Application of a Gas Market Model with Linear Programming

The Influence of the Dollar Exchange Rate on the Wholesale Price of Natural Gas in Northwest Europe until 2040

Maik Günther[1,2]

[1] Stadtwerke München GmbH
Emmy-Noether-Str. 2, 80992 München, Germany
Guenther.Maik@swm.de
[2] IU International University of Applied Sciences
Juri-Gagarin-Ring 152, 99084 Erfurt, Germany
Maik.Guenther@iu.org

Abstract. The price of natural gas at wholesale markets in Northwest Europe is influenced by numerous parameters. The USD to EUR exchange rate is one of these parameters. Using the LP-based gas market model WEGA, this paper will examine the impact of USD exchange rates on wholesale natural gas prices in Northwest Europe from 2025 to 2040. I can be shown with WEGA, that the USD to EUR exchange rate has a significant effect on natural gas prices at wholesale markets in Northwest Europe. However, this effect is not linear. A stronger USD compared to the EUR leads to a relatively strong price increase at the TTF to the same extent, while a weaker USD does not result in a 1:1 price decrease at the TTF. Please note: Calculations in this paper were made before the war in Ukraine started with its impact on the global gas markets. Thus, the results of WEGA should only be considered as demonstrating the capabilities of the LP-based gas market model for analyzing gas prices.

Keywords: LP, XPRESS, WEGA, exchange rates, USD, gas market model, wholesale market, TTF, Northwest Europe, LNG

1 Introduction

The use of fossil fuels must be phased out quickly in order to counter climate change. Until this goal is achieved, however, natural gas will continue to play an important role in energy supply. It is used as a feedstock in chemical industry, for power and heat generation and also in the mobility sector. There is a high demand for natural gas in Northwest Europe. Since indigenous production is declining in the long term and demand is falling too slowly, Northwest Europe will also have to import significant volumes of natural gas in the long term. There are two options to import large volumes of natural gas: via pipeline and via ships in the form of liquefied natural gas (LNG).

The price of natural gas at wholesale markets in Northwest Europe (e.g. Title Transfer Facility (TTF) and National Balancing Point (NBP)) is influenced by numerous parameters. These include not only the structure of supply and demand, but also factors such as the cost of US LNG [1], the price of oil [2], as well as the exchange rate of USD to EUR. The influence of the exchange rate is based on the fact that, in oil-indexed long-term contracts (LTC), a reference is made to crude oil or oil products traded in USD. Furthermore, in the case of hub-indexed US-LNG, the reference is usually the Henry Hub (HH), a trading point for natural gas in the USA, where natural gas is traded in USD. On the other hand, natural gas is traded in EUR at TTF or NBP. Changes in the exchange rate can therefore have an impact on wholesale prices for natural gas in Northwest Europe. This paper will investigate how this influence is manifested in Northwest Europe for the period from 2025 to 2040, using the worldwide gas market model WEGA, which is based on linear programming (LP). The TTF was chosen for the analyses, because the gas market in Northwest Europe is well-connected, making TTF a good reference for the region.

Please note: The calculations in this paper were made before the war in Ukraine started with its impact on the global gas markets. Therefore, the construction of additional LNG regasification terminals in Europe and changes in Russian gas exports are not considered in the scenarios. It can be assumed that the presented results of WEGA may differ when these changes are taken into account. Therefore, the results should only be considered as demonstrating the capabilities of the LP-based gas market model WEGA for analyzing gas prices.

This paper is structured as follows: In the next section the gas market model WEGA is introduced. Then the results of the sensitivity calculations with modified exchange rates are presented in section 3. This paper ends with a conclusion.

2 Gas Market Model WEGA

In 2013 Stadtwerke München GmbH (SWM) started to forecast global gas prices and gas flows by using the global gas market model WEGA [3]. This model can also be used for risk management [4]. It was developed with the FICO Xpress Optimization Suite. WEGA is a LP model and is based on the commercial Pegasus gas market model created by ÅFRY [5].

