---|---|---|---|
| Annual offtaken quantity | 17432 | 19456 | 18229 | 18759 | 18 469 |
| 5 % option (ToP = 95 %) | 872 | 973 | 911 | 938 | 923 |
| Number of days ("D") | 31 | 33 | 33 | 20 | 29 |
| 10 % option (ToP = 90 %) | 1743 | 1946 | 1823 | 1876 | 1847 |
| Number of days ("D") | 50 | 52 | 48 | 37 | 47 |
| 15 % option (ToP = 85 %) | 2615 | 2918 | 2734 | 2814 | 2770 |
| Number of days ("D") | 67 | 68 | 63 | 51 | 62 |

Source: data - Transgas a.s., (own calculations)

47 for JMP and SMP respectively and for the 15 % option the number of necessary days reaches two months. We can see that the number of days "D" is increasing function of the option quantity and that it is increasing at the decreasing rate.

The buyer shouldn't look at the average number of days but at some higher number or even at the maximum number during the examined period when he is deciding when he should start to sell the gas in the spot market. If he relies on the average number of days it could happen that he won't be able to sell the whole option quantity in the spot market. This situation always arrives when the demand of the buyer's customers is higher than is the average demand during the last four years. We can see that the exact number of the days "D" depends on the expected demand of the buyer's customers. However as we have seen before the buyer is not able to estimate his demand a hundred percent.

Consequently, the buyer has two possibilities. One is that he could exercise all the option quantity at the latest possible moment, but he risks that some part of the option gas quantity will remain unused. The second possibility is that he starts offtaking and immediate selling sooner, which increases the probability that he will take advantage from the whole option quantity. Thus the buyer is comparing two values: the price of the option premium which he has paid for the amount of the option quantity which he may not be able to use and the possible profit that he could get if he exercises the option later.

The question to resolve is what number of days the buyer will choose as the starting date for his option exercising. Let's take as an example 10 % option of JMP: the average number of days equals 43. The maximum for the four year period equals 49. Forty-nine days before the end of the year can bring about three situations: the buyer's option would be in-the-money, at-the-money or out-of-the money. When his option is at-the-money or out-of-the-money then he won't certainly exercise the option and he will wait to see if the situation will be better. Thus the question is what he will do when the option is in-the-money. The buyer can make an instant profit by selling the gas in the spot market or wait six more days and hope for the higher profit. The higher profit will occur only when the option will be more and more in-the-money till the end of the year. However if the option is for some time between 43 and 1 day at or out-of-the-money, then it will be better for the buyer to start the exercising 49 days before the end of the year. The buyer is choosing between some certain profit (if he starts 49 days before) against some uncertain but possibly higher profit (if he waits and starts 43 days before). We can suppose that in this situation he chooses the certain profit, because the risks that he won't be able to offtake the whole option amount is higher then the possible additional profit. Another reason could be that the managers of the LDC would probably prefer some certain profit from the option than waiting and maybe having nothing.

Under this approach we could argue in the same way as before that when the buyer is choosing between 49 days before and for example 55 days before he will choose to start the option exercising 55 days before the end of the year provided that the option is in-the-money. Continuing by the same procedure (comparing 55 days with 56, then 56 days with 57 etc.) one may conclude that the buyer would start the option exercising as soon as the option gets in-the-money which could mean "D" may be equal 364.

However the last statement is not true. It won't happen that the buyer will start to exercise the option for example 300 days before the end of year[26].As the number of days "D" is increasing, the probability that the whole option quantity won't be used is decreasing very fast. If the probability that the whole option amount won't be used is around 50 % when "D" equals 43 days (four year average), then when the "D" equals 49 days (four year maximum) the probability could be equal some 10 - 15 %. Consequently the probability will fall to some negligible value 1 % if we add some more days (let's say 3 days so "D" equals 49+3 = 52). This number of days "D" when the probability equals some negligible value is crucial, because the buyer has not any motive to start the option exercising sooner. This argumentation is based on the fact that the value of the option which is equal to the sum of its intrinsic value and time value. At some sooner time (D > 52) the buyer shouldn't exercise the option because he would sacrifice the time value of the option for nothing, because the probability that some part of the option quantity will be unused is the same for all days (D>52 , 364).

Taken together all the above findings show that it is evident that it is not possible to determine the precise optimal number of days "D", but that we could estimate it equal to the maximum number which occurred for the chosen period plus some more days (52 in our example).

[26] more precisely it could happen but then the buyer won't be maximizing his possible profit from the granted option

However this estimated number can't be taken take as a final number and used to determine the different maturity of "N" options which are embedded in the sales contract. The reason is that up to now we have supposed that the only possibility how the buyer can exercise the option is to buy the option gas from the seller and sell it in the spot market. But the buyer has also another way how to use the option gas quantity. He can also exercise the option by buying the option gas from the seller and selling it to his customers. To understand it better we should look closer at the buyer's reasons for having a granted option and the opportunity how to use it.

**Buyer's utilization of the embedded option**

We can assume that the buyer has two possibilities when he is completing the sales contract. The first one is that he can have a sales agreement without an embedded option. It is a sales contract containing 100 % take-or-pay provision. If the buyer chooses this type of contract he knows that he should offtake the whole ACQ in order to not to pay for the not offtaken gas. For this reason he should arrange the quantity of ACQ to be less than is his expected demand of customers. Consequently he knows that he will very probably need more gas than he has contracted with the seller. He will have to buy this additional unknown quantity of gas in the spot market sometime at the end of the year for an unknown price. So he is in the risky situation that could be resolved by hedging in the futures market with natural gas against the unfavorable gas price movement. However the hedging is not possible, because he doesn't know the quantity of gas he will need to buy. Thus by choosing the agreement without the embedded option the buyer is always having the uncertainty about the price for which he will buy some quantity of gas.

The second possibility is to have a sale agreement with the embedded option. It means that the take-or-pay provision is lesser then 100 % (e. g. 95, 90 or 85 %). We can again suppose that the buyer's purpose is to offtake all contracted gas for which the take-or-pay provision applies (AMQ). Therefore he would arrange the AMQ to be less then is his expected needed quantity of gas. Consequently at the end of the year the buyer's needed quantity "X" would be somewhere between AMQ and ACQ and therefore three situations can occur:

1. *Strike price < Spot price - shipping costs*

Then the buyer will offtake the whole option quantity. He will use one part (X-AMQ) to cover the demand of his customers and sell the remaining part, which he doesn't need, in the spot market and gain cash profit from this transaction.

2. *Strike price > Spot price + shipping costs*

Then the buyer won't offtake any part of the option quantity and he will buy the needed quantity (X-AMQ) in the spot market.

3. *Spot price + shipping costs > Strike price > Spot price - shipping costs*

Then the buyer will offtake only the part of the option which he needs (X-AMQ) and the rest of the option quantity will remain untaken.

So we can see that in the situation when the option is in-the-money (Strike price < Spot price - shipping costs) the buyer will use some part of the option gas quantity to cover the demand of his customers and only the rest he will sell in the spot market. This fact greatly influences the estimated value of "D".

As I have shown in the chapter 2., we are not able to determine what the buyer's total needed quantity of gas ("X") will be. However we need it to set the right maturities for our series of options. One possible way how to solve this problem is to assume that the needed quantity X will be in the middle between AMQ and ACQ (the reasons are the same as is argued in the chapter 2.).

