A model-based outlook on the KWKG tender in Germany
How flexibility enhances value in CHP portfolios
Jan Andersson and Rana Mitra

Introduction
1st December 2017, the subsidy rates for traditional CHP plants of 1 MW up to 50 MW was auctioned for the first time. The capacity of the first auction was 100 MW, after which 100 MW are auctioned twice a year. With subsidy rates of up to 70 €/MWh, participation in the auction was attractive for many companies. At the same time, however, the uncertainty was high before the auction. A central role was naturally played by the question of which results could be set in the auctions, with which bidding strategy one could place oneself successfully in the auctions and how the overall profitability of CHP projects could be presented under these framework conditions.

This paper highlights the cost-effectiveness of CHP projects in the upcoming auction round. A focus is also on an outlook on possible auction results as well as possible bidding strategies.

The aim is to provide information to market players through a clear model-based approach, and to assist them in the decision-making process.

Framework conditions for the auctions
The current KWKG act aims to increase cogeneration power generation to 110 TWh in 2020 and 120 TWh by 2025. The central instrument here is the auctioning of KWKG subsidies for the generation of CHP electricity.

There is an increasing interest among the participants to bid into the upcoming auctions. An interest that is also partly fueled by the fear that the CHP subsidies could be discontinued in the future, and thus any investment need for replacement or extension should be undertaken as soon as possible and under the regulations of the current CHP Act.

General regulations of the KWKG
Participation in the tender is compulsory for all new and modernized CHP plants with an electric CHP capacity between 1 MW and 50 MW. However, a transitional provision stipulates that facilities that were ordered in 2016 or have been granted a permit in accordance with the Federal Immission Control Act (BImSchG) and will be put into operation in 2018 are eligible to participate in the tender procedure.

The promotion of CHP power generation is basically possible for all fuels except coal. This means that CHP plants, for example, based on biomass (solid, liquid, gaseous), garbage-based plants as well as gas-based CHP plants are eligible to participate in the auction.

Traditional and innovative schemes
The auction distinguishes between traditional CHP and innovative CHP schemes. The Auction held in December 2017 did only consider traditional CHP, whereas the auction in June 2018 considered innovative CHP schemes.

Traditional CHP
The traditional CHP scheme focuses on the CHP performance of fuel fired plants, i.e. much the same as the guaranteed CHP scheme for plants larger than 50 MW. No additional technological specifications are made for this scheme. The legal framework provides for a maximum CHP bonus of 70 €/MWh for traditional CHP plants. In addition, subsidies for conventional CHP plants are limited to a total of 30,000 full load hours. Twice a year 75 MW of KWKG subsidy is auctioned under the traditional CHP scheme.

Innovative CHP
The so-called innovative scheme includes CHP plants that are combined with renewable heat generation technologies and additional power-to-heat technology. By this is meant, CHP plants, in combination with e.g. heat pumps, solar thermal or geothermal energy. The share of renewable heat must amount to at least 30% of the annual total heat production from the plant. For innovative CHP systems, the maximum subsidy rate is 120 €/MWh and the subsidy is limited to 45,000 full load hours. 25 MW of KWKG subsidies will be auctioned twice a year for the innovative CHP scheme.

In addition, there is also an annual limit for the subsidized amounts of energy. To encourage more flexible plant operation, the
subsidy per year is paid for a maximum of 3,500 full load hours. Only the first 3,500 full-load hours of a year will be eligible for subsidy. Herein lies an optimization challenge, namely, the plant should ideally run only during the 3,500 hours of the year with highest electricity prices. However, once reached the annual limit on full-load hours, it does not mean that the plant cannot be operated, only that exceeding operating hours will not be eligible for subsidy.

Furthermore, the additional support for CHP plants that replace a hard coal or lignite plant also does not apply within the framework of the auction. However, this so-called fuel-switch premium continues to be available for CHP plants above 50 MW.

Eligibility, Penalties and Collateral

In order to participate in the auction, neither a building permit nor a permit in the sense of the Federal Immission Control Act (BImSchG) is required. However, the plant location must already be specified at the time of bidding in the form of a postal address.

However, to achieve a high realization rate, a collateral security of 70 €/kW is to be deposited for each submitted bid. The collateral corresponds to about 5-10% of the project investment cost. Depending on the size of the bid, this equates to between € 100,000 and € 5,000,000 for CHP plants of 1 to 50 MW (for non-innovative systems). If the bidder violates notification obligations, auction guidelines or if commissioning is delayed, the security will be fully or partially withheld. First penalties take effect if commercial operation is started later than 48 months after contract. The penalty is performance-specific and not plant-specific. In the case of a system with 2 MW, which only achieves a capacity of 1.8 MW 54 months after contract, only an amount of € 19,200 corresponding to the difference of 0.2 MW will be retained.

