Enhancing of the Energy Efficiency of an Existing Waste Incineration Plant by Retrofitting with a District Heating Network

Wolfgang Rommel, Thorsten Freudenberger, Markus Hertel and Thomas Moritz

The German Cycle Economy Act (*Kreislaufwirtschaftsgesetz* KrWG) and discussions on *the turn of local energy policies* led to intensive examination of options for optimising utilisation of heat produced by the waste incineration plant (MKW) in Weißenhorn. This has been carried out by the waste management firm (Abfallwirtschaftsbetrieb – AWB) of the district of Neu-Ulm over a long period of time. This was also prompted by knowledge that utilisation of already generated energy in the form of combined heat and power generation (CHP) is one of the most efficient ways of achieving climate protection targets. This results from considering which courses of action are available for climate protection:

- Utilisation of less greenhouse gas-intensive energy sources or primary energy sources – *alternative energy sources*.
- Increasing the efficiency – *more efficient power plants* – and reducing greenhouse gas intensity (*CCS*) in energy conversion.
- Increasing the efficiency of delivered energy use – *energy efficiency*.
- Reducing energy consumption – *energy saving*.

From a physical point of view there is no difference; what is decisive is the ratio of one tonne CO_2 equivalent/kWh useful energy. Under economic aspects with the given boundary conditions, however, a large difference results with the CO_2 prevention costs and the type of delivered energy. Greenhouse gas emissions resulting from electricity generation are specified by the *cap* in emission allowance trading. Therefore, efficient heat utilisation as a contribution to climate protection is prohibited economically.

The Weißenhorn MKW is the only waste incineration plant in Bavaria without external heat utilisation. On the one hand this is due to historical reasons, and on the other, all efforts to date and the heat utilisation concepts drawn up have not yet resulted in implementation.

Through continuous project development involving local stakeholders, the breakthrough was finally achieved for the first utilisation of heat in the form of a heating network for the town of Weißenhorn. The plant in Weißenhorn can thus be used as an example for many similar plants throughout the whole world, which do not yet have efficient heat utilisation.

1. The situation in Landkreis Neu-Ulm

The district (Landkreis) of Neu-Ulm is located in the west of the Swabian administrative region in Bavaria, on the border with Baden-Württemberg. It extends south of the River Danube over an area of 51,586 ha and in 2015 had 168,471 residents.

Landkreis Neu-Ulm has set itself the task of making the region's energy supply sustainable. The objective is to guarantee future energy supply at affordable prices, and in a resource-efficient and environmentally compatible way, thus taking into account climate protection. An integrated climate protection concept (IKK) was drawn up by 2012, from which the initial situation, objectives and courses of action are detailed in order to push ahead with the turn of energy policies in the Landkreis. This is precisely where the problem of territorial authorities in handling climate protection concepts kicks in: Which direct options for action are there for the Landkreis, apart from all controlling and motivating measures, which can also be actually implemented? The energy supply of its own properties and influencing the material and energy recovery of material flows for which the administration is responsible are often the only options remaining open. The situation is different in Landkreis Neu-Ulm with its own district incineration plant, which until now has not had any external heat usage.

By considering the total final energy consumption by types of use (Figure 1) it becomes clear that 40 percent of the total final energy consumption in Landkreis Neu-Ulm is used to provide heat. Electricity accounts for 21 percent and fuels for 39 percent.

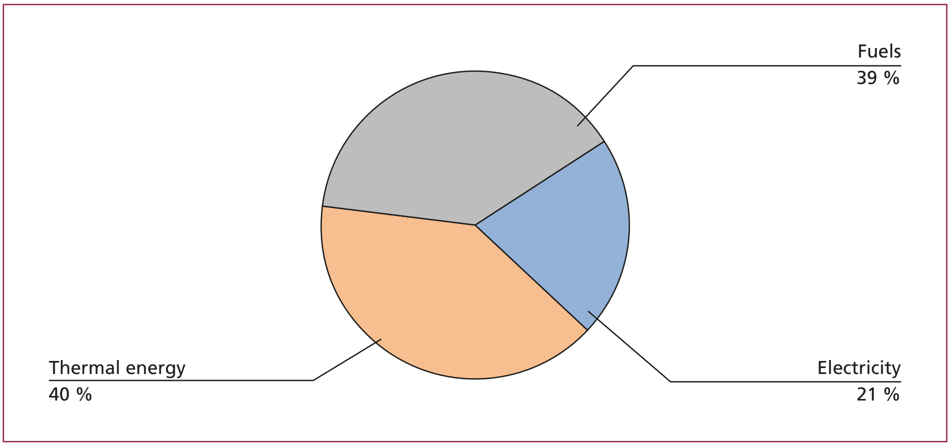


Figure 1: Total final energy consumption in Landkreis Neu-Ulm in 2010 by types of use

Source: B.A.U.M. Consult GmbH: Integriertes Klimaschutzkonzept für den Landkreis Neu-Ulm. Neu-Ulm, 07.01.2013

If the breakdown of CO_2 emissions by sectors is considered, the courses of action open to Landkreis Neu-Ulm and its municipalities with two percent of all properties belonging to them become clear (Figure 2).

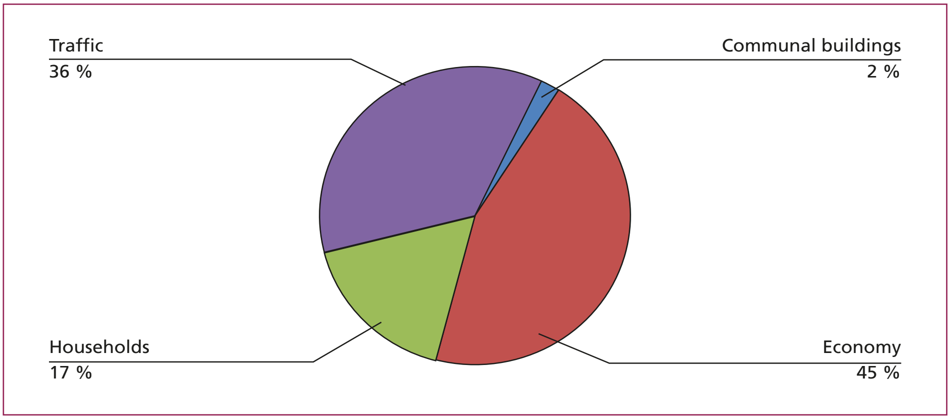


Figure 2: CO_2 emissions in Landkreis Neu-Ulm along the life cycle (LCA method) by areas in 2010

Source: B.A.U.M. Consult GmbH: Integriertes Klimaschutzkonzept für den Landkreis Neu-Ulm. Neu-Ulm, 07.01.2013

A potential ~226 GWh per year exists in the energy produced in the waste CHP plant in Weißenhorn (Figure 3), which has been in operation since September 1991. Although almost three decades of political discussions regarding the location and plant and several attempts at utilising the heat produced, all of which were not implemented for all kinds of different reasons, stand in the way of realising this potential.