If we suppose that the buyer will use half of his option gas quantity to cover the demand of his customers (X – AMQ = ACQ – X), then the quantity which he would like to sell in the spot market will also be half and the number of days "D" will decrease, but not to the half, because the unused daily quantity decreased as we are closer to the end of the year

In the following table 3.4. there are presented the new recomputed number of days "D" when I have supposed that the buyer will sell half the option quantity to his customers. If we take the previous example of JMP with 10 % option, then the option amount will decrease from 10 % to 5 % and the average "D" decreases from 43 to 24 days and the four year maximum from 49 to 30.

**Table 3.4.:** Recomputed number of days "D" for different size of take-or-pay when (in mil. kWh)

| JMP | 2000 | 2001 | 2002 | 2003 | Average |
|---|---|---|---|---|---|
| Number of days ("D") 5 % option | 9 | 15 | 13 | 11 | 12 |
| Number of days ("D") 10 % option | 18 | 30 | 25 | 22 | 24 |
| Number of days ("D") 15 % option | 26 | 39 | 35 | 32 | 33 |

Source: data - Transgas a.s., (own calculations)

The result of this subsection is that it is not easy to estimate the moment when the buyer should at the latest start to exercise the embedded option by selling the gas in the spot market. The problem of estimating is that we have to decide about the total quantity of the buyer's annual demand. But taking the same supposition as in the part 2, we can determine approximately the number of "D" i.e. the option different maturities corresponding to some average gas quantity that the buyer can sell in the spot market.

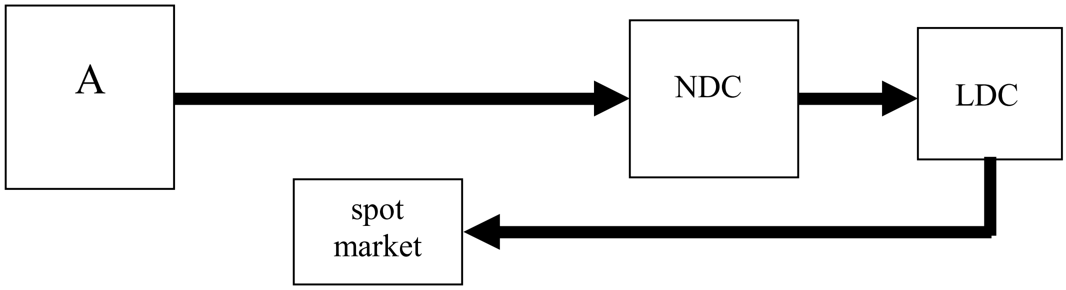
## 3.3.2. The transit of natural gas

### 3.3.2.1. <u>The shipping costs</u>

The costs of shipping play an important role in our option evaluation, because they are decreasing the buyer's payoff when he is exercising the option in the spot market. They represent the buyer's costs, which he has to pay for the transmission of gas to the spot market. There exist two possibilities how the buyer could deliver the gas to the spot market.

The first one is described in the figure 3.2. The producer delivers the gas to some delivery point A. He pays the shipping costs up to this place. The national distributing company (NDC) takes over the delivered gas and pays for the transit from the point A up to the local distributing company. The price which LDC pays for the gas to NDC includes the costs which the NDC had to pay for the transit between the point A and the LDC. Consequently, when the buyer (LDC) wants to sell the gas in the spot market he has to pay for the transit from him to the spot market.

**Figure 3.2.:** Non-cooperation between the buyer and the seller

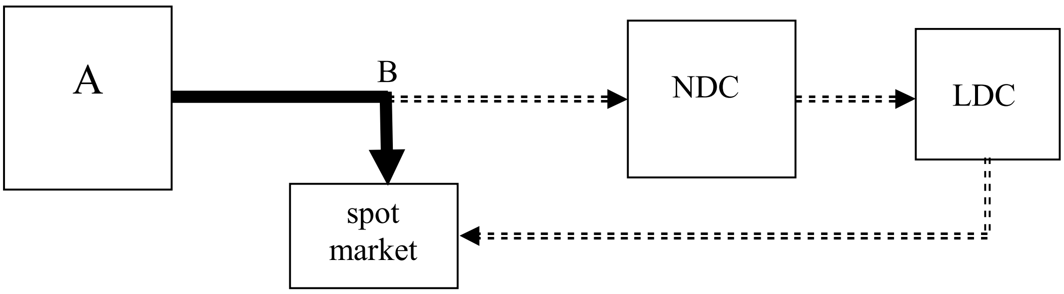



Source: Author

The inconvenience of this transportation system is that the gas might be transported twice in the same pipeline (once on the way to the LDC and secondly on the way from the LDC). Or if not by the same pipeline it could be transported from west to east and then back from the east to the west (or the other way around) by some parallel pipeline. This situation will occur when the spot market is situated around the delivery point A or along the pipeline, which leads from the point A to NDC, which is very probable situation.

If the seller and the buyer are in the previous situation then it is advantageous for both the sides to cooperate and transport the gas directly from the point A to the spot market (figure 3.3.). It means that the LDC will demand the buyer to swap the locations i.e. to change the delivery point.

**Figure 3.3.:** Cooperation between the buyer and the seller




Source: Author

There are more possibilities how they could divide the payment for the transit. The simplest possibility is that the buyer could pay for the gas delivered to the spot market at the same price as he is paying for the gas to be delivered to the standard location.

The second possibility is that the seller would pay for the transit up to point B. At the point B the seller sells the gas to the buyer for the same price as he is selling usually. Then the buyer will pay for the transit from the point B to the spot market. Cooperating in this way the seller will save the amount which he would have to pay for the transit from the point B to the LDC. The buyer will save the difference between the transit costs from LDC to the market and the transit costs from the point B to the spot market.

In a previous analysis we have supposed that the seller (NDC) has a simple shipping contract where he pays a flat rate for every transported unit of gas (e.g. $m^3$) without any fixed charges or minimal transported quantity requirements (ship-or-pay). It means that he pays the price which depends on the distance for which he transports the gas and on the quantity of transported gas. The contract implies that if the seller transports the gas only from the point A to point B then he will save the amount of money he would pay for the transit from B to NDC. He would also save the money he would have to pay for transit from the country border (NDC) to LDC. If the seller's shipping contract was similar to the currently described one, then the seller would certainly cooperate with the buyer, because it is profitable for him.

However there exist more complex shipping contracts than the one described above. It can be also the right to ship any volume of gas up to a specified limit for a fixed charge (the less gas moved, the higher the unit cost). Or the two above may be combined by charging a unit price plus a ship or pay penalty for failing to use the line above the stated minimum. These transportation tariffs may create the situation where the seller has to pay for the gas transit from the point B to the country border even if he is not actually transporting anything between these two points. It implies that the seller won't be profiting from the swap transaction, although he has to certainly pay some costs for the administration of the delivery point change. For that reason the seller will demand that the buyer pays some surcharge for the swap realization. As a result, he might refuse cooperation with the buyer.

In order to precede the situation when the seller is hesitating or refusing the swap, it would be best from the buyer's view to include the swap conditions into the sales agreement.