Auction design

Bids between 1 and 5 MW are permitted for traditional CHP systems. For innovative CHP systems, the upper bid limit is 10 MW. It is not allowed to split performance in one location into multiple bids, or to bid in parallel to the traditional and innovative auction. The auction is settled according to pay-as-bid procedure, which allows for competitive bidding and bidding strategies.

Development of bidding strategy

Before bidding on the auction, a bidding strategy should be worked out. In a pay-as-bid auction, every successful bid receives the amount with which it went to the auction. Therefore, the optimal bid is the one that is as close as possible to the last bid still to be cleared. Thus, unlike the pay-as-cleared method, pay-as-bid auctions invite to strategic bidding behavior. However, since no bidder knows the marginal price at the time of participation, there is an inevitable trade-off: the higher the bid, the lower the probability of winning, but the better the profitability in the event of a successful bid.

Methodologically, in past pay-as-bid auctions, it has proven to be helpful in determining a bid strategy in two steps:

- Determine the minimum bid, the so-called indifference price
- Determine whether it make sense to bid above the indifference price (strategic bid mark-up)

These steps are explained below.

Determine minimum bid

The indifference price is the bid price at which the bidder does not care whether he or she wins a bid or not. The basis for determining the indifference price is formed by accurate estimates of cost, revenue and risk structure of the project. Auctions mean competition and any competitive advantage can be converted into a higher probability of winning or obtaining better project returns. Therefore, accuracy is very important here.

One of the main parts of the indifference price is costs, especially investment costs. Investment costs can be determined relatively accurately, but it is important to use account for the full scope of the project. The second part is the determination of a risk-adjusted minimum return for the project. Frequently, more in-house discussions are likely to be around this topic as the operation of a CHP plant is not a risk-free business. Even if the CHP subsidy is safe, technical risks and, of course, the electricity price risk itself remain. Hence, the next step is to make an estimate of future market developments (electricity price, gas price, heat revenue and other variable factors).

It is important to make the calculation and decision-making process for determining the indifference price as objective as possible. It is also important to keep in mind the internal interests of the company and, if necessary, include a third-party perspective. The result is the indifference price of the investment, which should be as neutral as possible.

Strategic bid mark-up

The art of the auction strategy is to find a bid level for the project that appropriately reflects the return vs. risk appetite. However, this should not be a decision based on gut feeling, but rather be anchored on a sound analysis of the energy market.

There are no simple strategy recommendations. Rather, an individual strategy development is necessary, which includes the following factors:

Successfulness:
The necessity to realize the project plays an important role, i.e. the necessity to replace an existing CHP plant or increase capacity to maintain the heat supply of customers.

Risk appetite:
The risk preference differs between all bidders and projects. Certain companies will be prepared to accept a lower probability success if the expected return is favorable, while others may not.

Competition:
Not only the costs of your own project are relevant, but also the costs and bid strategies of the competitors. This requires an analysis of which projects might be included in the auction round and at what cost. Once an assessment of the above-mentioned topics has been completed, a promising bid strategy can be defined based on an optimization bid mark-up and the probability of winning.

Break-even analysis

The objective of this chapter is to determine a minimum bid for the auction for both the traditional as well as the innovative scheme. As discussed in the earlier chapter, from the costs and the expected revenues, it can be deduced which CHP subsidy the plants would need at least to achieve economic feasibility, i.e. the indifference price. This corresponds to the "break-even" bid, i.e. the bid level at which the capital value of the investments is exactly zero.

To determine this value, different plant configurations were defined and modelled in BoFiT optimization software. Figure 1 shows and overview of the BoFiT model that was developed for the analysis. The new CHP plant was considered to be part of an already existing portfolio of heat generating assets. By optimizing the new CHP plant in context of a larger portfolio gives additional aspects on the situation.

- A more realistic result of how the new CHP plant should be operated as the dynamic properties of the other assets also impacts the operation of the new CHP plant. This translates directly into greater accuracy when determining the bid strategy.
- The addition of a new plant with different dynamic properties will most likely give the opportunity to optimize the operation of existing assets. For example, if an existing asset can run at higher load and higher efficiency by introducing a new flexible plant there is a tangible value that is not directly related to the new plant itself, but rather the whole portfolio.