Figure 3:

MKW Weißenhorn

2. Energy efficiency of Weißenhorn MKW

Technical data of the energy generation part of Weißenhorn MKW:

- Steam production: 2 x 23.0 t/h with 400 °C and 40 bar pressure, which corresponds to a thermal output of approximately 40 $MW_{th.}$;

- The electrical output is max. 10 $MW_{el.}$; under the current framework conditions (waste quantity 105,000 tons per year) around 62,000 MWh per year electricity are generated by one turbine. Of this, around 16,000 MWh per year are used by the plant itself and around 46,000 MWh per year are fed into the electricity grid.
- Feedwater temperature: 135 °C.

Energy efficiency calculation R1

According to German Cycle Economy Act (KrWG) municipal waste incineration plants can recycle waste energetically, if they fulfil an energy efficiency of at least 0.60 for plants already in operation which were approved before 1 January 2009. The calculation is performed using the R1 energy efficiency formula and was performed several times in different operating years. R1 coefficients between 0.603 and 0.67 were achieved. The coefficients depend on the respective operating regimes and stoppages of energy generation and are influenced by estimations of parameters not recorded by measurement. Overall, however, the values show that without additional heat utilisation, the facilities long-term status as a recycling plant is at the very least at risk. This is accompanied by economic risks for the AWB and the Landkreis.

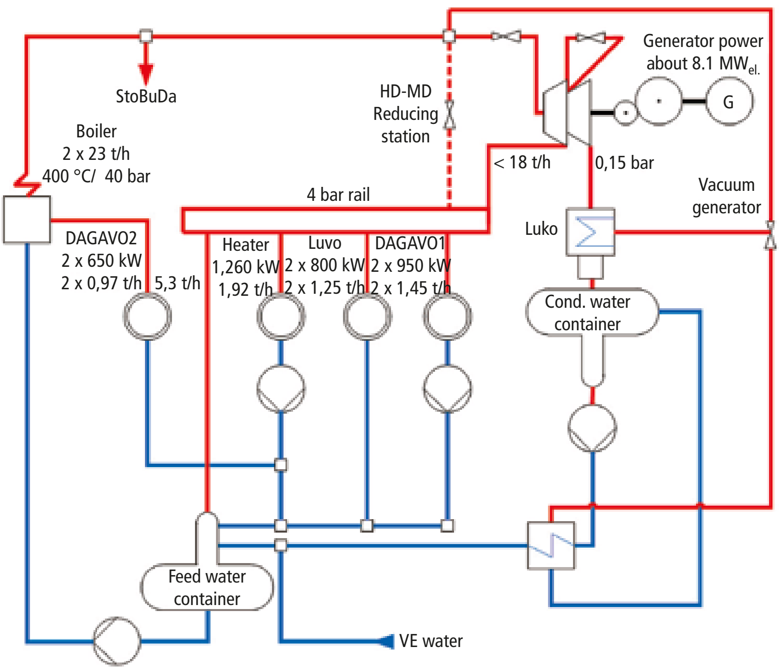


Figure 4: Block diagram of the water-steam system in Weißenhorn MKW, actual status

Source: I.C.E. AG, Ingenieurbüro für Umwelttechnik: Machbarkeitsstudie Fernwärmeversorgung ab MKW Weißenhorn. Wil (Schweiz), 2008

Additional coupling out of medium-pressure steam

In 2012, heat demand calculations and cost-effectiveness analyses of additional coupling out of energy in the form of medium-pressure steam from tapping the existing turbine (Figure 5) for district heating supply were performed.

The bleed steam from the medium-pressure part of the turbine has the following parameters:

- Pressure: approximately 3.8 to 4.0 bar,
- Temperature: approximately 165 to 170 °C.

The steam withdrawn has fed the following internal loads to date (Figure 4):

- Preheater, VE plant,
- Heating water preheater,
- Air preheater (Luvo),
- Steam-gas preheater (DaGaVo).

The residual steam is degassed in the feedwater tank for feedwater preheating. In total the quantity of harnessed steam lies between 6 and 8 t/h with peak values up to approximately 10 t/h.

According to the manufacturer's bleed steam diagram for the turbine the maximum extraction capacity is 4 bar steam at around 18 t/h; however, greater coupling out should be possible with the plant. Potential additional tapping and extraction of around 8 to 10 t/h medium-pressure steam thus results, which can be made available to external loads or consumers. This tapping would provide an output of 7 MW and, with continuous removal, between 50,000 and 60,000 MWh per year heat via the medium-pressure steam. Full coupling out of 7 MW would result in a drop in electricity generation of approximately 1.6 MW.

The R1 factor and other indicators such as the energetic net efficiency (ENE) or plant efficiency potential according to BREF (Plef) improve with increasing quantity of harnessed heat. At maximum coupling out of 7 MW the R1 energy efficiency would increase to 0.76.

Figure 5: Turbine revision at the MKW Weißenhorn

Utilisation of turbine exhaust steam

Utilisation of the heat in the turbine exhaust steam to provide hot water for a greenhouse was also examined. Until now, all the exhaust steam amounting to approximately 164,000 MWh per year has been discharged into the atmosphere via air condensers

(Lukos) with an electricity expenditure of approximately 2,000 MWh per year. The low-caloric heat contained in the steam is completely lost. In addition, electrical energy must be expended as the plant's own requirement for utilisation of the Lukos. The exhaust steam from the turbine, under the current operating regime, has the following parameters:

- Pressure: approximately 0.15 to 0.2 bar,
- Temperature: approximately 55 to 60 °C,
- Quantity: approximately 25 to 35 t/h, depending on extraction of medium-pressure steam.

