Flexibility is the new black

How flexibility enhances value in CHP portfolios in Germany

The growing use of renewable energy sources pushes towards lower and more volatile electricity prices. The Electricity Market 2.0 was adopted in Germany in 2016 to spur the transition towards a more flexible and modern energy system. In parallel, the new Combined Heat and Power (CHP) Act (Kraft-Wärme-Kopplungsanlagen, KWKG) introduces an auction system for CHP bonuses for small to medium size plants. This serves as a driver to enhance innovation and flexibility in CHP production. The current setup, with stronger price signals from the market and a pay-as-bid CHP auction, offers great possibilities for German utilities.

This paper analyses three bidding strategies in the CHP auction and how innovative and flexible technology adds value for utilities operating in this new market landscape. The analysis is based on in-depth power market optimization using forecasts and actual market data. Consumer heat price is the most critical parameter for many utilities. Our results indicate that the use of flexible and innovative energy generation technology increases profitability.

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1. Introduction

On December 1, 2017, the subsidy rates for traditional CHP plants from 1 MW up to 50 MW were 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, uncertainty was high before the auction. The central questions posed by the auction naturally were which results could be achieved in the auctions, with which bidding strategy could one place oneself successfully in the auctions and how could the overall profitability of CHP projects be presented under these framework conditions.

The first auction cleared at the €32-50/MWh interval for a total of 83 MW. The auction in June 2018 also included 25 MW renewable CHP systems, which demonstrates a will to modernize the heating sector in Germany.

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

2. Framework conditions for the auctions

The current CHP 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 CHP subsidies for the generation of CHP electricity.

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

2.1. GENERAL REGULATIONS OF THE CHP
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 Emission Control Act (BImSchG) and will be placed 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.

2.2. TRADITIONAL AND INNOVATIVE SCHEMES
The auction distinguishes between traditional CHP and innovative CHP schemes (see Table 1). The auction held in December 2017 only considered traditional CHP schemes, whereas the auction in June also included innovative CHP schemes.

Traditional CHP	Innovative CHP
Technological specifications	
• No additional technological specifications	• CHP plants combined with renewable heat generation technologies and additional power-to-heat technology, i.e. CHP plants with heat pumps, solar thermal or geothermal energy • Share of renewable heat at least 30% of the annual total heat production
Subsidies	
• Maximum €70/MWh • Limited to 30,000 full load hours • Subsidy per year paid for a maximum of 3500 full load hours	• Maximum €120/MWh • Limited to 45,000 full load hours • Subsidy per year paid for a maximum of 3500 full load hours
Auction	
• 75 MW of KWKG subsidy auctioned twice a year	• 25 MW of KWKG subsidy auctioned twice a year

Table 1. Comparison of the traditional and innovative CHP schemes.

2.2.1. 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. 75 MW of CHP subsidies are auctioned off twice a year under the traditional CHP scheme.

2.2.2. Innovative CHP

The so-called innovative scheme includes CHP plants that are combined with renewable heat generation technologies and additional power-to-heat technology. This means CHP plants in combination with, for example, 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 CHP 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 3500 full load hours. Only the first 3500 full-load hours of a year will be eligible for the subsidy. This presents an optimization challenge, namely, the plant should ideally run only during the 3500 hours of the year with the highest electricity prices. However, once the annual limit is reached for the 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.

2.3. ELIGIBILITY, PENALTIES AND COLLATERAL

In order to participate in the auction, neither a building permit nor a permit within the meaning of the Federal Emission 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 1-50 MW (for non-innovative systems). If the bidder violates the notification obligations, auction guidelines or if commissioning is delayed, the security will be fully or partially withheld. The initial penalties take effect if commercial operation is started later than 48 months after the 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 the contract, only an amount of €19,200, corresponding to the difference of 0.2 MW, will be retained.

2.4. AUCTION DESIGN

Bids between 1 and 50 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 at one location into multiple bids, or to bid in parallel in both the traditional and innovative auctions. The auction is settled according to a pay-as-bid procedure, which allows for competitive bidding and bidding strategies.