SWM has modified the original dataset of Pegasus using public sources as well as commercial data services. SWM frequently calculates future prices for NBP and TTF to ensure the plausibility of the results, which are then discussed with experts from SWM and other companies. The dataset is modified to reflect the specific assumptions and forecasts on parameters of SWM, including oil prices [2], gas demand [6], exchange rates, gas storage costs, gas field production costs, gas demand from power and non-power sectors, etc. The SWM fundamental power model [7] has been another source of data for SWM. It is important to note that all scenarios and results from WEGA in this paper represent the viewpoint of SWM.

WEGA optimizes each gas year in daily resolution $d \in D$ separately, ensuring, as a hard constraint, that the worldwide gas demand $Demand_{z,d}$ is covered every day by gas flows In and Out of demand zones $z \in Z$ (see Eq. 1). The different types of gas flows include:

- $PipeIn_{z,d}$, $PipeOut_{z,d}$ = flows from pipelines to demand zones and from demand zones to pipelines.
- $LNGIn_{z,d}$, $LNGOut_{z,d}$ = flows from LNG regasification terminals to demand zones and from demand zones to LNG liquefaction terminals.
- $InterconIn_{z,d}$, $InterconOut_{z,d}$ = flows between demand zones.
- $StorageIn_{z,d}$, $StorageOut_{z,d}$ = flows from gas storages to demand zones and from demand zones to gas storages.
- $FlexIn_{z,d}$, $FlexOut_{z,d}$ = flows from flexibility options to demand zones and from demand zones to flexibility options.
- $IndigenousIn_{z,d}$ = flows from indigenous production to demand zones.

$$\begin{aligned} Demand_{z,d} = {} & PipeIn_{z,d} - PipeOut_{z,d} \\ & + LNGIn_{z,d} - LNGOut_{z,d} \\ & + InterconIn_{z,d} - InterconOut_{z,d} \\ & + StorageIn_{z,d} - StorageOut_{z,d} \\ & + FlexIn_{z,d} - FlexOut_{z,d} \\ & + IndigenousIn_{z,d} \end{aligned} \qquad \forall z \in Z; d \in D. \tag{1}$$

Other hard constraints relate, for example, to the maximum capacity of pipelines, the maximum withdrawal rate of gas storage facilities, or take-or-pay clauses in LTCs. The objective of the optimization is to minimize the total annual costs C (see Eq. 2), whereby the following cost types are considered:

- CPr = production costs.
- CTr = transport costs.
- CSt = storage costs.
- CFl = flexibility costs.

$$Min\ C = \sum_{d=1}^{D} (CPr_d + CTr_d + CSt_d + CFl_d). \tag{2}$$

WEGA can calculate a scenario until 2040 within 25 minutes. The model dispatches resources through perfect competition under various constraints. Market power of producers and investment decisions are predetermined, but they can be adjusted by introducing scenarios. Scenarios can reflect possible situations such as the construction of pipelines [8],[9] or LNG terminals.

WEGA models the worldwide gas market as a network of nodes and edges (see Fig. 1).

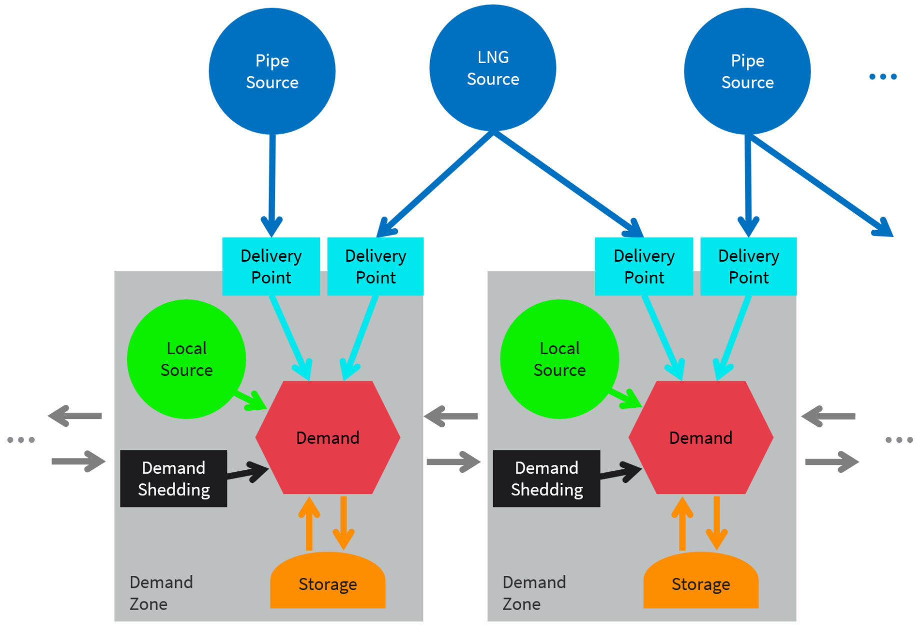

Fig. 1. The gas market model WEGA as a network of edges and nodes.