Depending on the additional coupling out of medium-pressure steam, e.g. for district heating utilisation, the theoretical usable thermal energy of the turbine's exhaust steam lies between 15 MW (with 10 t/h additional medium-pressure steam extraction) and 20 MW – without additional medium-pressure steam extraction for district heating. At an exhaust steam temperature of 60 °C from the turbine, a flow temperature of 55 °C can be achieved for the hot water. With an assumed purchaser demand of 1 MW, even under lower load conditions or failure of a boiler, sufficient energy is available for the required hot water generation. The consumption of electrical energy for the air condenser reduces depending on the exhaust steam quantity passed via the heat exchanger for condensation.

Measures for increasing heat utilisation/energy efficiency

Also in 2012, within the scope of a study, measures were worked up for increasing heat utilisation and energy efficiency in general, and with a particular view to increasing exported energy.

Here, as part of boiler optimisation, the coupling out of additional heat from the boiler could be achieved by installing additional evaporator/superheater heating areas for additional steam, which could be used given an appropriate purchasing situation. However, this would require not only technically sophisticated and expensive optimisation, but would also be time-consuming in approval legislation terms.

Coupling out additional heat from the flue gas downstream of the boiler (ECO) by installing additional heat exchangers and reducing the flue gas temperature from 200 °C (or 220 °C) to approximately 170 °C would also make it possible to generate additional heat coupling out on demand.

By replacing the DaGaVo2 operated with valuable high-pressure steam with a gas-gas heat exchanger or a heat displacement system, which transfers heat at high temperature level downstream of the boiler to the flue gas upstream of the SCR, the HP steam released could be used in the turbine for electricity generation.

Steam coupling out through increased tapping of the medium-pressure level of the turbine has already been mentioned and secured tapping of 18 to 20 t/h is possible. Theoretically the quantity of extraction steam is 36 t/h. Pursuing this option further, given an appropriate purchase situation, would also entail comparing an upgrade of the condensation turbine used to date with extension of the tapping options through to replacement with a new back-pressure turbine designed for a secured purchase situation.

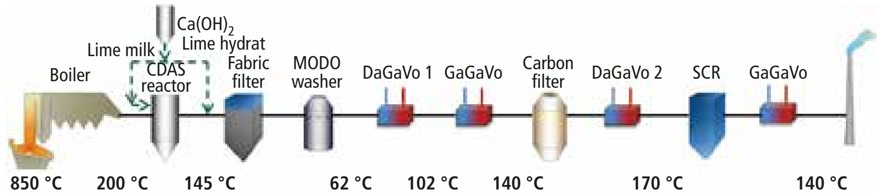


Figure 6: Flue gas route with temperatures in Weißenhorn MKW in the actual state

Source: Röhrs Process Technology GmbH: Studie zur Energieeffizienz des MKW Weißenhorn – Erstellt im Auftrag des AWB Neu-Ulm. Bad Homburg, 2012

Under the premise of not worsening the very low emissions level of the plant, there is still an opportunity to optimise flue gas cleaning under the aspect of energy efficiency. Basically, this would be achieved by substituting individual existing units based on wet technologies with dry plants. In wet scrubbers the reduction of the flue gas temperature from 140 °C to approximately 62 °C destroys the energy of the usable heat in the flue gas by approximately 1.5 MW per flue gas cleaning line. This can be performed in several steps and to different extents (Figure 6).

If a grinding and dosing system for sodium bicarbonate is added on and injection into the flue gas flow downstream of the reactor for final cleaning of HCl and SO_2 and capturing contaminant peaks, and addition of activated coke upstream of fabric filters to separate out mercury/heavy metals, the existing Modo scrubber, the DaGaVo1 and the GaGaVo could be uninstalled. Apart from the heat quantities that would be released for the coupling out of medium-pressure steam, the pressure losses in the flue gas path could be reduced significantly. With a complete changeover to sodium bicarbonate and implementation of the activated charcoal filter as the final cleaning stage, even higher heat coupling out from clean exhaust gas at high temperature difference would be possible. Equally, it is possible to achieve a complex heat displacement system with external heat coupling out with an additional 1.2 MW per line.

Depending on the measure implemented, with the measures listed above it would be possible to achieve R1 energy efficiency values of up to 0.76.

Attempts at implementing heat utilisation

Considerations by the various plant managers regarding heat utilisation have always been undertaken, but due to the situation at the location with a local population which rejected the plant for a long time and the associated political situation, nothing was done. Through sound operational management over the years and transparent discussion of the topics in the political committees, confidence has been developed over the years.

Pressure on energy use of an existing CHP plant as a baseload power plant was supported by increasingly intense discussion of climate change and progression of the turn of energy policies through to the 2nd nuclear power plant exit in 2012. Action in the turn of energy policies also affected the territorial authorities, so that from 2008 efforts in the Landkreis committees were intensified to finally implement waste heat uses from existing concepts.

In the years that followed there were several very promising approaches, none of which were implemented, however, for different reasons. The different opinions of the main public stakeholders (Landkreis and location municipality) even led to the town building its own heating network with infeed from a biogas plant, which supplies some of the town's properties.

One approach involving biomass drying, for which a preliminary contract was concluded with heat prices, was very promising but was not implemented due to the insolvency of the investor. Equally, all efforts of the Landkreis and town in the form of joint workshops, etc. to develop a district heating network in Weißenhorn were unsuccessful.

Ultimately, in 2012, this led to the decision to invite tenders for the district heating concession as a construction concession for the setting up and development of a district heating supply in the area of the town of Weißenhorn in negotiation procedures following a public competition. The objective was to acquire an external third party (energy supplier) for the project. In preliminary discussions with several relevant regional energy suppliers, interest and willingness to participate in such a call for tenders were made clear.

However, ultimately only one tender was submitted, whose conditions resulted in cancellation of the call for tenders and the topic of heat utilisation in Weißenhorn was once again back on hold.

