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# Converting steam-based district heating systems to hot water

Fig. 1

- **Changing the medium without resorting to a completely new installation: existing steam and condensate pipes can continue to be used**
- **Lower network construction costs, reduction in heat losses, increased efficiency of CHP plants**
- **Model for steam system operators in Germany and abroad**

*Increased efficiency thanks to lower temperature level: By connecting its turbine waste heat to a new hot water system instead of to a steam-based district heating system, the new gas and steam turbine plant in southern Munich is able to generate an additional 160 GWh of electricity per year*

Steam was the first heat transfer medium to be used for distributing heat in district heating systems. This is not surprising, since steam has always played a dominant role in the power station process, so that it was easy to supply customers near power stations with steam. Today, modern power plant technology enables the efficient exploitation of steam when generating valuable electricity. The maximum use of the primary energy is achieved through the co-generation of electricity and thermal heat in the form of hot water, which is why water is advantageous as a transfer medium for supplying district heating.

The increased use of district heating, in particular in the 1960s and 70s, increasingly revealed the disadvantage of steam-based systems: the construction and operation are, taken as a whole, much more expensive than hot water systems. Steam-based networks require a complex condensate system and thus considerable servicing and maintenance work. They have considerably higher operating temperatures, resulting in greater heat losses. Steam requires elaborate pipe and connection systems, which means that it is expensive to connect new customers and the potential for extending district heating systems is limited. The high temperatures also reduce effective cogeneration as well as the inclusion of lower temperature heat from industrial waste heat or renewable energy. Today, most steam systems are in need of refurbishment and their future viability is very much in doubt. At the same time, new impetus for district heating is coming from the gas market, since the charges for using gas grids have considerably reduced and the gas prices are currently anything other than stable. The consequence: district heating offers new market potential, and the pressure on the remaining steam system operators to convert is increasing.

Steam systems have already been converted in some German cities. Here the heat transfer medium has always been converted in conjunction with the new installation of a hot water distribution network. As part of a BMWi research project, a technical and economic conversion concept was developed and implemented for the Munich steam system – the largest in Germany. A particular feature of the Munich pilot scheme is that this is the first time anywhere in the world that an existing steam and condensate pipe network has continued to be used as hot water supply and return pipes. Therefore, in conjunction with a planned new gas and steam turbine plant, one of the most cutting edge district heating systems in Germany is being created in Munich.

## ▶ Initial situation, goals

Several smaller steam systems, for example in Braunschweig, Leipzig und Baden-Baden, have already been converted to hot water in the past, whereby completely new hot water systems were always installed. This procedure, however, would have involved enormously high construction costs for the network in Munich's inner city. In addition, it was also proved as part of a preceding research project that Munich's steam system could only remain economically viable if the existing steam and condensate pipes were used and converted to hot water in the foreseeable future. The investment volume is clearly reduced and optimised heat generation capacities from the cogeneration can be utilized at an early stage. Nevertheless, in technical terms such a conversion of a steam system represents uncharted territory. The diverse impacts on all areas of the district heating system – ranging from the generation and the distribution to the customers – mean that its success was in no way guaranteed. ■

### Goals of converting steam-powered district heating networks to hot water:

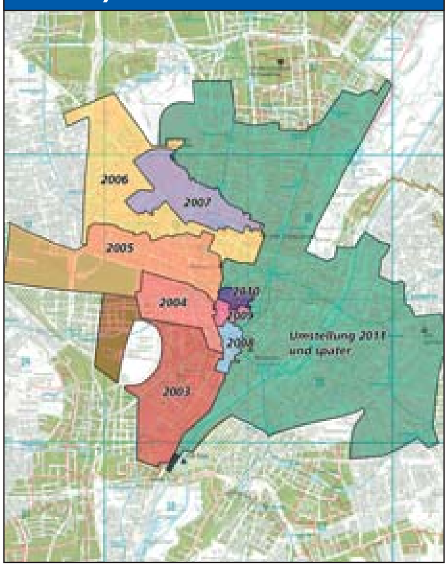
- Lower network temperatures
- Cheaper heat generation
- More efficient electricity generation through lower turbine output parameters
- Condensate system can be dispensed with
- Reduction of heat losses
- Lower investment in terms of replacement parts (pre-insulated bonded pipe system) and new construction
- Lower operating costs