Within the network of the global gas market, WEGA uses several types of nodes, including [1]:

- Demand zones: In the WEGA, demand zones refer to regions, countries, or hubs, such as TTF, NBP and HH. Demand zones are sometimes aggregated to reduce CPU-time for optimization. Each zone has a gas demand in daily resolution for the forecasting horizon [10],[11].
- Pipe and LNG sources: These are gas fields with a pipeline connection and/or a connection to LNG export facilities, such as the Yamal gas field in Russia. The available parameters for these sources include minimum and maximum production capacities, production costs, and annual production profiles (such as that of the Groningen gas field). These parameters can be set with annual, monthly, or daily resolution within the forecasting horizon.
- Local source: Indigenous production can be modeled as individual gas fields. The same parameters as those for gas fields with pipeline connection and/or a connection to LNG export facilities are available for these nodes.
- Delivery points for pipe sources: Gas fields with pipeline connections require delivery points within demand zones.
- Delivery points for LNG sources: Gas fields with LNG connections require delivery points within demand zones (LNG regasification terminals).

– Gas storages: In WEGA, gas storage facilities are modeled differently depending on their location. Facilities in Europe are modeled individually, while those in North America and China are aggregated into groups. Each facility or group is characterized by storage volume, injection and withdrawal capacity, short-run marginal costs, and long-run marginal costs.
– Demand shedding and flexibility options: WEGA can perform demand shedding to ensure a feasible solution. However, this indicates a need for calibration adjustments to the dataset. Additionally, flexibility options such as price levels for coal-to-gas switches and interruptible customers are available in demand zone.

The transportation of gas between the above explained nodes is represented through edges. In WEGA each edge connects two nodes. There are different types of edges, such as shipping routes for LNG, transmission pipelines, and interconnectors. To model gas flows in both directions between two nodes, two edges are required. Furthermore, 1:n connections are possible. For instance, a gas field with pipeline connections can be linked to several pipeline delivery points. Similarly, a liquefaction terminal can be connected to multiple regasification terminals. Further details about WEGA can be found in [1], [2] and [12].

In Fig. 2 the dashboard of WEGA is depicted with three sections. In section 1 a scenario can be selected. Section 2 shows individual views for analyzing results and modifying parameters of a scenario. Once such a view is selected, it is displayed in section 3. WEGA also integrates the business intelligence software Tableau for visualizing parameters and results.

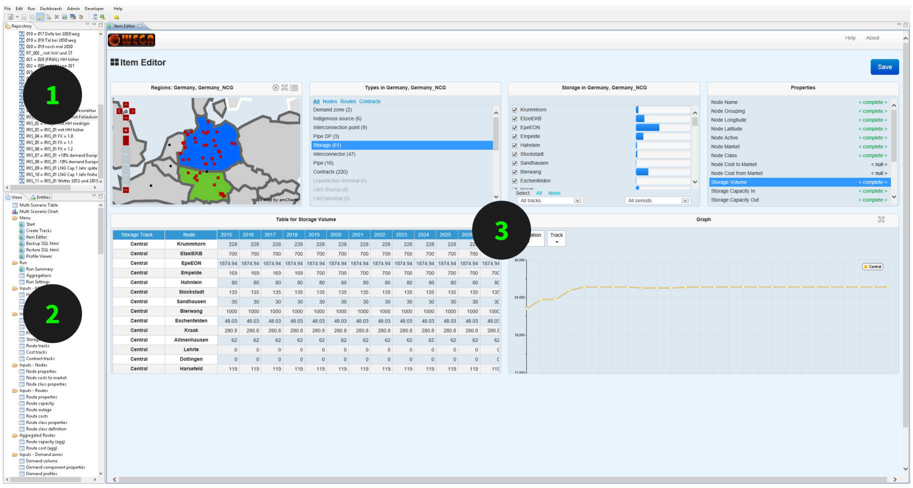

Fig. 2. Screenshot of WEGA with three sections.