3. Heat utilisation study

The energy supply structure is currently exposed to enormous dynamism. This poses new tasks and growing challenges for energy supply companies. The current energy supply structure must therefore be examined and optimised in contiguous regions. Optimised energy utilisation in regional clusters is therefore to be viewed as being an important contribution to climate protection. Weißenhorn MKW had already been part of general considerations in a large collaborative study of bifa in 2009 for the regional heat suppliers of the Ulm/Neu-Ulm economic region. With extensive district and local heating networks and power plants with a primary energy factor of 0.22, these regional suppliers have had a model climate protecting effect for the heat supply of a cross-state economic region (Bavaria and Baden-Württemberg). In the combined heat study, the connection of district heating areas in Ulm/Neu-Ulm incl. their extension to Senden and a merger with the MKW in Weißenhorn was proposed as a checkable option for a cluster solution.

In addition, in 2010, a waste management strategy concept was drawn up by bifa for AWB Neu-Ulm, in which the importance of the waste incineration plant for the Landkreis and implementation of heat utilisation was highlighted.

Therefore, AWB engaged bifa Umweltinstitut GmbH to check implementation options from its experience of project implementations and from a different perspective to those applied to date and if applicable to develop it further until it was ready for implementation. The objective of the work was to develop one or several customised concepts for optimising heat utilisation.

The objective was to be achieved via a modular approach, which can essentially be divided into two steps, after which a decision will be made whether the project is to be developed further:

- Survey of the existing situation and analysis of the potential,
- Concept development and assessment,
- Further project development by involving relevant stakeholders and more precise definition of the basis of the decision making.

Heat coupling out

The possibilities for using the heat of Weißenhorn MKH are pointed out using the following 3 diagrams. Incineration of the waste produces steam with around 400 °C and 40 bar in the steam generator. This steam drives the turbine, in which part of the thermal energy is converted into kinetic energy and ultimately electricity is produced in the generator. The electricity generated is used to cover the MKW's own requirements. The remaining electricity is fed into the electricity grid and is remunerated. Following the first turbine stage, part of the steam with approximately 168 °C and 4 bar is branched off (extraction steam) for internal power plant processes, for example, flue gas cleaning. Downstream of the turbine a cooled and relaxed steam with approximately 57 °C and 0.15 bar remains, which is cooled further in condensers and is converted into hot water (Figure 7). A small part can still be used for preheating purposes in the power plant. However, a large parts is lost heat, which is discharged in the atmosphere. Thus, there are three different energy levels (pressure and temperature) in the power plant process, which are available for coupling out heat. Basically, Weißenhorn MKW has a substantial potential of heat to be discharged with approximately 30 MW output or around 226,000 MWh per year (without electricity generation).

To supply a district heating network, steam with 4 bar and 168 °C is harnessed from Weißenhorn MKW and the heat is fed into the district heating network via a heat exchanger. Figure 8 shows the coupling out of steam and symbolic representation of a heat exchanger for transferring the heat to a water network. Thus, less steam is available for electricity production, which ultimately means reductions in electricity income. The heat discharged to the atmosphere via the condenser downstream of the turbine is also somewhat less. If approximately 10,000 MWh per year district heating were to be provided, the electrical efficiency would drop from 22.1 percent to 21.7 percent, the total efficiency of the power plant would however increase from around 22.1 percent to around 25.2 percent.

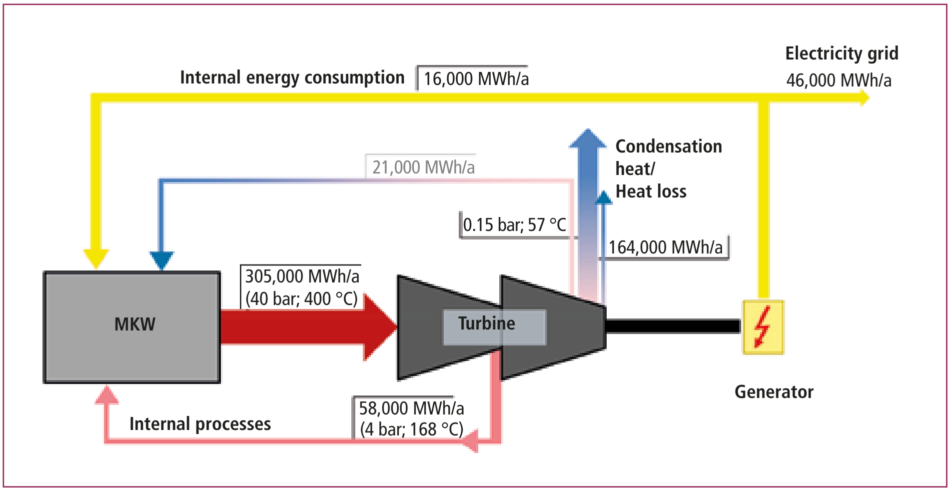
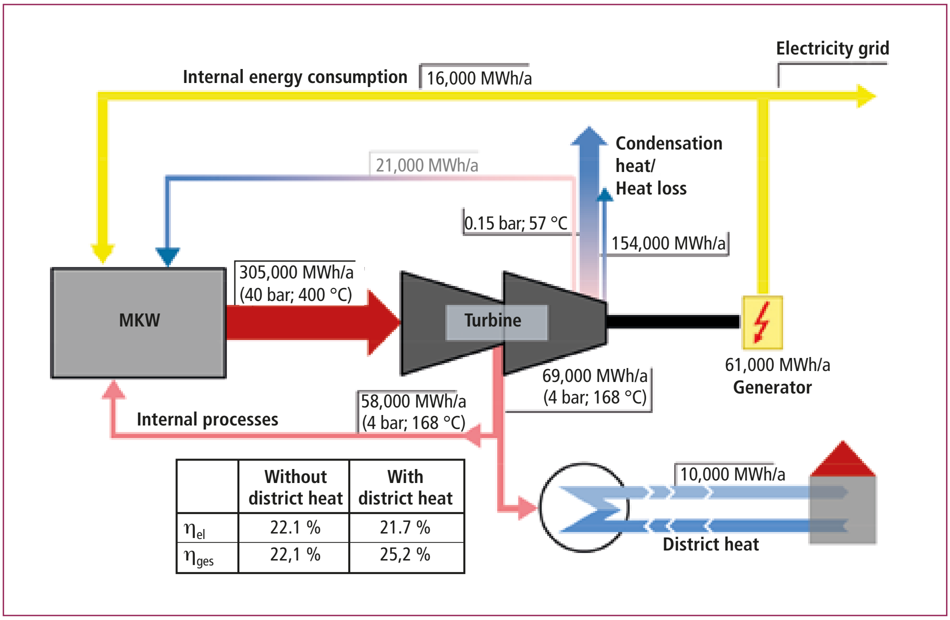