**Fig. 2: Age-related refurbishment and new construction no longer has to be conducted using dome-shaped duct technology (left image), but can now be carried out more cheaply using a directly buried, pre-insulated bonded pipe system (right image).**

## ▶ Converting Munich's steam system

Even in 2000, the gradual growth in the network structures over many years meant that a large part of the Munich district heating system still had high supply temperatures throughout the year. Two thirds of the connection value was attained in sub-networks with supply temperatures greater than 100°C and peak temperatures well in excess of 130°C. Therefore it was not possible to use cheap pipe-laying technology with a pre-insulated bonded pipe system. High operating and maintenance costs for the dome-shaped ducts and numerous shafts meant that Munich's district heating was not economic when taken as a whole. This particularly applies to Munich's largest high-temperature network, the steam system, which has a total pipeline length of around 250 km, 4,400 customers and a connection value of 1,200 MW. In fact, most of these customers do not even require high temperatures: around 95% of Munich's district heating customers require thermal heat at a temperature level less than 100°C. Only 5% use the high temperatures provided by district heating for generating steam for canteens, air conditioning, low-pressure steam heating and in absorption cooling systems. For this reason, lowering the supply temperatures when converting the steam system into a hot water system is not just sensible but accords with market demands.

**Fig. 3: Schedule for converting the steam system in Munich from 2003**



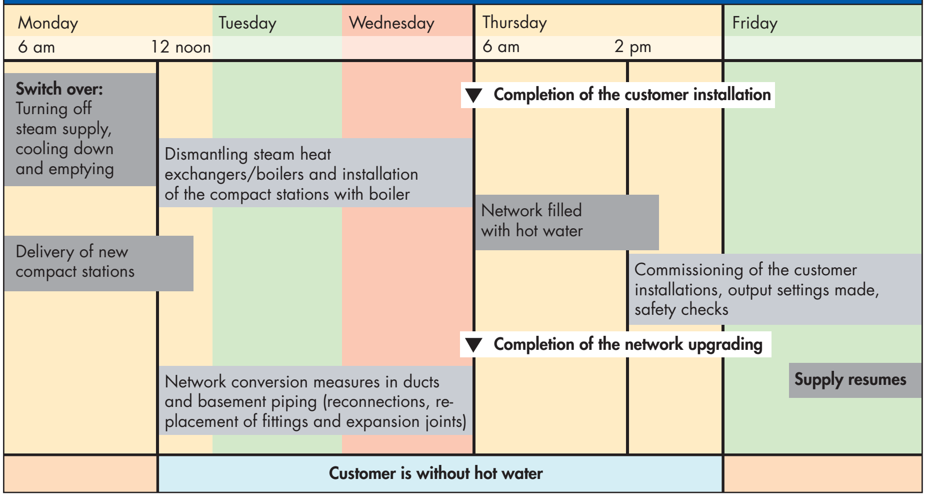

The focus of the steam system conversion is on upgrading networks and constructing new customer stations. It is necessary to upgrade the piping, since the future hot water system will be operated with higher pressures. Although the existing pipelines are generally adequate for the higher pressures, network installations such as fittings and expansion joints must be modified. Because glass fibre-reinforced plastic pipes are used, the maximum return pressure is limited to 10 bars, which therefore limits the maximum supply pressure.