3 Experiments and Results

To analyze the influence of the USD exchange rate on wholesale prices of natural gas in Northwest Europe, a base case scenario is created with 1 EUR = 1.2 USD; fixed from 2025 until 2040. For further details about the base case, reference is made to [1] and [2].

Using the WEGA gas market model, sensitivity calculations were performed by creating four scenarios in which only the USD exchange rate was varied while keeping all other parameters constant with respect to the base case. These scenarios are:

- 1 EUR = 1.4 USD: The Value of the USD is decreased by 16.67 % compared to the base case.
- 1 EUR = 1.3 USD: The Value of the USD is decreased by 8.33 % compared to the base case.
- 1 EUR = 1.1 USD: The Value of the USD is increased by 8,33 % compared to the base case.
- 1 EUR = 1.0 USD: The Value of the USD is increased by 16.67 % compared to the base case.

The results of the calculations are depicted in Fig. 3. The dashed and dotted lines are for orientation at ± 8,33 % and ± 16.67 %. The colored lines show the deviation of the TTF price (traded in EUR) from the base case in %.

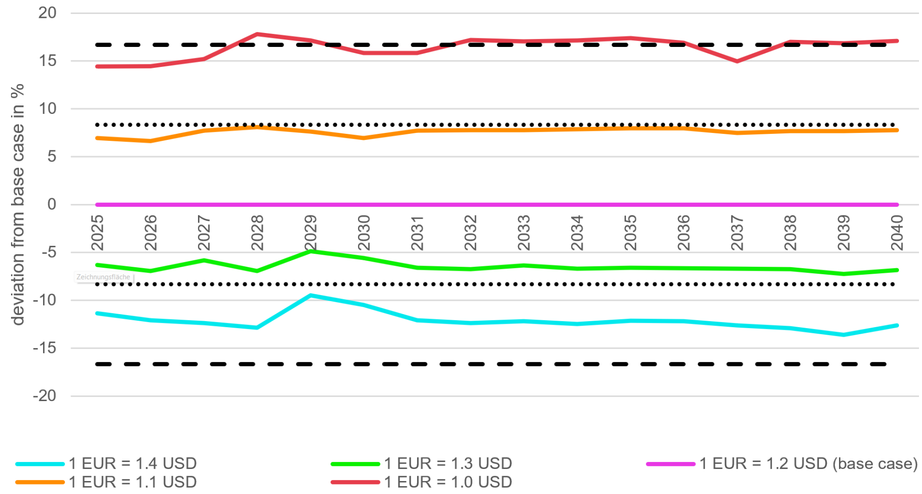

Fig. 3. Influence of the EUR/USD exchange rate on the TTF price from 2025 to 2040 compared to the base case with 1 EUR = 1.2 USD (dashed and dotted lines are for orientation).

It can be seen in Fig. 3, that an increase in the value of the USD compared to the base case leads to an increase in the price of natural gas at TTF, as more

EUR are required to purchase 1 MWh of natural gas. On the other hand, Fig. 3 shows that a weaker USD leads to declining wholesale prices of natural gas at TTF. However, the effect is not as significant as it is with a stronger USD.

One reason could be that in the base case, US LNG often sets the prices in the northwest European gas market, and any price increase caused by a stronger USD is directly reflected 1:1 in higher prices for natural gas at TTF. In contrast, a weaker USD results in a smaller price reduction for natural gas at TTF, because although US LNG moves further left in the merit order, other sources, which are also needed to cover the demand, are quick to set the price for natural gas at TTF.

4 Conclusion

In this paper, the LP-based global gas market model WEGA was described and the relation between exchanges rates and wholesale natural gas prices due to oil-indexation and hub-indexation was explained. Moreover, using sensitivity analyses, the influence of modifications of the USD to EUR exchange rate on wholesale gas prices in Northwest Europe was demonstrated.