#### 3.3.2.2. The free capacity in the pipeline system

Another factor, which greatly influences the option's exercising, is the free capacity of pipelines. In order that the buyer can sell the gas in the market he needs available transportations capacity. Pipeline capacity is limited by the pipeline's diameter and maximum design pressure and by its compressor configuration – the distance between compressors and the ratio between the compressors' inlet and outlet pressure[27].

The national distributing company transports the gas from the point A to its country. It books the needed capacity in the pipelines from the point A to the point NDC for the whole year, because it knows that they will be transporting the gas every day.

The local distributing company usually distributes the gas to its customers, which are around its base or in the country. For that purpose it owns or books the needed local pipelines. However if the LDC (the buyer of the option) sells the gas in the spot market it has to use another pipelines which it doesn't use otherwise. The LDC can't book the capacity in advance. It doesn't know when and how much gas they want to transport, because it doesn't know if the option will be in-the-money. Therefore the buyer must depend or gamble on the free capacity in the pipeline system which he needs to transport the gas to the spot market. Consequently at the time when the buyer wants to exercise the option by selling certain gas in the spot market three different situations can occur:

1. The buyer would be able to get the needed capacity, so he will sell the gas in the market.
2. The buyer wouldn't be able to get all needed capacity (he gets only part of it) and so he will sell only the part of the amount of gas he wanted to sell.
3. The buyer wouldn't be able to obtain any capacity. Therefore his intended transaction won't be realized.

However in current situation when we don't know the location of the hub and all other facts about the pipelines leading into it we are not able to assess

[27] S. Cornot-Gandolphe, (2002): „*Flexibility in Natural Gas Supply and Demand*", International Energy Agency and OECD, Paris

the probabilities of unfavorable situations. Therefore we can only simply state that the nonexistence of the free capacity limits buyer's ability to take profit from the granted option when he intends to realize the transaction in the spot market. Thus when the possibility of the nonexistence of free capacity exists then the value of the embedded option should be lowered for some percentage amount.

## 3.4. Optimal time of the option's exercising

The important point of our analysis is to determine the optimal time when the buyer should start to exercise the option gas quantity, because it greatly influences the nature of our options. In the previous part we have shown that the options are American style and we are able to approximately estimate their maturities. It means that the buyer can exercise the option anytime up to its maturity. But as we will prove in the subsequent part, the buyer has no reasons to exercise the option sooner than at the latest moment when he knows that he will able to use the whole option quantity.

As we have shown before the buyer can use the option gas to satisfy the demand of his customers or to gain profit in the spot market from the prices' differences. The buyer's business is sale and distribution of gas to its customers. It is not the speculation with options. Moreover he is obliged to assure the gas deliveries with no exceptions but the upstream failure. Therefore his primary use of the embedded option is to satisfy the demand of his customers. Profiting in the spot market is his secondary utilization.

The fact that the buyer is primarily using the option to cover the fluctuating demand implies that he should sell in the spot market only that gas about which he surely knows he won't need. It means that he should avoid the situation where he has used the whole option gas quantity before the end of the year and he is obliged to buy the gas in the spot market for whatever price it will be. The reason for such behavior is caused by the existence of the shipping costs, the uncertainty about the free capacity in the pipelines and the possibility of a high spot price at the end of the year.

For the explanation let's imagine a situation where the buyer was too eager and has offtaken the option quantity of gas before the end of the year and needs to buy some amount "Y" in the spot market, because of the high demand of his customers. This quantity of gas "Y" he has already sold in the spot market for the price $P_1$ and he has to buy at some new price $P_2$. To complete these two transactions he has to pay double shipping costs $2.C_s$ (for the transit in the market and from the market). The buyer's final position depends on the development of the price $P_2$. If the price $P_1$ is equal to $P_2$ then he won't be neutral, because of the existence of the double shipping he has to pay. His break-even point is $P_2 = P_1 - 2.C_s$ and he will gain if price $P_2$ is less then price $P_1$ minus the shipping costs Cs. Therefore the buyer is in the risky situation but the probability whether he will lose or gain is not the same. The probability that he will lose is more then 50 percent[28], because of the shipping costs which cause that if the price doesn't move or if the price moves to the right direction but only a little (less then is $2.C_s$) the buyer will lose.

The implication of previous findings is interesting. We have found out that the buyer should exercise the embedded options exactly at the time of maturities, which we have derived in the part 3.3.1.3. This statement has important influence on our option evaluation. By setting the optimal time for each option we get rid of the American style of these options and we would be able to evaluate them as a set of European style options with different maturities.

The advantage of such a fact is substantial. Firstly, the evaluation of American options is much more difficult and in some cases almost impossible. Secondly, our set of American options represented an obstacle in our option evaluation, because the time of exercising of one option conditioned the time of other options. Each of these options could be exercised anytime up to its maturity, but having a restriction on the number of options which can be daily exercised, except days when some other options have been exercised. It means that it wasn't true American style but some "dirty" American option which evaluation would be even more difficult.

[28] supposing that there is the same probability that the spot price will increase or decrease

## 3.5. Option evaluation

In the previous part the option's specific characteristics were described and we have derived the maturities for the set of options. Consequently the next step is the evaluation of the embedded option with having respect to these specificities. As was shown earlier, the buyer's payoff from the granted option depends on the difference between two variables: the spot price of the natural gas and the price of the gas determined by the gas price formula. In order to evaluate the difference between these two independent variables we can look at the option as the spread option.

Before the subsequent evaluation by spread option formulas, it is necessary to mention that there is also other possibility. The second approach is based on the forecast of the future strike price (in our case mainly the December formula price). When the strike price is estimated, then the option can be evaluated using the classical Black-Scholes model for the call option, which incorporates the mean-reversion of the gas spot price[29]. The disadvantage of the approach is that the final price of the option is highly sensitive how accurately we are able to estimate the strike price. This paper inclines to the spread option evaluation however the strike price estimation approach is also applicable.

### 3.5.1. Spread option definition

Even though the term *spread* is sometimes understood as the difference between the bid and ask prices (for example, one often says that liquid markets are characterized by narrow bid/ask spreads), the term is most frequently used for the difference between two indexes: the spread between the yield of a corporate bond and the yield of a Treasury bond, the spread between two rates of returns, etc., are typical examples. Naturally, a spread option is an option written on the difference between the values of two assets[30]. But, its

[29] For the option models with mean-reversion see e.g. Schwartz (2000), Clewlow (1999) or Lari-Lavassani (2001).

[30] or even among three underlying assets when the option value depends on two individual spreads

definition has been loosened to include all forms of options written as a linear combination of a finite set of indexes. In the currency and fixed income markets, spread options are based on the difference between two interest or swap rates, two yields, etc. In the commodity markets, spread options are based on the differences between the prices of the same commodity at two different locations (location spreads[31]) or between the prices of the same commodity at two different points in time (calendar spreads), or between the price of electricity and the price of a particular fuel used to generate it (spark spreads [32]), or between the prices of inputs to, and outputs from, a production process (processing spreads), as well as between the prices of different grades of the same commodity (quality spreads). The New York Mercantile Exchange (NYMEX) offers the only exchange-traded options on energy spreads: the heating oil/crude oil and gasoline/crude oil crack spread options[33].