3. Development of bidding strategy

Before bidding in the auction, a bidding strategy should be developed. 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 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:

1. Determine the minimum bid, the so-called indifference price

2. Determine whether it makes sense to bid above the indifference price (strategic bid mark-up)

These steps are explained on page 5.

3.1. 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 the 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 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 to determine 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.

3.2. STRATEGIC BID MARK-UP

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

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

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

Risk appetite: The risk preference differs between all bidders and projects. Certain companies will be prepared to accept a lower probability of 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.

4. 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, the CHP subsidy the plants would need at least to achieve economic feasibility, i.e. the indifference price, can be deduced from the costs and the expected revenues. This corresponds to the "break-even" bid, namely, the bid level at which the capital value of the investments is exactly zero.

To determine this value, different plant configurations were defined and modeled in BoFiT optimization software. Figure 1 shows an 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 within the context of a larger portfolio gives additional aspects on the situation:

1. A more realistic result of how the new CHP plant should be operated as the dynamic properties of the other assets also impact the operation of the new CHP plant. This translates directly into greater accuracy when determining the bid strategy.

2. 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 a 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 entire portfolio.

For all of these scenarios, the amount of the CHP subsidy was subsequently varied until the net present value of the investments was approximately zero.
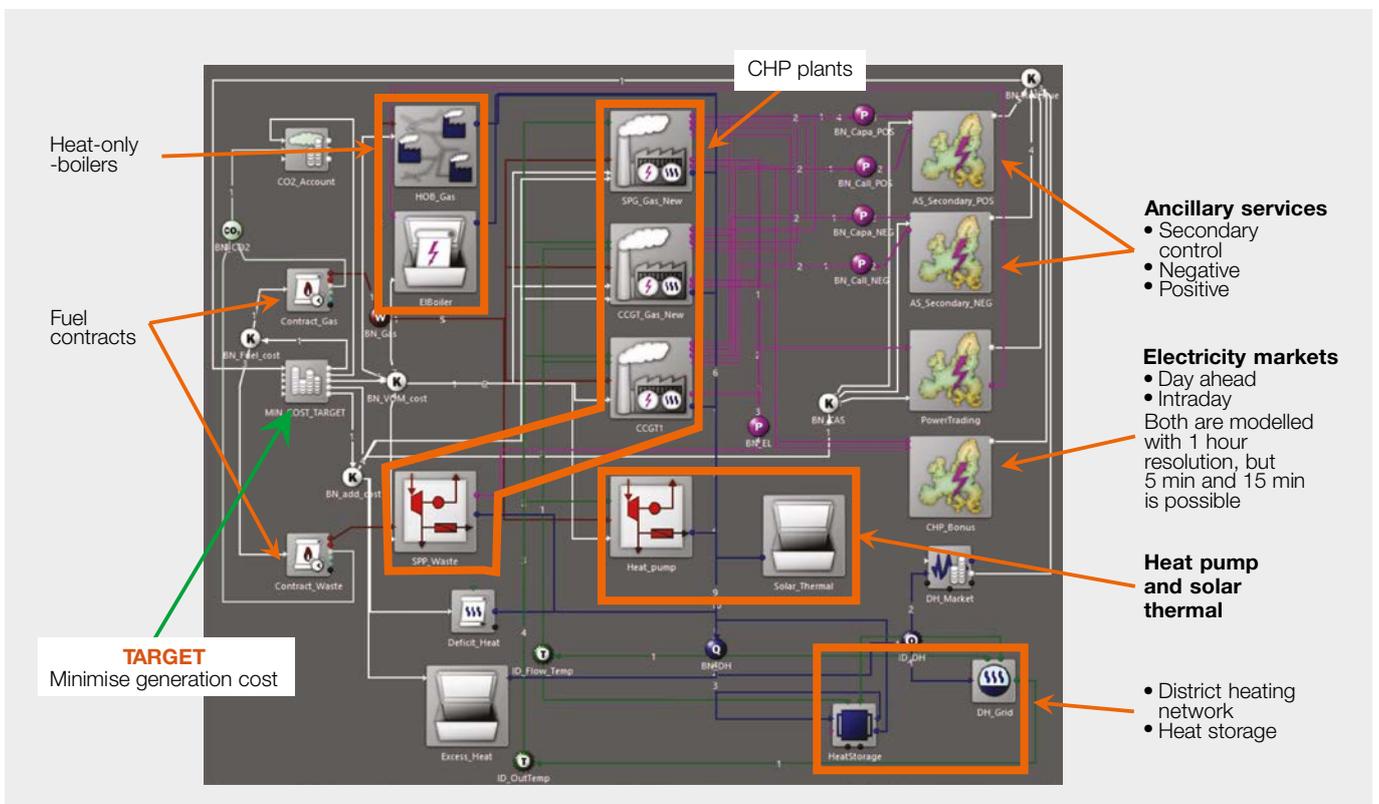