Figure 7: Simplified energy diagram for Weißenhorn MKW – actual status



	Without district heat	With district heat
η_{el}	22.1 %	21.7 %
η_{ges}	22,1 %	25,2 %

Figure 8: Simplified energy diagram for Weißenhorn MKW with heat coupling out

A further possibility is to supply a steam network, provided purchasers require heat in the form of steam (mostly process steam utilisation). As several purchasers with process steam exist in Weißenhorn, this is an option worth checking. In this case, high-quality steam at the level of 400 °C and 40 bar – so-called main steam – is mixed with steam of the 4 bar line, in order to obtain the required energy level of approximately 10 bar and 180 °C, to supply the process steam user (Figure 9).

Utilisation of the so-called low-temperature heat downstream of the turbine with approximately 57 °C is only possible for very limited applications such as drying processes or preheating, and is in competition with other waste heat producers.

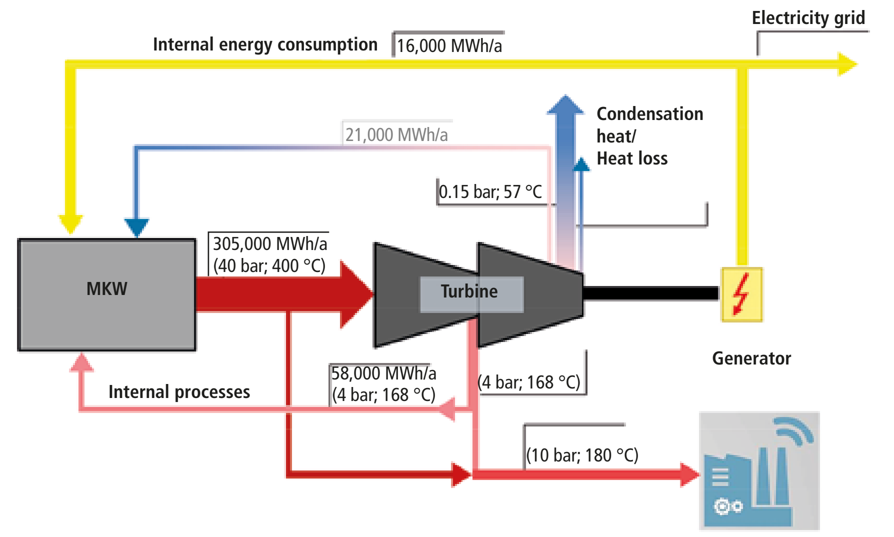


Figure 9: Simplified energy diagram for Weißenhorn MKW with steam coupling out

Coupling out heat at the energy level 40 bar and in particular 4 bar (steam or district heating supply) is to be welcomed from an energy point of view (combined heat and power generation). A corresponding drop in income from the electricity income feed-in payments must however be taken into account in the calculation.

Heat purchasers

An important point for drawing up the concept was the inclusion and compilation of possible heat purchasers. The following basic options were checked regarding their feasibility.

- Piped heat supply within Weißenhorn,
- District heating pipes to Senden, Illertissen or Vöhringen,
- Mobile heat transport systems,
- Other heat utilisation concepts such as drying, etc.

At the same time, for example, for heat supply within Weißenhorn, several pipe route options were examined – depending on potential heat purchasers and development stages – in an initial check for technical and economic feasibility. Initial calculations showed good implementation prospects for piped heat supply within Weißenhorn provided appropriate combinations are chosen. Equally, district heating pipes to Senden, Illertissen or Vöhringen proved to be interesting possibilities, which justify further checking.

Other heat utilisation utilisation concepts

Apart from the provision of process heat and heat for heating purposes or drinking water treatment, there are other heat utilisation possibilities in the low-caloric area. These include:

- Sewage sludge drying,
- Drying of biomass (wood chips, pellets, etc.),
- Heating for aquacultures,
- Greenhouse heating,
- Production of biochar.

For the provision of heat for drying purposes, suitable companies would have to be found, which would locate in the immediate vicinity of Weißenhorn MKW. As low-caloric thermal energy (condensation heat downstream of the turbine) is often sufficient for drying processes, such a heat utilisation has no or only minor effects on the MKW's electricity generation. However, here the heat from Weißenhorn MKW is in competition with the waste heat of other energy generation plants (for example biogas plants), which due to basic legal conditions (e.g. German renewable energy law (EEG) grants) often give away their heat without monetary payment. Therefore, low income opportunities must be assumed from the view of the MKW operator. A similar situation applies to the provision of heat for heating aquacultures or greenhouses.

All contacts with low-caloric applications therefore proved to be uneconomic at the time, as the investment in coupling out and pipe laying to a company locating in the neighbourhood cannot be achieved (paid back). If a larger purchaser were to locate in the area it may be worthwhile to start negotiations about a heat price. For example, larger-scale greenhouse projects are interesting. To this end, areas of at least 5 to 6 ha could be developed in the immediate vicinity of the MKW. However, the ideas regarding a heat price in specific negotiations are still far apart.

District heating pipes outside of Weißenhorn

Due to the location of Weißenhorn MKW in the west of the town of Weißenhorn, considerations were checked regarding supplying the three neighbouring towns of Senden (around 21,500 residents), Vöhringen (around 13,000 residents) and Illertissen (around 17,000 residents) (Figure 10).

The lengths of the respective district heating pipes in the above-named neighbouring towns and the expected investment costs are shown in Table 1.