For a general two asset spread option the payoff for calls and puts equals respectively:

$$Spread_{Call} = \max(0, S_1 - S_2 - X)$$

$$Spread_{Put} = \max(0, X + S_2 - S_1)$$

In our case of the embedded option, $S_1$ represents the spot price of natural gas, $S_2$ represents the gas price formula and the exercise price X is equal to zero, but we can replace it by the shipping costs (assuming that all the additional costs that the buyer has to pay in order to sell the gas in the spot market are negligible).

Before we can advance to the evaluation we have to decide how to model the spread between the spot and formula price.

### 3.5.2. Modeling of spread

Since the relevant data about the spot or futures prices from liquid gas market are not currently available, the spread between the formula and spot

[31] Soronow (2002a)

[32] Deng et all. (1999)

[33] Crack Spread Handbook, NYMEX (2001)

price is not accurately known. For that reason, we will show how to model the spread in general[34].

#### 3.5.2.1. One-factor or two-factor approach

When modeling any random process we must decide on the number of independent sources of uncertainty to incorporate into the model. For spread options, the process under scrutiny is the evolution of the spread through time. Traditionally, models of the spread on the difference between two variables have taken either a one-factor or a two-factor approach.

The simplistic one-factor approach explicitly models the spread by treating the value of the spread itself as a single stochastic factor (i.e. as an asset price). In contrast, the two-factor approach models the spread indirectly and assumes each price used in constructing the spread represents an independent (although usually correlated) source of risk.

These two approaches have a variety of advantages and disadvantages. For example, the single factor approach is simpler and requires collection of only one set of price and volatility data. In addition, the option value is only sensitive to changes in the spread levels, not the underlying prices. Since the one-factor approach models the spread directly, the model produces single delta with respect to the spread itself.

On the other hand, the two-factor model is more practical since it is reasonable to assume that the two prices have their own source of uncertainty and as a matter for practical hedging, this approach by modeling the spread indirectly produces two deltas: a delta with respect to each individual price, not just to the spread. The two-factor approach is more preferable if the only available hedging vehicle is a position in each factor and the deltas of these two components are likely to be very different. The inconvenience is that it requires us to estimate how the two prices that create the spread are correlated.

#### 3.5.2.2. Lognormal distribution versus normal distribution

In addition to the number of separate factors that we use, we must also decide how to model those factors. The lognormal model assumes that the factor under consideration follows a lognormal distribution. In other words,

[34] Soronow (2002b)

continuously compounded price returns follow a normal distribution. This distribution is asymmetric, positively skewed, and most significantly assumes that the factor being modeled cannot take negative values. Most academics agree that the lognormal model is a better approximation of the behavior of energy prices, but does that also hold good for a spread?

Clearly not always. The assumption that natural gas and oil prices cannot take negative values and therefore they follow lognormal distribution is reasonable. But if we assume that the spread itself is lognormally distributed then we have implied that the spread cannot become negative. This is a strong assumption that can be valid for some spreads but needn't be for some others. Generally, we have no means of knowing which of the two prices in the spread is going to be the greater at any time, and therefore we should allow for negative spreads.

The lognormal assumption could therefore impose a serious limitation on the one-factor model, because the difference of two lognormal distributed variables needn't to be lognormal and therefore we have to give reasons for its validity. On the other hand, in the two-factor model, we don't have such a problem to solve, because each factor represents a price and the spread can be positive or negative depending on which price is greater.

When there is the possibility that the spread will take negative values then the normal model should be used in the one-factor case. The normal model assumes that the factor being modeled follows a normal distribution between any two points in time. Unlike the lognormal distribution, the normal distribution is symmetric and allows for negative values. For example, with a mean of zero a normal distribution assumes that negative values are just as likely as positive ones. This is clearly the sort of distribution that we are looking for with a spread.

In the two-factor model of the spread, however, using a normal distribution for each of the prices would be inappropriate, because gas and oil price distributions are neither symmetric, nor are they capable of negative values.

### 3.5.2.3. Price process: random walk or mean-reversion

The most known price process is Geometric Brownian motion[35] (GBM) which assumes that the variance of the distribution (either normal or lognormal) of the stochastic factor grows linearly with time. In other words, the further out in time we gaze, the greater is our uncertainty about the value the factor will take. If the factor being modeled is the spread, then this assumption would imply that the distribution of the spread grows larger in both directions with time. For the two-factor case, this implies that the distribution of each price grows larger with time. Is this a valid assumption? Before we can answer the question we have to look closer at the price characteristics.

#### Characteristics of formula and natural gas prices

Before starting with the description of the mathematical models, it is important to keep in mind the actual behavior of commodity prices that we are trying to model. Natural gas and oil prices are somewhat different than other prices set in financial markets, which follow GBM process. Due to short term supply and demand imbalances, spot prices and prices for short-term delivery of the commodity tend to exhibit significantly different behavior than prices for delivery of the commodity in the future, or forward prices. The following description concerns the behavior of natural gas prices[36], whilst the behavior of the formula price will be discussed hereafter.

#### Natural gas spot prices

There are several important properties associated with the volatility of spot natural gas prices, principal among them being:

- *Seasonal Effects:* In response to cyclical fluctuations in supply and demand mostly due to weather and climate changes, energy prices tend to exhibit strong seasonal patterns.

[35] Often called random walk. The process is based on the assumption that price changes are independent of each other and that price changes have constant mean and volatility.

[36] As there is no liquid market with natural gas in the Europe, the proprieties of natural gas prices behavior are based on the experience from U.S.

- *Mean-Reversion:* Prices tend to fluctuate around and drift over time to values determined by the cost of production and the level of demand. This property is shared by most commodities. In the framework of energy commodities Pindyck (1999) analyzes a 127-year period for crude oil and bituminous coal and a 75-year period for natural gas and concludes that prices exhibit mean-reversion towards a stochastically fluctuating trend line.

Mean reversion process can be thought as a modification of a random walk, where the price changes are not completely independent of one another but somehow related. Mathematically, we can express the phenomena of mean reversion as following:

$$S_{t+1} - S_t = \alpha\left(S^* - S_t\right) + \sigma\varepsilon_t \qquad (3.1.)$$

where: $S_t$ is the spot price, $S^*$ is the mean reversion level or long run equilibrium price, α is the mean reversion rate or the speed of the reversion, σ is the volatility and ε is random price change from t to t+1.

From the equation (3.1.), it follows that the mean reversion component or 'drift' term is governed by the distance between the current price and the mean reversion level, as well as by the mean reversion rate. If the spot price is below the mean reversion level, the mean reversion component will be positive, resulting in an upward influence on the spot price. Alternatively, if the spot price is above the mean reversion level, the mean reversion component will be negative, thus exerting a downward influence on the spot price. Over time, this results in a price path that drifts towards the mean reversion level, at a speed determined by the mean reversion rate.

Notice that the mean reversion process has an important feature which is crucial in the evaluation. As the gas spot prices exert high volatility the GBM process would produce prices that can reach unrealistic levels for long periods of time. Unlike pure GBM, the mean reverting GBM price process described above ensures prices to gravitate over time toward the mean reversion price levels.