Figure 1. BoFiT model overview.

4.1. SCENARIOS

The scenarios for the traditional and innovative schemes differ a bit as the requirements are different. However, the objective is the same to minimize generation cost while fulfilling boundary conditions on heat production. Table 2 outlines the scenarios in detail and are described below.

For the traditional scheme, a small and a large plant were considered at 9 MW and 50 MW of electrical power, respectively. The different plant sizes offer a view on how the specific investment cost impacts 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 emissions trading system (ETS) certificate trading.

The innovative scenario differs from the small traditional case only in the sense that the renewable heat generation assets have 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 places a limit on how many hours the 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 runs for 2500-3000 hours, which is slightly less than the upper limit of 3500 hours.

| Asset	Traditional 10 MW Peaking	Traditional 50 MW Peaking	Innovative 10 MW
Heat demand (peak)	30 MW$_{th}$	140 MW$_{th}$	30 MW$_{th}$
Waste (MHKW)	12 MW$_{th}$	37 MW$_{th}$	12 MW$_{th}$
Gas boiler	30 MW$_{th}$	140 MW$_{th}$	30 MW$_{th}$
Heat storage	100 MWh$_{th}$ 20 MW$_{th}$	400 MWh$_{th}$ 65 MW$_{th}$	100 MWh$_{th}$ 20 MW$_{th}$
Engines	1 x Wärtsilä 20V34SG 9 MW$_{th}$	5 x Wärtsilä 20V34SG 48 MW$_{th}$	1 x Wärtsilä 20V34SG 9 MW$_{th}$
Solar thermal	–	–	10 MW$_{th}$
Heat pump	–	–	8 MW$_{th}$

Table 2. Overview of modeled scenarios.

4.2. MODEL ASSUMPTIONS

The size of the plant is the factor that has the largest effect on the specific investment costs of the plants. The assumptions used for the modeling and consequent feasibility study are listed in Figure 2. The stated investment costs are engineering, procurement & construction (EPC) investment costs. It should be noted that investment costs can vary widely depending on the situation and the special requirements posed by the project. For this calculation, the investment cost for the large engine plant is taken to be €850/kW and €1100/kW for the small case.
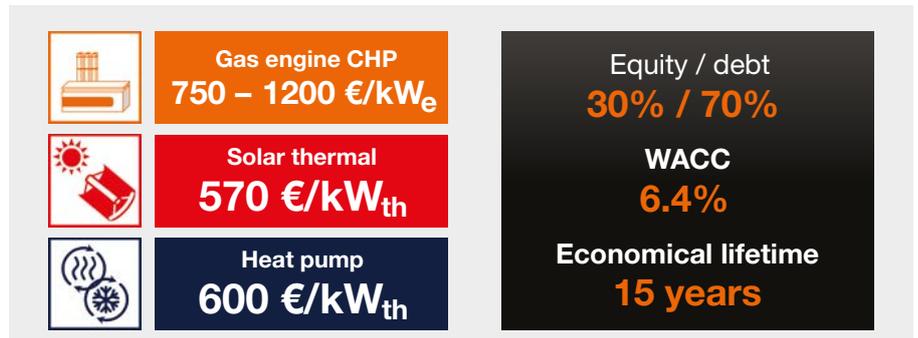
Figure 2. Investment related parameters.