For all these scenarios the KWKG subsidy was subsequently varied in amount until the net present value of the investments was approximately zero.
How flexibility enhances value in CHP portfolios

Scenarios

The scenarios for the traditional and the innovative scheme differ a bit as the requirement are different. However, the objective is the same to minimize generation cost while fulfilling boundary conditions on heat production. Table 1 outlines the scenarios in detail and are described below.

For the traditional scheme a small and a large plant were considered, 9 MW and 50 MW electrical power respectively. Different plant sizes offer an view on how the specific investment costs impact the feasibility. It should also be emphasized that the smaller case is dimensioned so that the rated thermal input is less than 20 MW and therefore is exempted from ETS certificate trading.

The innovative scenario differs from the small traditional case only in the sense that the renewable heat generation assets has been added, i.e. 10 MW solar thermal and an 8 MW heat pump. The solar thermal generation profile corresponds to central Germany latitudes with a capacity factor of around 20%. As the innovative scheme requires that 30% of generated heat comes from the renewable assets it indirectly puts a limit on how many hours that plant can run without having to drastically oversize the solar thermal and the heat pump. The model results show that engine plant in the innovative scheme is running 2,500 to 3,000 hours, which is slightly less than the upper limit of 3,500 hours.

Model assumptions

The size of the plant is the factor that has largest effects on the specific investment costs of the plants. The assumptions used for the modelling and the consequent feasibility study are listed in Figure 2. The stated investment costs are turn-key (or EPC) investment costs. It should be noted that investment costs can vary widely depending on the situation and special requirements posed on the project. For this calculation the investment cost for the large engine plant is taken to be 850 €/kW and for the small case 1,200 €/kW. As the KWKG excludes industrial self-generation from the auction it is assumed that all generated electricity is fed to the grid portfolio. Figure 4 and Figure 5 show examples of the dispatching for the portfolio for traditional and innovative schemes respectively. What can be noted from all the examples below is the dynamic operation of the engine plant with a lot of starts.
and stops during the day. It is clear that the engine plant is following the price signals on the market, i.e. it only runs when prices are high. This frequent start-stop behavior is only possible to achieve with heat storage in the portfolio that can decouple electricity and heat production.

Furthermore, in the winter week example for the traditional CHP scheme the engine plant behaves more like a base load CHP plant and only reacts to very unfavorable electricity prices, which can be explained by the necessity to provide heat to the consumers. In comparison, the winter example for the innovative scheme looks very different. The inclusion of a heat pump opens for better optimization also on the heat generation side, i.e. the engine plant is continuously following the price signals and does not operate as a base load plant.

During the summer season the engine plant is only operating sporadically when the prices are high. For the innovative scheme a big part of the heat demand is covered by solar thermal together with storage.

**Calculation of break-even subsidy rates**

Adding the results of the dispatch modeling, i.e. operating revenues and costs, together with the fixed operating costs and the cost of capital, one obtains an overall picture of the profitability of the plants. Figure 6 shows the determined break-even CHP subsidies of the plants. The point where the lines intersect the X-axis is the “break-even CHP subsidy rate”. Overall, the level of subsidy rates required is low. The plants considered here, larger gas engine power plants, can hence be very competitive in the auction.

The level of subsidy required for traditional plants is in the range of 25 to 30 €/MWh. Furthermore, the larger plant types tend to have lower break-even rates, i.e. they have a specifically lower need for subsidies. This is due to the lower specific investment and operating costs of the plants.

For the innovative scheme the break-even value lies at approximately 35 €/MWh, which is less than what could be anticipated considering the small plant size and the additional capital cost of solar collectors and heat pump. However, the longer eligibility period of 45,000 full-load hours is one obvious explanation. In addition, a couple of conclusions can be made based on the result:

- Inclusion of renewable heat generation equipment allows for more flexibility also on the heating generation side. This gives the opportunity to optimize heat generation irrespectively of electricity production.
- Despite the positive effects of renewable heat generation assets, the related investment cost still outweighs the benefits. However, decreasing investment costs and increasing emission costs could change this rapidly.