Natural gas forward/futures prices[37]

Whilst it may seem that the discussion about gas futures doesn't belong to our analysis, the opposite is true. There are several reasons why to use futures prices instead of spot prices in our option evaluation.

Futures prices do not exhibit the same seasonality of spot prices. The term structure of forward/futures prices has seasonal characteristics embedded within it. For example, consider a future price for delivery shortly after a harvest of an agricultural product. Prior to the harvest, the spot price may be high, reflecting depleted supplies of the product, but the future price will not be high. Because it is for delivery after the harvest, it will be low in anticipation of a drop in prices following the harvest. The same logic can apply for gas, where we can observe high prices in winter and low prices in summer. Thus using the futures prices we can incorporate seasonality into the price process.

Futures contracts would be most probably more widely traded on the emerging spot market with natural gas and therefore ensuring necessary liquidity. This argument follows from the experience of the current commodity exchanges where often the nearest maturity futures price is used as a proxy for the spot price.

When we move towards the using of futures price, it is necessary to mention the relationship between the spot and future price. The premise here is that forward/futures prices are the market's "best guess" (unbiased estimate) of future spot prices. In the financial markets, due to the non-arbitrage conditions, there is an analytical formula for the forward prices:

$$F(t,T) = S(t)e^{r(T-t)} \qquad (3.2.)$$

where *r* represents risk-free interest rate which we assume to be constant and non-stochastic.

In the case of commodities Brennan and Schwartz (1985) established an expansion to the pricing of forward contracts in those commodity markets where the underlying asset can be stored. Analyzing the theory of storage, they

[37] The supposed assumption of constant interest rates implies the equality between forward and futures prices.

incorporated the convenience yield "y" which captures the benefit from owning the commodity minus the cost of storing it.

$$F(t,T) = S(t)e^{(r-y)(T-t)} \qquad (3.3.)$$

Formula price

The formula price is composed from two main elements: the fixed part and the variable part, which depends on some energy prices. As the content of the formulas is not publicly known we will take the one published by Ruhrgas and suppose for the matter of simplicity that it is composed of a fueloil index[38].

$$P = P_0 + 0{,}00175.(FO - FO_0) \qquad (3.4.)$$

First of all we have to modify it by taking out the fixed parts $P_0$ and $FO_0$ and add them to the value of the strike price to capture correctly the evolution of the price process. The term taken out of the formula in our case would be $P_0 - 0{,}00175 \cdot FO_0$.

By such a revision, the payoff of our option will remain the same but the price distribution would be correct, because the volatility of the variable term will have influence only on this term and not the whole expression.

Consequently, the point of interest is only the variable term of the price formula. The same conclusions about mean-reversion and seasonality that we did for natural gas prices hold also for the oil price process. The difference is that instead of one spot price the average of several months' spot prices is applied. Therefore we can expect that the volatility won't be high, because averaging will cut off high fluctuations. One of the consequences of monthly

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[38] Adding another factor to variable term would imply only more difficult computation of its volatility (the correlation between these two factors has to be estimated) but the other conclusions will stay the same.

average is that we have to assume that a complete set of futures contracts[39] for fueloil is traded when using the futures prices instead of spot ones.

Another difficulty follows from the situation that the formula price evolution is evolving discontinuously, changing only once a month. However the basic assumption of all options formulas is the continuous price evolution.

In the one-factor approach, it won't cause much trouble. We are taking the spread between two prices as a single variable. As one price is evolving continuously and the second price is changing only sometimes then their difference, spread, would be evolving continuously[40].

On the other hand, in the two-factor approach, the price discontinuous would negatively influence the result of our evaluation. Fortunately, we can assume that the price is continuous in one case. It is when the maturity of the option is the same as a recalculation date of the price formula. If we suppose that the recalculation date is the first day of a month then we are able to evaluate the options with maturities on the first day of a month.

The idea behind the argumentation can be explained by the following example: Consider two price indexes: index A is computed every day as a average of 60 previous daily quotations and index B is also computed every day as a average of 60 previous daily quotations but lasts without change for 30 days and then is recalculated again. These two indexes would be surely equal to each other only at the recalculation day "t" (they may be equal also on some other day but only by chance.) Therefore when we are evaluating the option with maturity at the time "t", we can replace index B by the index A.

Now we can return to the earlier question about the validity of the GBM assumption. According to the previous statements about the prices' processes we can see that in case of the two-factor approach the mean-reverting model for our stochastic processes should be used.

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[39] It can seem as a too hard assumption but consider that even if the full set of contracts is not traded, we can compute the monthly average price from the existing futures contracts without loosing the reliability.

[40] Strictly speaking there will be some small jumps between the day before recalculation and the recalculation day, but we will suppose that these jumps are negligible.

However for the one-factor approach it is questionable. The research is not homogeneous about the distribution of the spread in such a case, but usually it inclines to use the Brownian motion instead of mean-reversion. In this paper, we are also going to use GBM but with the modification by change of underlies, i.e. using the futures prices instead of spot prices[41]. The logic behind it is that the spread of the futures indexes already incorporates the seasonality and mean reversion and therefore evolves randomly following GBM.

It is also necessary to mention how we treat the convenience yield which is a standard parameter of one factor models. But what is the convenience yield of the spread? As a matter of practice, we simply suppose that the convenience yield of the spread is zero within the one-factor model.

### 3.5.3. Spread option evaluation formulas

In this part we will show several possibilities how to evaluate the spread option. Firstly, we will present the simple approaches treating the spread as a single asset. Then, we will advance to a more sophisticated method, which can provide more accurate results.

The common notation for the following options formulas is:

$F_g^{t,T}$ represents gas futures price at time *t* with maturity in time *T*

$F_f^{t,T}$ represents fueloil futures price at time *t* maturing in time *T*

$X$ is the strike price

$r$ is the continuously compounded risk free interest rate (assumed constant)

$\sigma$ the volatility (assumed constant)

$\rho$ the correlation between gas and fuel oil (assumed constant)

*H* energy conversion factor

$\mathrm{N}(x)$ is the standard normal cumulative distribution function

$n(x)$ represents standardized normal density function

[41] Some practitioners would argue that the distribution of the spread follows a mean reverting process. In other words, if the spread grows larger or smaller it will eventually gravitates back towards its mean equilibrium level. The formulas for evaluation can be found e.g. in Brooks (2002) or Schwartz (1997 and 2000)

### 3.5.3.1. One - factor models

The one-factor models are the uncomplicated but simplified approach. The first one presented here supposes that the probability that the spread will ever become negative is nil. The second one, assume the normal distribution, therefore the previous supposition is not necessary.