As the CHP excludes industrial self-generation from the auction, it is assumed that all generated electricity is fed to the grid through the Day-ahead and Intraday markets and the generated heat is fed to a local district heating network. Figure 3 shows the district heating demand considered for the large case. The same profile has been used for the small-scale case scaled down accordingly.
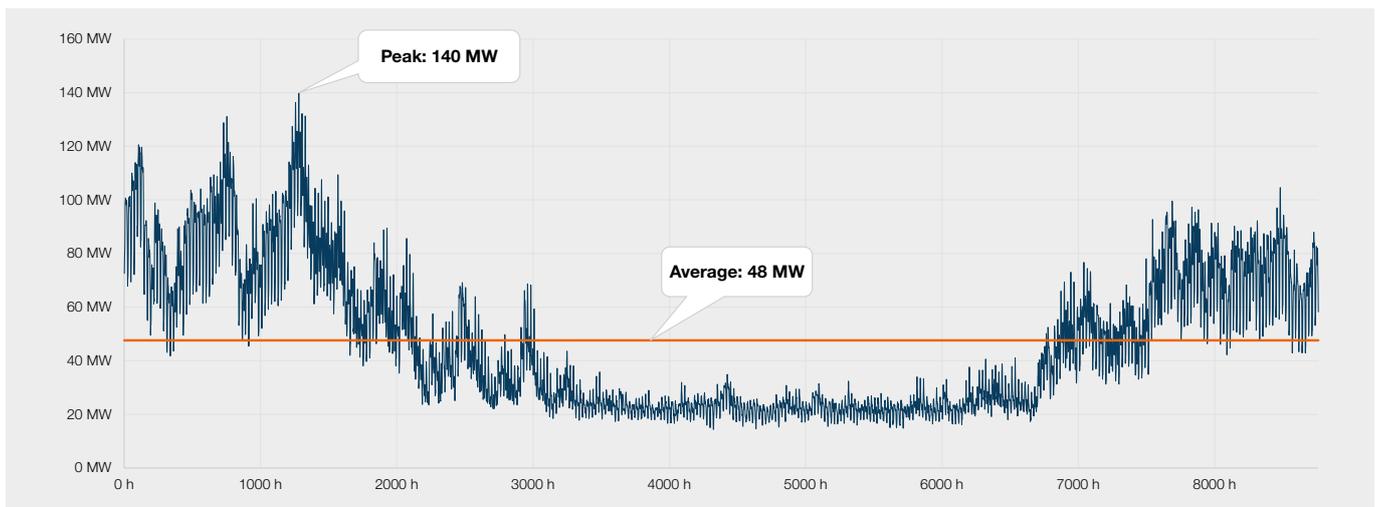
Figure 3. District heating demand profile for the large case.

Another important assumption is that the electricity, fuel and CO_2 prices used in the optimization are from 2016. This neglects a significant possibility to improve economic feasibility, as many model-based forecasts predict an increase in electricity prices relative to the gas prices (spreads) in the beginning to middle of 2020.