**Outlook for the future**

The first auction held in December 2017 cleared in the interval 32 to 50 €/MWh with two plants >30 MW. Analyzing the results of the December auction it is clear...
that the above method pinpointed the low end of the subsidy rate and the tendency to favor larger projects over smaller. The higher end of the interval is clearly below the maximum of 70 €/MWh, which is also indicating that the bidders did more than speculative bidding. The interest in the tender for CHP plants has declined in the second round. 14 bids with a total volume of 91 MW generation capacity would have been awarded a contract, informed the Federal Network Agency. The tender volume of 93 MW was thus not completely exhausted, partly because the authority excluded a bid that did not meet the legal requirements. Compared to the first tendering round of December 2017, both the number of bids, 20 and their total capacity (225 MW) have declined. The first auction cleared at the interval 32 to 50 €/MWh for a total of 83 MW. Nevertheless, the auction mechanism has proved to be a competitive instrument for bringing the new CHP plants in the energy mix. In particular, the level of extra charges, which again remained well below the fixed ceiling of 7 cents / kWh. The average cleared bid value was 4.31 cents / kWh, compared to the first round (4.05 cents / kWh) has gone up. The lowest bid value of the most recent round was 2.99 cents / kWh, the highest bid value was 5.20 cents / kWh. In addition, the Federal Network Agency also announced the results of the first tender for innovative CHP systems. For such plants with additional renewable heat source or with electric heat generator (power-to-heat) there has been a separate auction of 25 MW. Again, the volume was not completely exhausted. Five bids with a volume of just under 21 MW received a surcharge, two others were treated as invalid. The average additional value was 10.27 cents / kWh – well above the value of the regular tender.

Since KWKG does not included any fuel switch premiums for coal replacement projects in the auction segment, the economic effects of this additional remuneration were not taken into consideration here. However, it is apparent in the market that many projects are attempting to project larger systems (> 50 MW) and thus obtain the fuel switch premium outside of the auction segment.

For the upcoming auction in December 2018, a similar result can be expected as the amount of MW’s are almost the same compared to last two auctions.

The heating sector is often overlooked when discussing emissions and reduction targets. The fact is that the generation of heat in Germany accounts for roughly the same amount of CO₂ emissions as electricity generation. Therefore, the initiative to include renewable heat generation as a special segment in the KWKG is showing a will by the German government to reduce emissions in the heating sector as well. Even though renewable heat generation technology still requires higher investments it is pointing towards a new, more environmental friendly future for CHP.

---

**Modelling primary NOx and primary N₂O of Pulverised Fuel Combustion and Circulating Fluidised Bed Combustion**

Frans van Dijen

With more stringent emission limits with time, including NOx and N₂O, and due to the high costs of secondary measures for NOx emissions reduction, knowledge of primary NOx and primary N₂O is very important. With this knowledge, primary NOx and primary N₂O can be reduced at low costs and in this way costs for secondary measures are much reduced as well. By applying the knowledge presented, the project costs of a CFBC plant can be lower than those of a PFC plant.

Knowledge regarding primary NOx and primary N₂O, and their models, is useful for operators of PFC and CFBC regarding the influence of (the change of):

- Fuel, with PFC and CFBC
- Lambda, with PFC and CFBC
- Temperature, with CFBC
- Addition of limestone to the bed, with CFBC

Knowledge regarding primary NOx and primary N₂O, and their models, is useful for suppliers of boilers, burners, etcetera, regarding the influence of (the change of):

- Design, with PFC and CFBC
- Fuels and fuel flexibility, with PFC and CFBC
- Conversion of the boiler for other fuels, with PFC and CFBC
- Developing assisting systems / software, with PFC and CFBC
- Temperature, with CFBC
- Addition of limestone to the bed, with CFBC

With this thesis, the mathematical models of primary NOx of CFBC, primary NOx of PFC and primary N₂O of CFBC were improved. The models are based on chemical aspects, such as thermodynamics, kinetics and reaction mechanisms.
Yes, I would like to order a subscription of VGB PowerTech.

The current price is Euro 275.– plus postage and VAT.

Unless terminated with a notice period of one month to the end of the year, this subscription will be extended for a further year in each case.

Return by fax to

VGB PowerTech Service GmbH
Fax No. +49 201 8128-302

or access our on-line shop at www.vgb.org | MEDIA | SHOP.

Name, First Name
Street
Postal Code               City                             Country
Phone/Fax

Date       1st Signature

Cancellation: This order may be cancelled within 14 days. A notice must be sent to VGB PowerTech Service GmbH within this period. The deadline will be observed by due mailing. I agree to the terms with my 2nd signature.

Date       2nd Signature
VGB POWERTECH as printed edition, monthly published, 11 issues a year

Annual edition 2017 as CD or DVD with alle issues from 1990 to 2017: Profound knowledge about electricity and heat generation and storage.

Order now at www.vgb.org > shop > Journal