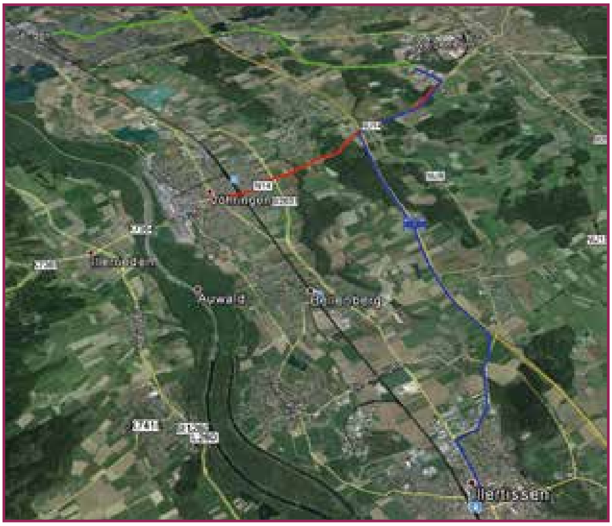


Figure 10:

Possible routes of district heating pipes to Senden, Illertissen and Vöhringen

Table 1:

Possible district heating pipes outside of Weißenhorn

	Unit	Senden	Vöhringen	Illertissen
Distance from the MKW	km	7.1	4.7	8.2
Investment* (net) without grants	EUR	7.1 mln	5.1 mln	7.4 mln

* Investment only includes the district heating pipe, not the costs of local heat distribution

The most favourable basic conditions of the district heating pipes outside Weißenhorn shown in Table 1 are provided by a district heating pipe to Senden. Here heat distribution infrastructure starting from a heat generation plant already exists. In addition, the existing connecting pipe between the heating network in Neu-Ulm and the heating network in Senden could be used to connect Weißenhorn MHW to the Ulm/Neu-Ulm heating network.

In the towns of Vöhringen and Illertissen, at present, there is no infrastructure within the town area for distributing heat. Economic operation of a heating pipe to Vöhringen or Illertissen is therefore highly dependent on the number of possible heat purchasers and from this the deliverable heat quantity. The greater distance of a heating pipe to Illertissen compared to Vöhringen could be partially compensated for by the connection of larger heat purchasers such as a clinic or water leisure park. However, in both towns further investigations into heat sinks or even the drawing up of a heat register for the town areas would be necessary, in order to determine reliable figures.

Piped heat supply within Weißenhorn

Initial calculations showed good implementation prospects for piped heat supply within Weißenhorn provided appropriate combinations are chosen. In an initial step, various options were drawn up for piped heat supply within Weißenhorn.

For a possible network development in Weißenhorn, a next important step was to inform the current active stakeholders of the town of Weißenhorn, AWB and Landkreis Neu-Ulm about the potential possibilities, opportunities and risks of the concept and to agree on a joint will to implement. This was prerequisite in order to take the next project development step and was achieved. This meant that the next step, phase 3, could then be taken, i.e. contacting larger heat consumers.

Due to the large investment sums required for piped water supply within Weißenhorn, it is indispensable to hold discussions with potential heat purchasers before any further decisions are made. Here the potential purchasers must be asked about their basic willingness to purchase an external supply with the relevant basic conditions (technology, prices, …) and time implementations, need for replacement or new investment and the load curves of the heat loads/consumers. There was a positive attitude among possible heat purchasers and a willingness to carry out a check with their specific consumption values. The data and information obtained in the discussions were fed into the existing calculations. These are public properties and companies in the location. In the discussions with the companies in the existing business park and the clinic it was found that they need steam for their production or hygiene processes.

From this new knowledge, the following pipe and supply options resulted, which were calculated accordingly (also Figure 11):

Option 1: Large steam/heat cluster (light blue, black, orange and green) steam pipe through the business park to the Stiftungsklinik clinic. From there heating network via Kaiser-Karl-Straße to the Realschule school.

Option 2: Industrial steam (light blue) steam supply for companies in the business park

Option 3: Heat up to the Stiftungsklinik (violet, green and orange)

Option 4: Large heating network (violet, green, orange and dark blue)

In option 1 the steam pipe up to the Stiftungsklinik is prerequisite for further routing as a district heating network with heat source water.

The existing town heating network, which is fed from the biogas plant and which is routed via the outdoor swimming pool to the town-owned properties, is drawn in brown.

The calculations showed that separation of the supply of industrial companies with a steam network (option 2) and a separate district heating supply in the town centre of Weißenhorn up to the Stiftungsklinik (option 3) is economically more attractive than option 1. In the large steam/heat cluster the combination of a steam network to supply industrial steam users and the Stiftungsklinik and continuation as a district heating network from the Stiftungsklinik via the town centre of Weißenhorn to the Realschule is planned. The reason for this result is that a considerable length of steam network has to be laid for the Stiftungsklinik as a purchaser of steam. In addition, all heat required for the subsequent district heating network must be routed through the steam network.

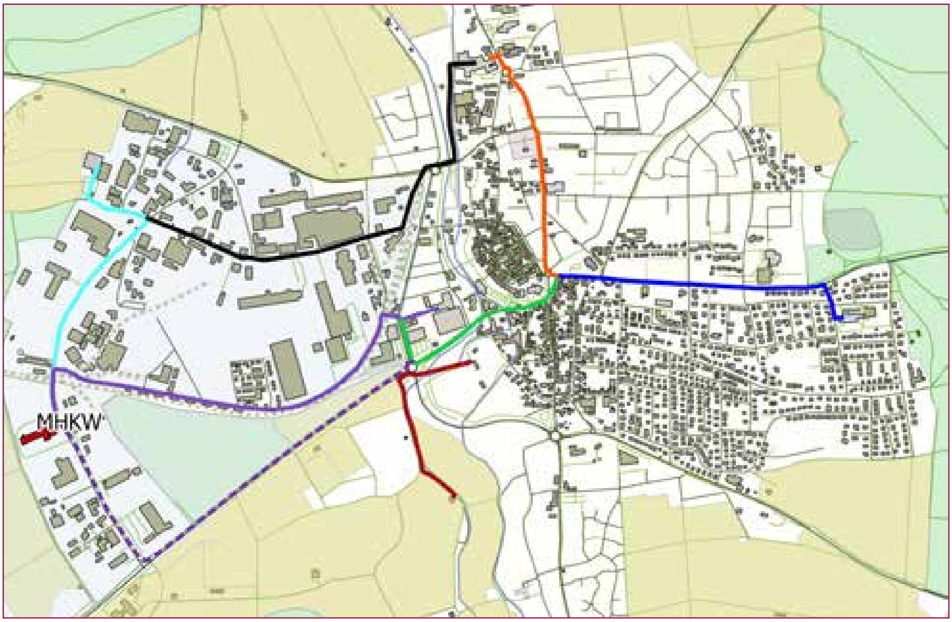


Figure 11: Overview of the network routes

Source: OpenStreetMap 2016

Thus, higher pressures are necessary for the coupling out. Option 2 supplies two specific larger process steam users and can supply heat users along the route too via appropriate extraction. All town centre heat sinks in Weißenhorn are to be supplied via option 3. Continuation to the clinic taps further potential. Around 2/3 of the heat demand of the clinic is required as heat and around 1/3 as steam. Option 4 with continuation from the town centre eastwards towards Weißenhorn is to be viewed as a development stage in this form or through residential areas.