The customer stations are converted by installing new compact stations, which are much smaller than steam customer stations. This means that the customers have much more space available in their basements. The conversion only takes place during the summer months when there is no heating, each time within the period of one week, so that 'normal' customers are without hot water supplies for 5 working days. For customers where this could be critical, such as hospitals and hotels, hot water is made available during the conversion period. This is provided using mobile hot water containers in different sizes, which are supplied to specific areas or customers. If required, mobile heating generators can also be hired. Since 2003, around 400 customers on average have been converted per year and 23 km of pipes have been upgraded. If required, the Munich municipal utility company, Stadtwerke München (SWM), will coordinate the conversion process, procure new compact stations and commission heating installation companies. Thanks to an excellent public relations campaign and little damage, the public response has been overwhelmingly positive.

### Benefit from greater efficiency

With the conversion of the steam system, the Munich municipal utility company has also improved the efficiency of its cogeneration plants. This is because the new method for distributing heat with hot water enables the turbines in the CHP plants to produce steam more efficiently than before. Here the steam is extracted and, by means of heat condensers, used for generating hot water with low pressures. With the same amount of heat production and almost the same fuel consumption, more electricity is generated and the production costs are considerably reduced. This advantage can be directly used at the new gas and steam turbine power plant in southern Munich (with an electrical output of up to 450 MW).

**Fig. 4: Network conversion in practice: Installation procedure during a conversion week**




The heat exchanger stations for converting steam to hot water will be installed in all generating plants that do not require upgrading in the short and medium term. At the same time there is a reduction in both heat losses and emissions in the network: the reduced energy consumption saves on electricity imports from Germany's grid, and there are potential $CO_2$ savings of more than 100,000 t/a. In addition, there are practical advantages for district heating customers. For example, the costs for new connections are considerably reduced, and, because hot water systems are very inert, customers will not immediately suffer a cut in supplies should a generating plant fail.

## Costs, economic viability

Internal studies by the Stadtwerke München (SWM) have shown that in relation to the pipeline length, the specific operating and maintenance costs for the steam system are on average twice as much as for hot water systems. The ensuing savings in converting to hot water amount to several million euros a year, although of course during the conversion years the savings will only be commensurate with the progress made with the conversion. The conversion of the steam system will be profitable in the long term, since the additional costs resulting from constructing a new hot water main pipe (southern link), the network upgrading, subsidies for new customer stations and modifications to the generator plants, etc., will be more than offset by the savings made as a result of additional earnings from the increased electricity generation, the lower operating and network expansion costs, and the reduced heating losses. The main impact will only be felt, however, during refurbishment, when existing pipes in dome-shaped ducts can be replaced with cheaper pre-insulated bonded pipe system technology.

## Summary

The most important finding is that it is possible to convert the Munich steam system during the scheduled yearly phases and with the envisaged technical concepts. The upgrading of the network has functioned. Thanks to the preceding pressure tests made in the condensate system, less damage occurred after the conversion than had been expected.

The customer conversion was also carried out as planned, and the difficult logistics in terms of coordinating the network upgrading with the customer conversion within a week for each conversion area was also solved successfully.

Last but not least, the project also sets an example for local climate protection, since the successful conversion means that not only has it been possible to prevent the replacement of Germany's largest steam system with a gas supply, and thus prevent a negative message being sent out to other steam system operators, but it has also been possible to achieve maximum energy savings and emission reductions in Munich. A welcome side effect is the fact that the use of cheap, pre-insulated bonded pipe system technology creates new economic potential for utilizing district heating, which was previously not considered possible with the elaborate dome-shaped duct construction method.

**Fig. 5: Use of a mobile heating container**

# ▶ Model for other steam systems

The Munich pilot project has encouraged other major steam system operators in Germany and abroad to take a look at converting their steam systems and to consider implementing the new conversion method. In 2002/2003, a conversion concept based on the new method was developed in Salzburg (Austria) and already implemented from 2005. Particular motives there were the flooding problem caused by the flooding of the Salzach River and the plan to integrate more waste heat sources into the heat supply.