**Option pricing formula with futures prices and GBM - Black 76'**

In 1976, Fischer Black published a paper addressing the problem of how to model the commodity prices. His solution was to model forward prices as opposed to spot prices, because forward prices do not exhibit the same non-randomness of spot prices. Even if the theory has evolved since the time of publishing this paper and nowadays mean-reversion models are used to value the option on commodity futures, we can still use this model for our purpose, because we are evaluating spread and not a single commodity. The price process is described by following stochastic differential equation (SDE):

$$dF^{t,T} = rF^{t,T}dt + \sigma_F dW(t) \qquad (3.5.)$$

Consequently, the value for a call price *C* is:

$$C\left(F^{t,T}, X, T-t\right) = e^{-r(T-t)}\left[F^{t,T}\mathrm{N}(d_1) - X\mathrm{N}(d_2)\right] \qquad (3.6.)$$

with: $d_1 = \dfrac{\ln\left(F^{t,T}/X\right) + \left(\sigma^2/2\right)\cdot(T-t)}{\sigma\cdot\sqrt{(T-t)}}$ and $d_2 = d_1 - \sigma\sqrt{T-t}$

where: $F^{t,T} = \left(F_g^{\,t,T} - H \cdot F_f^{t,T}\right)$ represents the difference between gas futures price and the fueloil futures price (at time *t* with maturity in time *T*)

Note that spread fluctuation sizes would increase for large spreads and decrease for small ones (volatility is expressed as a % of price).

**Options pricing formula with futures prices and ABM**

If there exists the possibility, that the spread becomes negative, then the previous model Black 76' is not applicable. Then, we have to leave GBM leading to lognormal distribution and use normal distribution with the arithmetic Brownian motion (ABM) for the dynamic of the spread.

The premise of the pricing formula proposed in this section is to assume that the risk-neutral dynamics of the spread $S(t)$ is given by a SDE of the form:

$$d\left(F_g^{t,T} - F_f^{t,T}\right) = r\left(F_g^{t,T} - F_f^{t,T}\right)dt + \sigma_F dW(t) \tag{3.7.}$$

The advantage of ABM is that it leads a closed form formulae. Based on Poitras (1998), the price of call option is:

$$C\left(\left(F_g^{t,T} - F_f^{t,T}\right), T-t, \sigma_F, X\right) = e^{-r(T-t)}\left\{\left[\left(F_g^{t,T} - F_f^{t,T}\right) - X\right]N(d) + \sigma_F\sqrt{(T-t)}\,n(d)\right\} \tag{3.8.}$$

with $$d = \frac{\left(F_g^{t,T} - F_f^{t,T}\right) - X}{\sigma_F\sqrt{(T-t)}}$$

The advantage of the both preceding models is that the option value is only sensitive to changes in the spread levels, not the underlying prices.

### 3.5.3.2. <u>Two - factors models</u>

The two-factor models are more complicated, since we are modeling two different variables. Their main advantage is that they are able to incorporate different mean-reversion rates for each price in the spread. As all more complex models, their disadvantage is that they need to input more parameters which are not directly observable.

**Option pricing formula with futures prices and mean-reversion**

In this model we assume that the futures prices of natural gas and fueloil follow correlated mean-reverting processes:

$$dF_i(t) = -\lambda_i\left(\log F_i(t) - F_i^*\right)dt + \sigma_i(t)F_i(t)dW_i(t), \quad i = g, f \tag{3.9.}$$

where $W_g$ and $W_f$ are two correlated Brownian motions.

For the evaluation, we will apply findings of Deng et al. (1999) who show that the price of a European spread option is given by the following equation[42]:

$$C(F_g^{t,T}, F_f^{t,T}, X, T-t) = e^{-r(T-t)}\left[F_g^{t,T} N(d_1) - \left(H \cdot F_f^{t,T} + X\right) N(d_2)\right] \qquad (3.10.)$$

with $$d_1 = \frac{\ln\left(F_g^{t,T} \Big/ HF_f^{t,T} + X\right) + \left(v^2 \big/ 2\right) \cdot (T-t)}{v \cdot \sqrt{(T-t)}}$$ and $$d_2 = d_1 - v\sqrt{T-t}$$

$$v^2 = \frac{\int_t^T \left[\sigma_g^2(s) - 2\rho\sigma_g(s)\sigma_f(s) + \sigma_f^2(s)\right] ds}{T-t}$$

Note that Deng (1999) states that the mean-reversion parameters of the futures price of gas and oil don't enter the pricing formula (3.10.) since the futures contracts of natural gas and oil are traded commodities and thus the mean-reverting effects are eliminated through the construction of the replicating portfolio using the traded futures contracts.

The advantage of this approach is that it leads to real no-arbitrage pricing formulae and the corresponding hedging strategies, but only when a complete set of futures contracts is available.

**Option pricing formula with spot prices and mean-reversion process**

In this part, we suppose that the risk-neutral dynamics of the two underlying indexes are given by the stochastic differential equation of the mean-reversion form:

$$dS_i(t) = S_i(t)\left[-\lambda_i\left(\log S_i(t) - S_i^*\right)dt + \sigma_i dW_i(t)\right] \qquad i = 1,2 \qquad (3.11.)$$

where, as before, the volatilities $\sigma_1$ and $\sigma_2$ are positive constants, $W_1$ and $W_2$ are two Brownian motion with correlation $\rho$, $\lambda_1$ and $\lambda_2$ are two positive constant and $S_1^*$ and $S_2^*$ are real constants which can be estimated as a simple

[42] The authors value the spread option by constructing an instantaneous risk free portfolio using the electricity and generating fuel futures contracts and the riskless asset.

function of the asymptotic mean reversion level. The positive constants $\lambda_i$ give the rates of mean reversion and can be easily estimated from historical data[43] (see Box 2.). The indexes satisfying dynamical equations (3.11.) tend to revert toward the levels $e^{S_i^{*\infty}}$ if we set $S_i^{*\infty} = S_i^* - \sigma_i^2/2\lambda_i$ .

Consequently, after setting $\log S_i(t) = s_i(t)$ and applying Ito's Lemma, we get following SDE which shows us that logarithms of indexes follow the geometric Ornstein – Uhlenbeck process:

$$ds_i(t) = -\lambda_i\left[s_i(t) - S_i^{*\infty}\right]dt + \sigma_i dW_i(t) \qquad i = 1,2 \qquad (3.12.)$$

Now, we can derive the explicit formulae for the indexes *Si*(*T*) in terms of exponentials of correlated Gaussian variables. As $S_i(T) = e^{s_i(T)}$ we get:

$$S_i(T) = e^{S_i^{*\infty} + e^{-\lambda_i T}\left(S_i(0) - S_i^{*\infty}\right) + \sigma_{i,T}\xi_i} \qquad (3.13.)$$

where $\sigma_{i,T} = \sigma_i\sqrt{\frac{1-e^{-2\lambda_i T}}{2\lambda_i}}$ *i = 1,2* and $\xi_1$ and $\xi_2$ are *N*(0,1) random variables with correlation coefficient $\tilde{\rho}$ given by:

$$\tilde{\rho} = \frac{1}{\sigma_{1,T}\sigma_{2,T}}\mathrm{E}\{\xi_1\xi_2\} = \rho\frac{\sqrt{\lambda_1\lambda_2}}{(\lambda_1+\lambda_2)/2}\frac{1-e^{-(\lambda_1+\lambda_2)T}}{\sqrt{1-e^{-2\lambda_1 T}}\sqrt{1-e^{-2\lambda_2 T}}} \qquad (3.14.)$$

Consequently, the price *p* of a spread option, with strike *X* and maturity *T*, on the difference between the underlying indexes $S_1$ and $S_2$ whose dynamics are given by (3.11.) is given by the risk neutral expectation formula (3.15.) In order to compute the risk-neutral expectation giving the price *p*, the only thing we need is the joint density ($f_t$) of the couple ($S_1$, $S_2$) of random variables under that particular risk-neutral measure. This density is usually called the state price