4.3. DISPATCH MODELING

One of the results from the BoFiT modeling is the operational profiling of the entire portfolio. Figure 4 and Figure 5 show examples of the dispatching for the portfolio for the traditional and innovative schemes, respectively. What can be noted from all of 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 a portfolio that can decouple electricity and heat production.
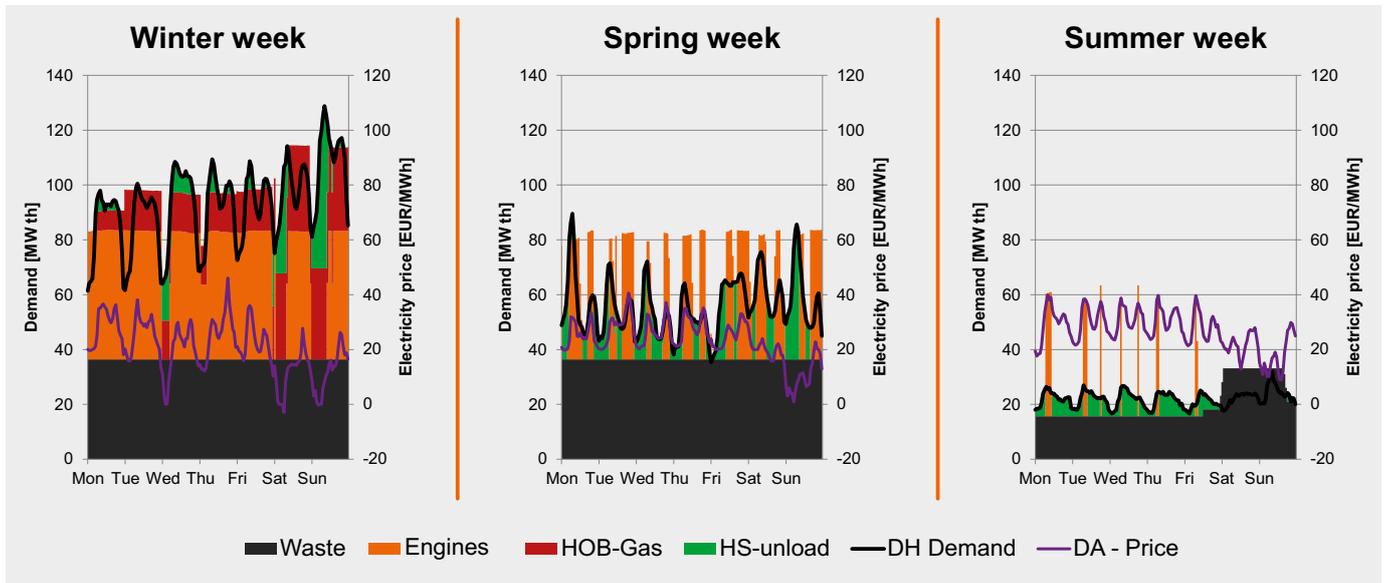
Figure 4. Weekly dispatch examples for traditional CHP portfolio.

Furthermore, in the winter week example for the traditional CHP scheme, the engine plant behaves more like a baseload 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 enables better optimization also on the heat generation side as the engine plant continuously follows the price signals and does not operate as a baseload plant.
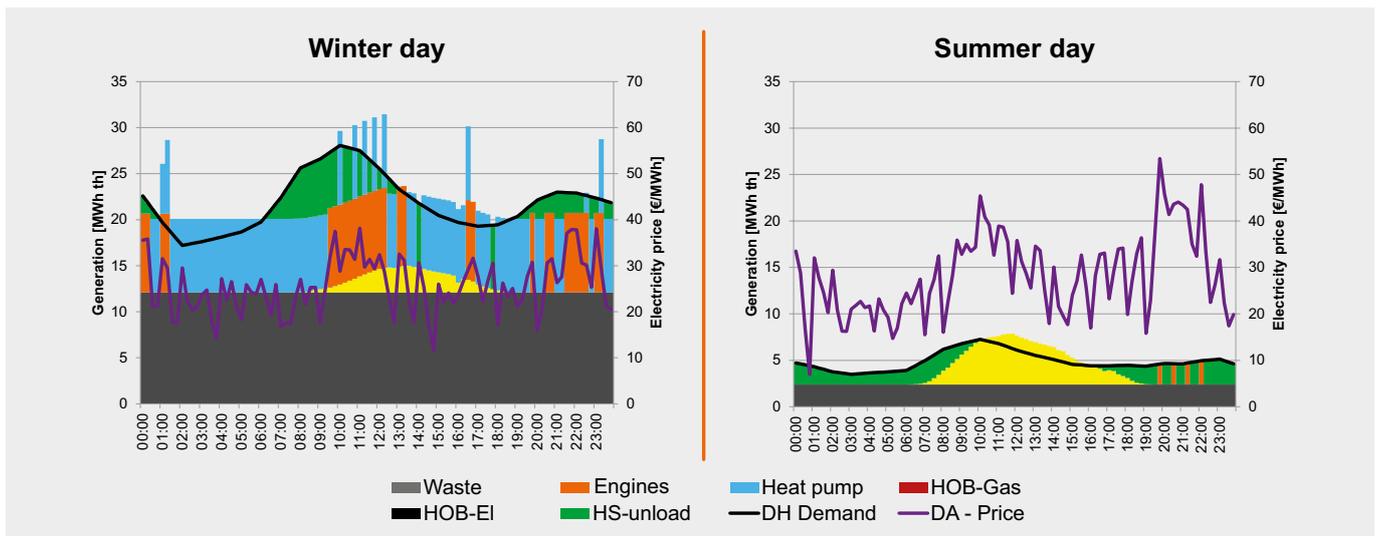