The competitiveness of the examined options was checked using rough heat production costs. To achieve greater reliability of the heat production costs in this phase, sensitivities were determined with a large number of parameters:

For options 2 and 3, the usual market supply prices, not only for the industrial but also for public properties and private households are to be achieved (Bavarian average value for detached houses around EUR 83.64 MWh net mixed price). By separating into a steam network and a district heating network for the town centre up to the Stiftungsklinik the investment costs are lower and mutual dependency is removed. Thus, standard market prices are to be achieved for the respective purchaser clientele large industrial consumers and public properties, and private households.

Therefore, the recommendation was made in favour of option 2 steam network to the large industrial consumers and option 3 district heating network via the town centre to the Stiftungsklinik. Option 4 is to be seen as the development target of option 3.

As a next step there was a need to make fundamental decisions for both options and to start specific negotiations, in order to be able to start the preliminary design. For option 2, in the first half of 2015, decisions had to be made by larger purchasers, who have a substantial influence on the economic feasibility.

From AWB's point of view the prospect of a heat supply pipe to Senden should also be pursued further. This required holding coordination discussions with the local energy suppliers in Senden.

At the beginning of 2014, the last district administrator initiated another important step in the political committees. A report on the economic and technical aspects of further operation of Weißenhorn MKW up to 2035 was drawn up. Topics such as the obligation to repay grants as part of grant commitment periods, taxation interpretation in case of further operation or shutdown, contractual relationships and ensuring long-term capacity utilisation, arranging the pending investment, the legal charge situation, technical parameters as well as social, ethical and ecological parameters were dealt with. Finally, the county council (Kreistag) made the landmark decision to continue operation beyond 2021 with a view to 2035. This establishes the ability to act for contractual ties beyond 2021, whether regarding waste quantities or investments in heat utilisation.

Subsequent closure of the only German waste pyrolysis plant in the adjacent district with effect from 31.12.2015, enabled additional waste quantities which have to be submitted via a special purpose municipal agreement (*Zweckvereinbarung*) to be secured.

4. District heating project development company

With the election of the new district administrator in the spring of 2015 and their assumption of office, the topic of use of the MKW's heat then gathered pace. All facts such as the courses of action of the climate concept in the Landkreis, and the need to secure the AWB long-term spoke in favour of continuing to support the topic.

At the beginning of June 2015, a steering committee was founded with representatives of all parties on the town council, the town of Weißenhorn and Landkreis Neu-Ulm, as well as the AWB, which accompanies all further activities outside of the political committees. This was required, as current developments arose not only regarding the steam pipe to the two large production purchasers but also for an additional utilisation of waste heat to dry large quantities of wood pellets.

One of the two planned steam purchasers had to register insolvency and further operation of the business was unclear for many months. Therefore, the steam pipe (option 2) was backed away from. A new option for heat utilisation resulted from the location of a pellet factory with drying of wood pellets and an average heat purchase of approximately 90,000 MWh per year. For this utilisation, direct negotiations were held for the AWB and ultimately, in September 2015, a preliminary contract with fixed conditions was concluded.

For further implementation, the steering company did not want to take on board an external third party at the time. This led to the recommendation that a project development company be set up, consisting of 50 percent Landkreis Neu-Ulm and 50 percent Weißenhorn town, in order to establish the ability to act, and which was ultimately implemented by the new district administrator in the autumn of 2015.

What followed was the drawing up of a heat register for the town of Weißenhorn, a preliminary design for the two development stages of the district heating network in Weißenhorn and negotiations with more than 10 special contract customers regarding preliminary contracts with fixed conditions.

With the results of the contract negotiations, a preliminary design and a detailed cost estimate with income statement, consideration of reinvestment, liquidity analysis, delayed starting up of the connecting firms and thus income and a large number of sensitivities, the basis was created in order to determine the effects of deviations as a result of the final design or during the construction period.

Heat quantities in the heating network

The calculation is based on a sold heat quantity in option 3 of 5,560 MWh per year and in option 3+4 of 7,600 MWh per year, which is based on 9 (V3) or rather 11 (V3+V4) special contract customers plus a connection rate of 30 percent private households (28 households in V3 and V3+V4), which lie along the route in the centre and at the end point V3.

Heat demand calculation/expected consumption

A heat register was drawn up for the whole area of Weißenhorn town, in order to determine the potential areas. A conservative approach was assumed for private households with a connection rate of 30 percent (30 percent achieved after 6 years) whereby each connected household was assumed to have an annual consumption to date of 30,000 kWh per year (in future 22,500 kWh per year district heating supply). Public properties were asked to supply their specific consumption figures of the last year and, where possible, recent years and these were used as the basis of the calculation. The actual average consumptions of recent years are available for industrial/industrial/church purchasers. In order to take into account the efficiencies of the individual heating system, an annual efficiency of 75 percent was assumed for the respective heating systems. For 90 percent of the assumed heat demand in the calculation of the basic options, specific consumption figures of recent years are available. Heat loss in the network was assumed with 20 percent, whereby less loss is to be assumed in operation.

Development opportunities of the Weißenhorn heating network

Apart from the basic options V3 and V3+V4, opportunities result for developing the heat network around the planned routes of the two basic options. In the following table *extension* means short branch pipes from the main routes, which would tap further private household potential (see network plan; Figure 12). Both options, each with and without extension, are also feasible with 60 percent private household connection rate instead of 30 percent (Table 2).

	Priv. HH connection rate 30 % Heat quantity MWh/a	Priv. HH connection rate 60 % Heat quantity MWh/a
Option 3	5,560	5,965
Option 3 with extension	6,620	7,680
Option 3+4	7,600	9,450
Option 3+4 with extensions	9,620	11,650

Table 2:

Extension opportunities of the Weißenhorn heating network

For a heat quantity of 10,000 MWh per year a CO_2 saving between approximately 2,500 (replacement of natural gas heating systems) and approximately 3,700 tons CO_2 equivalents result per year.