The results reveal, that the USD to EUR exchange rate has a significant effect on natural gas prices at wholesale markets in Northwest Europe. However, this effect is not linear. A stronger USD compared to the EUR leads to a relatively strong price increase at the TTF to the same extent, while a weaker USD does not result in a 1:1 price decrease at the TTF.

Please note: The calculations in this paper were made before the war in Ukraine started with its impact on the global gas markets. Therefore, the construction of additional LNG regasification terminals in Europe and changes in Russian gas exports are not considered in the scenarios. It can be assumed that the presented results of WEGA may differ when these changes are taken into account. Therefore, the results should only be considered as demonstrating the capabilities of the LP-based gas market model WEGA for analyzing gas prices, which was developed with the FICO Xpress Optimization Suite.

References

1. Günther, M.; Nissen, V. (2021). *Effects of the Henry Hub Price on U.S. LNG Exports and on Gas Flows in Western Europe.* In: Qyyum, M. A.; Lee, M.; He, T. (eds.): Gases, Vol. 1, No. 2, Special Issue. Liquefied Natural Gas: Value Chain Enhancements, MDPI, pp. 68-79.
2. Günther, M.; Fallahnejad, M. (2020). *Analysis of NCG prices under different shapes of oil price recovery with a world-wide gas market model.* In: Nguyen, K. D.; Goutte, S. (eds.): Handbook of Energy Finance. Theories, Practices and Simulations, World Scientific Publishing, pp. 301-316.
3. Günther, M. (2020). *Implementation and Operation of a Gas Market Model at Stadtwerke München.* In: Book of Abstract of the 3rd Conference of the EURO Working Group on the Practice of Operations Research. Challenges in the deployment of OR projects, online event, September 28-29, p. 12.

4. Günther, M. (2021). *A Global Gas Market Model for Risk Management: Effects of U.S.-LNG on Gas Markets in Western Europe.* In: Book of Abstracts of the 31st European Conference on Operational Research (EURO XXXI), Athens, July 10-14, pp. 47-48.
5. Davies, G.; Sarsfield-Hall, R. (2014). *Gas SCR—Cost Benefit Analysis for a Demand-Side Response Mechanism. A Report to Ofgem*, Pöyry.
6. Günther, M.; Schimpf, M. (2016). *Auswirkungen von Energieeinsparungen auf den Gasbedarf und den Gaspreis in Deutschland bis 2040.* In: Mayr, H. C.; Pinzinger, M. (eds.): INFORMATIK 2016, Kaiserslautern, September 26-30, LNI, Vol. P-259, pp. 1213-1226.
7. Schaber, K.; Roth, H.; Fallahnejad, M. (2014). *Can the Gas Sector Provide the Flexibility to the Power Sector for the Integration of Renewables?* In: 13th Wind Integration Workshop, Berlin, November 14, pp. 46-51.
8. Günther, M.; Nissen, V. (2019). *Impact of Nord Stream 2 on Gas Flows in Europe.* In: 16th International Conference on the European Energy Market (EEM 2019), Ljubljana, September 18-20, IEEE Xplore, No. 388.
9. Günther, M.; Nissen, V. (2019). *Gas Flows and Gas Prices in Europe: What is the Impact of Nord Stream 2.* In: ENERDAY 2019 – 13th Conference on Energy Economics and Technology, Dresden, April 12.
10. Fallahnejad, M.; Günther, M.; Eberl, B. (2017). *Long-Term Forecast of Residential & Commercial Gas Demand in Germany.* In: Book of Abstracts of the Vienna Young Scientists Symposium (VSS 2017), Vienna, June 1-2, pp. 108-109.
11. Fallahnejad, M.; Günther, M.; Eberl, B. (2016). *Creating Standard Load Profiles in Residential and Commercial Sectors in Germany for 2016, 2025 and 2040.* In: Optimization Online.
12. Günther, M. (2017). *Practical Application of a Worldwide Gasmarket Model at Stadtwerke München.* In: Dörner, K. F.; Ljubic, I.; Pflug, G.; Tragler, G. (eds.): Operations Research Proceedings 2015. Selected Papers of the International Conference of the German, Austrian and Swiss Operations Research Societies (GOR, ÖGOR, SVOR/ASRO), Vienna, September 1-4, Springer, pp. 715-721.