According to the German Heat and Power Association (AGFW), there are around 100 steam systems in Germany with a total pipeline length of around 1,300 km. Parallel to the first conversion stages in Munich, it was investigated whether it was possible to transfer the method to other steam systems based on projects planned for Ulm, Dortmund and Würzburg. However, although there was potential in all three networks, more unfavourable hydraulic conditions existed with the condensate system diameters. This meant that considerably more upgrading would have been required than in Munich. A more favourable feature in other networks was the fact that the condensate pipeline systems were mostly laid using steel pipes, so that considerably higher pressures are possible in the return feed.

**Fig. 6: Overview of the current steam system conversions**

| Steam system | Connection value [MW] | Conversion | Conversion period |
|---|---|---|---|
| Hamburg (Germany) | 250 | Being carried out | 2002-2010 |
| Kiel (Germany) | 320 | Being carried out | 2002-2012 |
| Munich (Germany) | 1,250 | Being carried out | Since 2003 |
| Salzburg (Austria) | 170 | Being carried out | Since 2005 |
| Ulm (Germany) | 150 | Detailed study concluded | From 2009 ? |
| Paris (France) | 4,285 | Detailed study concluded | ? |
| Dortmund (Germany) | 150 | Preliminary study concluded | |
| Ft. Myer, Virginia (USA) | 25 | Preliminary study concluded | |
| Würzburg (Germany) | 250 | Preliminary study concluded | |
| Gera (Germany) | 190 | Preliminary study concluded | |

# Conclusion, outlook

The research project was able to offer a new approach for converting the largest German steam system from steam to hot water. This is based on the principle of continuing to use existing steam and condensate pipes: the steam pipes are used as hot water supply pipes, while the condensate pipes are used for the hot water return system. In contrast, previous steam system conversions were based on the principle of replacing the steam system with a hot water system. This method requires considerable investment and is practically impossible to carry out in inner city areas for construction and transport-related reasons. Thanks to the successful conversion, many other steam systems are now being investigated to see if they are suitable for using this new method. It is already being used in Salzburg (Austria). Since the first conversion phase in 2005, the experience gained there has also been positive.

Nevertheless, there are still aspects that need to be solved in practice. For example, as with all steam systems it is important to estimate the importance of direct steam users. This is because experience has shown that direct steam customers often require special solutions and/or can dispense with steam in favour of alternatives.

The efficient use of energy at low temperature levels will become increasingly important in the future in order to be able to achieve climate protection goals by reducing $CO_2$. Steam systems are unsuitable for achieving these goals, so the pressure to convert will continue to increase with all steam systems that are still in operation. In addition, the conversion of steam systems can offer new dynamism for expanding district heating systems as a whole.

The results of the Munich pilot project have been presented in several specialist workshops and to other steam system operators. This has developed into a regular exchange of experience. 100 companies in Germany could enjoy possible spin-off effects. In addition, these could also have an impact on other companies in the international context, particularly in France and eastern Europe.

## PROJECT ADDRESSES


- GEF Ingenieur AG
  Dr. Andreas Schleyer
  Ferdinand-Porsche-Straße 4a
  D-69181 Leimen

- Stadtwerke München GmbH
  SWM Services GmbH
  Helmut Stadtmüller
  Jörg Spannig
  Emmy-Noether-Straße 2
  D-80992 München


## ADDITIONAL INFORMATION

**Literature**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**Service**

- Additional information is available online from BINE at www.bine.info (Service/InfoPlus) in German.

**Images**

- Figures 1-5: SWM Services GmbH
- Figure 6: GEF Ingenieur AG

## PROJECT ORGANISATION


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Jürgen Gehrmann
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BINE Informationsdienst

FIZ Karlsruhe GmbH, Büro Bonn
Kaiserstraße 185 – 197
D-53113 Bonn

Tel.: +49 228 92379-0
Fax: +49 228 92379-29

bine@fiz-karlsruhe.de
www.bine.info

KERSTIN CONRADI · Mediengestaltung, Hennef