In addition, further industrial companies exist in the direct catchment area of the MKW. A shopping centre lies along the course of the planned route. Further residential and mixed use areas with corresponding heat demand are developable from the planned main routes. Equally, 2 new business parks are currently being designed, which could be taken into account in the design of the business parks.

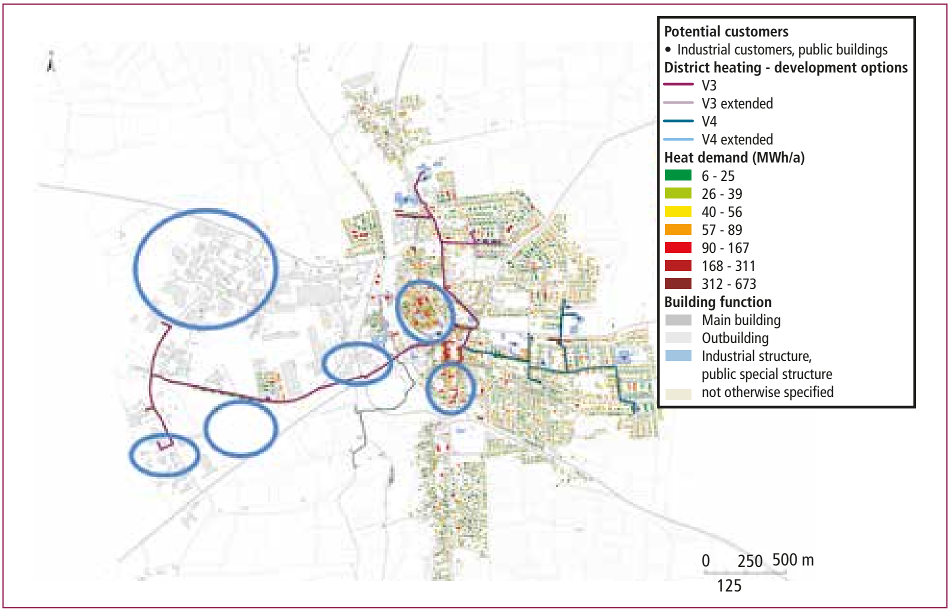


Figure 12: Development options for Weißenhorn district heating network (encircled in blue)

Sources: bifa 2016; basic geographic data. Bayerische Vermessungsverwaltung 2016

The characteristics of the Weißenhorn district heating network can be seen in Table 3.

Item	V3	V3+V4
Network length	6.4 km	8.2 km
Heat sales: Basic options, conservative approach, > 70 % secured via preliminary contracts	5,560 MWh per year	7,600 MWh per year
Heat output: Basic options, conservative approach	4.7 MW	6.5 MW
Investment costs (without BAFA grant)	5.75 mln EUR	7.3 mln EUR
Primary energy factor	between 0.05 and 0.4 depending on the assessment of the fp expert	

Table 3:

Characteristic data of the Weißenhorn heating network

In July 2016, the political decision is due in the town and Landkreis, to start the final design and at the same time to plan the political decision-making process regarding the participation of a third party. The first development stage is planned to be put into service for the heating period 2017/2018, development of stage 2 one year later.

An approach from an energy point of view, initially without taking into account the interests of stakeholders and possible operators, followed by the involvement and continuous project development with the main stakeholders as *troubleshooters*, led to both the stakeholders in the Landkreis and those in the local municipality being convinced of the project's worth. Accompaniment of the project will continue until implementation by the public sector or with an external third party is certain.

For Weißenhorn MKH this means the first step towards Weißenhorn MHKW (waste CHP plant). In parallel with the district heating network, in the foreseeable future decisions will be made regarding the location of a pellet factory. A market correction is currently occurring in pellet production, which has an effect on possible location. Alternatively, a district heating pipe to Senden will be further pursued. Once the first heat uses have been implemented, a more cost effective possibility for implementing low-caloric waste heat uses will also result. In a few years time we will see which heat uses have actually been implemented and whether it is more worthwhile to upgrade the existing condensation turbine or to purchase a new back-pressure turbine.

5. References

[1] B.A.U.M. Consult GmbH: Integriertes Klimaschutzkonzept für den Landkreis Neu-Ulm. Neu-Ulm, 07.01.2013

[2] bifa Umweltinstitut GmbH: Prüfung und Entwicklung von Wärmekonzepten für das MKW Weißenhorn – Wärmenetz für Weißenhorn – Erstellt im Auftrag des AWB Neu-Ulm. Augsburg, 18.11.2014

[3] I.C.E. AG, Ingenieurbüro für Umwelttechnik: Machbarkeitsstudie Fernwärmeversorgung ab MKW Weißenhorn. Wil (Schweiz), 2008

[4] Röhrs Process Technology GmbH: Studie zur Energieeffizienz des MKW Weißenhorn – Erstellt im Auftrag des AWB Neu-Ulm. Bad Homburg, 2012

[5] Wischenbarth, P.: Der Landkreis Neu-Ulm und seine Vorläufer – eine Verwaltungsgeschichte. Landkreis Neu-Ulm (ed.), Neu-Ulm, 2012

Bibliografische Information der Deutschen Nationalbibliothek

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.dnb.de abrufbar

Thomé-Kozmiensky, K. J.; Thiel, S. (Eds.): **Waste Management, Volume 6**
– Waste-to-Energy –

ISBN 978-3-944310-29-9 TK Verlag Karl Thomé-Kozmiensky

Publisher: TK Verlag Karl Thomé-Kozmiensky • Neuruppin 2016
Editorial office: Professor Dr.-Ing. habil. Dr. h. c. Karl J. Thomé-Kozmiensky, Dr.-Ing. Stephanie Thiel, M. Sc. Elisabeth Thomé-Kozmiensky, Janin Burbott-Seidel und Claudia Naumann-Deppe
Layout: Sandra Peters, Anne Kuhlo, Janin Burbott-Seidel, Claudia Naumann-Deppe, Ginette Teske, Gabi Spiegel und Cordula Müller
Printing: Universal Medien GmbH, Munich