Figure 5. Daily dispatch examples for an innovative CHP portfolio.

During the summer season, the engine plant only operates 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.

4.4. 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, an overall picture of the profitability of the plants can be obtained. Figure 6 shows the calculated 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 €25-30/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.
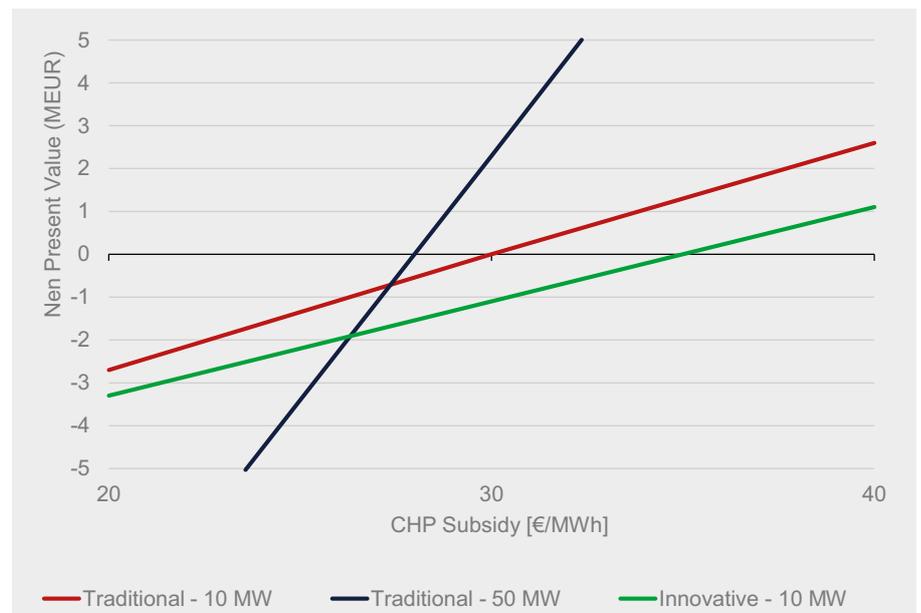
Figure 6. CHP subsidy versus net present value.

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:

1. The 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.

2. 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 rapidly change this.

5. Outlook for the future

The first auction held in December 2017 cleared in the €32-50/MWh range 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 ones. The higher end of the interval is clearly below the €70/MWh maximum, which also indicates that the bidders did more than bid speculatively.

Since CHP does not include 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 auction in June 2018, subsidies for 93 MW traditional CHP and 25 MW innovative CHP were auctioned. The 93 MW for traditional CHP consists of 75 MW defined by the CHP plus an additional 18 MW that did not clear in the first auction. The clearing price for the traditional auction was much the same as last time, but for the innovative the lowest clearing price was close to 80 €/MWh. The reason for this is most likely conservative and speculative bidding as this was the first innovative auction.

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 CO_2 emissions as the generation of electricity. Therefore, the initiative to include renewable heat generation as a special segment in the CHP reveals the intention of the German government to reduce emissions in the heating sector, as well. **Even though renewable heat generation technology still requires higher investments it points towards a new and more environmental friendly future for CHP.**

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IN BRIEF

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