[43] A simple linear regression can be used to relate historical price changes to historical prices. Recently, complex calibration techniques that fit model parameters to historical spot price data have been developed. The most used is the Kalman filtering method (see e.g. Schwartz (2000) or Harvey (1989))

density. Therefore, we can write the price of a spread option as a double integral.

$$p = e^{-rT}\mathrm{E}\left\{(S_1(T) - S_2(T) - X)^+\right\} = e^{-rT}\iint (S_1 - S_2 - X)^+ f_t(S_1, S_2)\, dS_1 dS_2 \qquad (3.15.)$$

Pricing the spread option by computing these integrals numerically can be done by Monte Carlo approximations, but even a good approximation of the price *p* is not sufficient in practice, because it doesn't provide Greeks parameters for hedging. That's why we will turn to the closed form formulae. However, it is not possible to get the strictly accurate closed form of double integral as is the form presented by Black and Scholes in the case of classical options. Fortunately, Carmona a Durrlemann (2003a) have found out very accurate approximation which is presented hereafter[44].

They have shown, that we can approximate the value of the option by the following function $\prod$ with real constants $\alpha, \beta, \gamma, \delta$ and $\chi$.

$$p = e^{-rT}\mathrm{E}\left\{(S_1(T) - S_2(T) - X)^+\right\} = \Pi(\alpha, \beta, \gamma, \delta, \chi, \widetilde{\rho}) \qquad (3.16.)$$

provided we set:

$$\alpha = e^{-rT + S_1^{*\infty} + e^{-\lambda_1 T}\left(S_1(0) - S_1^{*\infty}\right) - \sigma_{1,T}^2/2} \quad \text{and} \quad \beta = \sigma_{1,T} = \sigma_1\sqrt{\frac{1 - e^{-2\lambda_1 T}}{2\lambda_1}},$$

$$\gamma = e^{-rT + S_2^{*\infty} + e^{-\lambda_2 T}\left(S_2(0) - S_2^{*\infty}\right) - \sigma_{2,T}^2/2} \quad \text{and} \quad \delta = \sigma_{2,T} = \sigma_2\sqrt{\frac{1 - e^{-2\lambda_2 T}}{2\lambda_2}},$$

$\chi = e^{-rT}X$ and $\widetilde{\rho}$ is defined as in (3.14.)

Now, we have to approximate the price of the spread option provided that we introduce the notation $\theta^*$ for the solution of the equation (3.17.), where the angle $\phi$ is defined by setting $\widetilde{\rho} = \cos\phi$.

[44] The authors derived a family of upper and lower bounds for the price *p*. Among other things, they show that the supremum $\hat{p}$ of their lower bounds provides a very precise approximation to the exact price *p*.

$$\frac{1}{\delta\cos\theta}\ln\left(-\frac{\beta\chi\sin(\theta+\phi)}{\gamma[\beta\sin(\theta+\phi)-\delta\sin\theta]}\right)-\frac{\delta\cos\theta}{2}= \\ =\frac{1}{\beta\cos(\theta+\phi)}\ln\left(-\frac{\delta\chi\sin\theta}{\alpha[\beta\sin(\theta+\phi)-\delta\sin\theta]}\right)-\frac{\beta\cos(\theta+\phi)}{2} \quad (3.17.)$$

Then the following equation gives us the closed form formula for the approximate price $\hat{p}$.

$$\hat{p}=\alpha\cdot\mathrm{N}\left(d^*+\sigma_1\cos(\theta^*+\phi)\sqrt{T}\right)-\gamma\cdot\mathrm{N}\left(d^*+\sigma_2\sin\theta^*\sqrt{T}\right)-Xe^{-rT}\cdot N(d^*) \quad (3.18.)$$

where $d^*$ is the solution of equation (3.19.) where the angles $\phi$ and $\varphi$ are set in $[0,\pi]$ such that $\cos\phi=\tilde{\rho}$ and $\cos\varphi=(\sigma_1-\tilde{\rho}\sigma_2)/\sigma$.

$$d^*=\frac{1}{\sigma\cos(\theta^*-\varphi)\sqrt{T}}\ln\left(\frac{\alpha\sigma_1\sin(\theta^*+\phi)}{\gamma\sigma_2\sin\theta^*}\right)-\frac{1}{2}\left(\sigma_1\cos(\theta^*+\phi)+\sigma_2\cos\theta^*\right)\sqrt{T} \quad (3.19.)$$

Using the formula (3.18), we can compute the partial derivatives of the price, the so-called Greeks[45]:

$$\vartheta_1=-\alpha\varphi\left(d^*+\sigma_1\cos(\theta^*+\phi)\sqrt{T}\right)\cos(\theta^*+\phi)\sqrt{T} \qquad \vartheta_2=\gamma\varphi\left(d^*+\sigma_2\cos\theta^*\sqrt{T}\right)\cos\theta^*\sqrt{T}$$

$$\chi=-\gamma\varphi\left(d^*+\sigma_2\cos\theta^*\sqrt{T}\right)\sigma_2\frac{\sin\theta^*}{\sin\phi}\sqrt{T} \qquad \kappa=-N(d^*)e^{-rT}$$

where $\vartheta_1$ and $\vartheta_2$ denote the sensitivities of the price $\hat{p}$ (3.18.) with respect to the volatilities of each asset, $\chi$ is the sensitivity with respect to their correlation parameter $\tilde{\rho}$, $\kappa$ represents the sensitivity with respect to the strike price X. Knowledge of these parameters is very useful. Since parameters like volatilities or correlations are not directly observable, the corresponding sensitivities show how errors on these parameters affect price and hedging strategies.

[45] For the proofs see Carmona (2003b).

Even if in the beginning the last model seems very complicated, it should provide the best, most accurate results when we are pricing the spread option on two commodities.

## Box 2.: The calculation of mean-reversion rates, levels and volatilities in Excel

A simple linear regression can be used to relate historical price changes to historical prices. This practical example illustrates how to calculate it and compare it with the square root of time rule used in case of GBM.

1. Choose a particular price series. Column A (rows 2–11) in table 3.4. contains historical prices for asset X over a ten-day period.
2. Calculate the standard deviation assuming that returns are independent. Column B (rows 3–11) shows the daily returns, denoted u. Use Excel's built-in STDEV function to calculate the daily volatility (cell B14). Using the square-root-of-time rule, we annualize to obtain S* (cell B16) assuming that time is measured in trading days and there are 250 trading days per year. In our example, the annualized volatility would be equal to 265%, (16.7% x $\sqrt{250}$).
3. Calculate the absolute price changes. Column D (rows 3–11) shows the daily changes.
4. We can estimate the mean-reversion rate in a relatively simple and robust manner by regressing absolute price changes (Column D) on the previous price levels (Column E).

5. Use the Excel functions SLOPE, INTERCEPT and STEYX (residual standard deviation) to calculate the parameters from the regression. The mean reversion speed is the negative of the slope, while the long run mean is the intercept estimate of that regression divided by the mean reversion speed.
6. The volatility of dollar price changes is given by the residual standard deviation calculated with STYDX. If we want to obtain percentage volatility, we would just need to divide by the long run mean (see E20).

We can see that the volatility of our forecast based on mean-reversion would be around 13,2 % of the forecast price level, which is substantially lower than the 265 % calculated with the square root of time rule. It is caused by the fact that price changes are not independent through time but have some degree of memory about previous price changes.

**Table 3.4.:** Calculation of mean-reversion rates, levels and volatilities in Excel

| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | **Date** | **Current Price, $** | **Price Change, %** | **Price Change, $** | **Previous Price, $** |
| 2 | 1.4.2009 | 15 | | "y" values | "x" values |
| 3 | 2.4.2009 | 18 | 18,2% | 3 | 15 |
| 4 | 3.4.2009 | 15,5 | -14,9% | -2,5 | 18 |
| 5 | 4.4.2009 | 12 | -25,5% | -3,5 | 15,5 |
| 6 | 5.4.2009 | 14,5 | 18,9% | 2,5 | 12 |
| 7 | 6.4.2009 | 13 | -10,9% | -1,5 | 14,5 |
| 8 | 7.4.2009 | 15 | 14,3% | 2 | 13 |
| 9 | 8.4.2009 | 17 | 12,5% | 2 | 15 |
| 10 | 9.4.2009 | 15,5 | -9,2% | -1,5 | 17 |
| 11 | 10.4.2009 | 14 | -10,2% | -1,5 | 15,5 |
| 12 | | | | | |
| 13 | | **Standard deviation** | | **Regression parametrs** | |
| 14 | | STDEV(u) | 16,7% | SLOPE | -0,89 |
| 15 | | SQRT(250) | 15,81 | INTERCEPT | 13,24 |
| 16 | | S* annualised | 263% | STEYX | 1,98 |
| 17 | | | | | |
| 18 | | Speed | | | 0,89 |
| 19 | | Long run mean (Intercept/Speed) | | | 14,93 |
| 20 | | Volatility (STEYX/Long run mean) | | | 13,2% |

### 3.5.4. The evaluation of the embedded option

In order to evaluate the embedded option, we should apply one of the spread options' formulas from the previous part with the different maturities that we estimated earlier. However, before proceeding to it, we have to take into account that the applying has one limitation. We can use the model only to evaluate the option with the maturity on the first day in the month (at the recalculation day), but because the gas price formula which forms one part of the spread is changing only at this day. Therefore we can't evaluate the options with maturities on the other days.

One possibility how to solve it lies in the necessary simplification. We must evaluate all options that are maturing in same month as if they were maturing at the beginning of the month. It means that we evaluate on the first of December all the options with maturity in December and on the first of November the options with the maturity in November. The result of such a method will be a little under evaluation of the price due to the fact that we don't include the possibility that the price can rise between the first day in the month and the precise maturity day.

A difficulty links to the previous statement of undervaluation. We should add some value to get the correct price of the whole embedded option. The problem is how to state this value. We are not able to evaluate it precisely by mathematics formulas for option derivatives; the concept of forward option can't be used here. Thus, we can either arbitrary add some number to the embedded option value or we can take a weighted average of the value of the option maturing at the beginning of month and the value of the option maturing at the consecutive month in order to approximate the value of the option maturing in the middle of the month.

# CONCLUSION

The paper studies the unexplored and unpublished part of the contractual relationship in the gas industry. It aims to pioneer the evaluation of the options embedded in gas sales contracts and analyzes it in two market situations.

In the current market situation where there doesn't exist any liquid spot market with natural gas, LDC can use the granted option only to cover the fluctuating demand of its customers. For that reason we should look at the option as the flexibility of the total offtaken quantity but not as the financial options which can be used to gain profit from favorable market price development. Consequently, we have chosen a cost based approach for the evaluation.

The main idea is that we have firstly estimated the expected seller's costs resulting from the granted flexibility and subsequently we have studied the possibilities of how the seller can input these costs into the price for which he is selling the gas. The seller's goal is to motivate the buyer to offtake as much gas as possible and at the same time set the price so that he gets paid for the not-offtaken part of the flexible quantity. We have shown several ways of how to set the price, explaining its advantages, disadvantages and the possibility of the buyer's acceptance but we don't determine the "best one", because the final price agreement is not unique, but would be the conclusion of bargaining between the two concerning parties. Our findings about the price setting should serve as a starting point for the negotiator in order to know which direction to choose and what possibilities are disadvantageous for them.

In the second part we aimed at the future situation when the accessible spot market with natural gas emerges and the LDC will have the possibility to sell the flexible gas quantity and make a profit. In this future situation, the granted flexibility represents the financial option, more specifically a set of options with the same features. After assessing the buyer's motives and offtaking characteristics, we have shown that he will exercise the options no sooner than at the time when he knows that he won't need the option gas quantity to satisfy demand of customers. This finding helps us to get rid of the American style of option in favor of a more convenient European style. Having respect for the maximum daily quantity that the buyer can offtake, we estimated the latest time when the buyer should start to exercise the granted option to be able to use it whole if the market price is favorable.

Considering the embedded option whose payoff is governed not only by the floating exercise price but also by the floating strike price, we have chosen the spread option models, because they evaluate the difference between two floating variables, which is exactly the case of the embedded option. The important point of the analysis was to realize that energy commodity prices do not behave in the same manner as the shares do. They don't satisfy the classical random walk assumption. They fluctuate considerably from day to day due to varying demand and offer but in the long-term they are close to some slightly increasing value, which represents the costs of production and distribution. Therefore the mean-reversion price process is more suitable when we are evaluating the options based on the spot prices. In the case of futures the specific commodity behavior is already included in the price and the random walk can be used.

Spread options are non-trivial instruments. There exists two main methods of how to evaluate the spread between the gas spot price and the gas price formula. We have shown two essential possibilities for each group. First two models represent a simple approach that is easy to use and require a small collection of data, because we are taking the spread as a single variable, but it can produce some misestimates when the necessary assumptions are not satisfied. It is a convenient but not illuminating solution. The other two models are more suitable and should provide more accurate results. In this case, we are modeling the spread as a result of two individual variables and we can select the correct price behavior for each of them. The inconvenience is that more parameters, such as the correlation between these two assets, have to be estimated and the calculations are more difficult. However as these parameters play a significant role in the evaluation and their omission can considerably affect the price, it is better to face the complications than use the first models. Presumably, all these models should be used to be sure about the computed price.

Note that the paper doesn't apply the models on real data due to the nonexistence of relevant data of the spot gas market, but it gives the essential framework of how to proceed when the necessary data are available.

In general, this paper presents a first venture into the estimation of the buyer's advantages from the granted option. Even though the goal to analyze it and to propose the approximate evaluation has been met, there still exists some room for the extension. One limitation lies in the fact that using two factor models, we can correctly evaluate the option only on the first day of the month. We can't apply the models at the other maturities, which imply that the evaluation is only approximately accurate. We haven't also included the evaluation of take-or-pay provision into the analysis. We can't forget that it also represents a value that on the contrary the buyer grants to the seller and it can be seen as a counterbalance against the granted option. Also the problems about transit and the existence of free capacity were discussed only partly, because the future situation about the hub and related pipelines was unknown. I hope that the paper will be discussed and some extensions will appear in the future.

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