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Detailed information on energy research

Future heating supply designed

Duisburg is adapting its gas and district heating networks to the declining population

BINE Information Service

Over the past thirty years, the population of Duisburg has fallen by more than a fifth, and the heating requirement has also reduced. A team of experts has investigated how the municipal utility company can adapt the heating supply in accordance with these developments by 2050. A main recommendation: The interconnection of two district heating networks would increase the primary energy efficiency and cut costs, mainly because industrial waste heat could be better utilised.

On behalf of the Duisburg municipal utility company, experts from an engineering firm have designed scenarios for the possible heat provision in 2020, 2025, 2030 and 2050. They have based their studies on the assumption that the city loses residents every year as the importance of coal and steel declines. In Duisburg, many residential and commercial properties are vacant, and the heating demand is reducing. District heating and gas lines supply almost the entire urban area with heat. In the district heating areas, there is usually a parallel provision with gas. The municipal utility company operates district heating plants at five locations (Fig. 1). Most of the heat supplied comes from combined heat and power plants based on gas or coal. These feed heat into the “Central/West/South” and “North” networks. Although the total heating requirement in the scenarios reduces by between 25 % and 33 % by 2050, there are still medium to high thermal densities in the Central, South and North district heating networks. In the West district heating network, the thermal densities are expected to decline significantly in comparison to today.

“When designing the scenarios, the optimisation of the costs played an important role,” says project manager Susanne Ochse from GEF Ingenieur and adds: “Among other things it was concerned with making better use of existing capacities and

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improving the network structure." As references for their calculations, the experts used the heating requirements, load profiles, generation systems and other data from the 2011 base year. Based on this reference year, they investigated how the network structures could be optimally adapted and whether a change of energy carriers in the provision of heating and hot water makes sense. Here they varied different parameters such as the demographic trends, the heating requirement development, energy sources, energy prices and prices for emission certificates.

Linked district heating network increases the feed-in possibilities

To improve the economic and environmental efficiency of Duisburg's district heating, it makes sense to link the Central/West/South district heating network with the neighbouring district heating network. This is connected to the Lower Rhine district heating connection line (Fig. 2). The two networks are operated at similar temperatures, which would enable heat to be exchanged without having to provide reheating. If there was a connection, the neighbouring network could draw heat from the Duisburg CHP plants and Duisburg could take advantage of the heat mix from the Lower Rhine district heating connection line. "Along the Rhine network there are many industrial plants whose waste heat potential – especially in the summer – has not yet been fully exploited until now. If the waste heat utilisation was increased and the CHP share of the electricity produced in the cogeneration plants were to rise, this would increase the exergy efficiency and primary energy efficiency of the overall system," says Ochse. The overall system will be more economical if the cheapest heat sources can be utilised in future in larger quantities. The connecting line will be economical if the capital and operating costs can be refinanced through the more flexible use. In addition, the CO_2 balance will be improved if heat generators with low CO_2 emissions displace ones with higher CO_2 emissions. The connection would increase the number of generation plants feeding into both networks, thereby increasing the security of supply should individual generation plants or network sections fail. The connection between the two networks is being checked as part of a planning approval procedure.

City divided into supply areas

In order to expand the supply of district heating, existing areas have to be densified and new areas developed. Here, for example, the southern parts of the city come into consideration. Ochse: "In order to keep the costs as low as possible, it makes sense to expand in areas that are already close to the district heating network. In addition, it should be ensured that the thermal density is high enough there in the long term to make the expansion economically feasible." In many areas of Duisburg there is a parallel distribution of heat and gas. In order not to operate parallel infrastructures in an uncontrolled manner, the experts differentiated the supply areas into areas where priority could be given to either gas or district heating as well as into areas where parallel network structures should also remain in the medium or long term. For this purpose, the experts defined priority, existing and mixed areas (Fig. 3). In the district heating priority areas, the supply should be expanded in the long term, whereby the thermal density is particularly important.

	Central-West-South pipe network	*North pipe network*
Transport and house connection pipes	*318.6 km*	
Total no. of connected customer stations	*6,280*	
Annually injected heat volume	*634 GWh*	*64 GWh*
Heat generation plants	*Mainly: Hochfeld site with coal-fired CHP plant (139 MW_{th}); Wanheim site with gas-fired CHP plants (255 MW_{th})* *Optional: East oil-fired heating plant (28 MW_{th}), South gas-fired heating plant (14 MW_{th}), West gas-fired heating plant (16 MW_{th}),*	*Connected to the Lower Rhine district heating connection line, as security: North gas-fired heating plant (64 MW_{th})*
Network temperatures	*Return: 50 to 70 °C*	*Return: 50 to 70*
	Supply: 85 to 130 °C	*Supply: 90 to 130*

Fig. 1 *Key data for the district heating system belonging to the Duisburg municipal utility company*

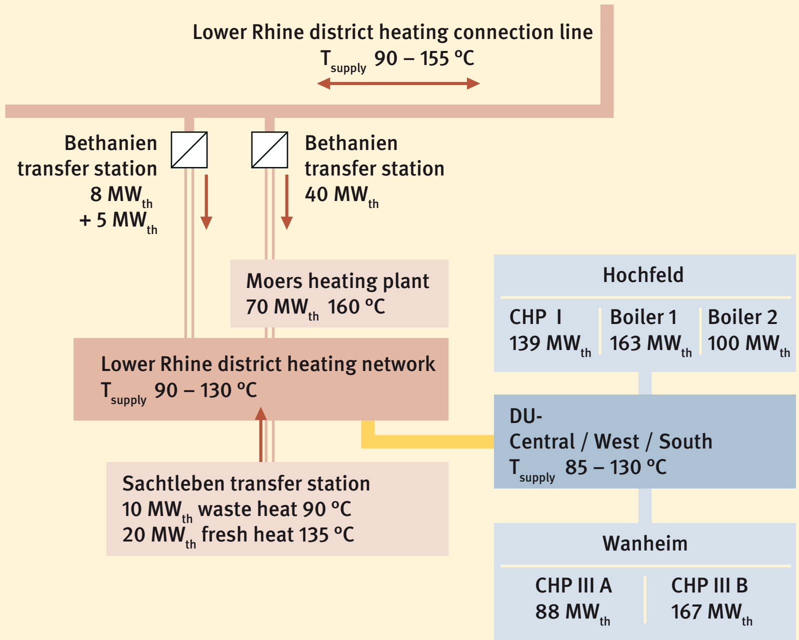

Fig. 2 *This is how the connection between the Lower Rhine district heating connection line and the Duisburg Central/West/South network could look like.*

In the central part of Duisburg there are large areas that are only supplied with gas. These mostly consist of former port areas. It would be difficult to expand the district heating here because of the heating requirement structure and the geographical location. In the long term, it is intended to reduce the parallel supply with gas and district heating in the existing and priority areas. The networks will not always be renewed in each case. Instead, it will be checked in individual cases whether in supply terms it is technically possible and economically sensible to dismantle network sections.

The experts estimate that the refurbishment of buildings and the declining population will further reduce the heating requirement. Both networks are generously designed and, depending on the feed-in constellation, provide surplus capacities. A temperature reduction would improve the circulation,

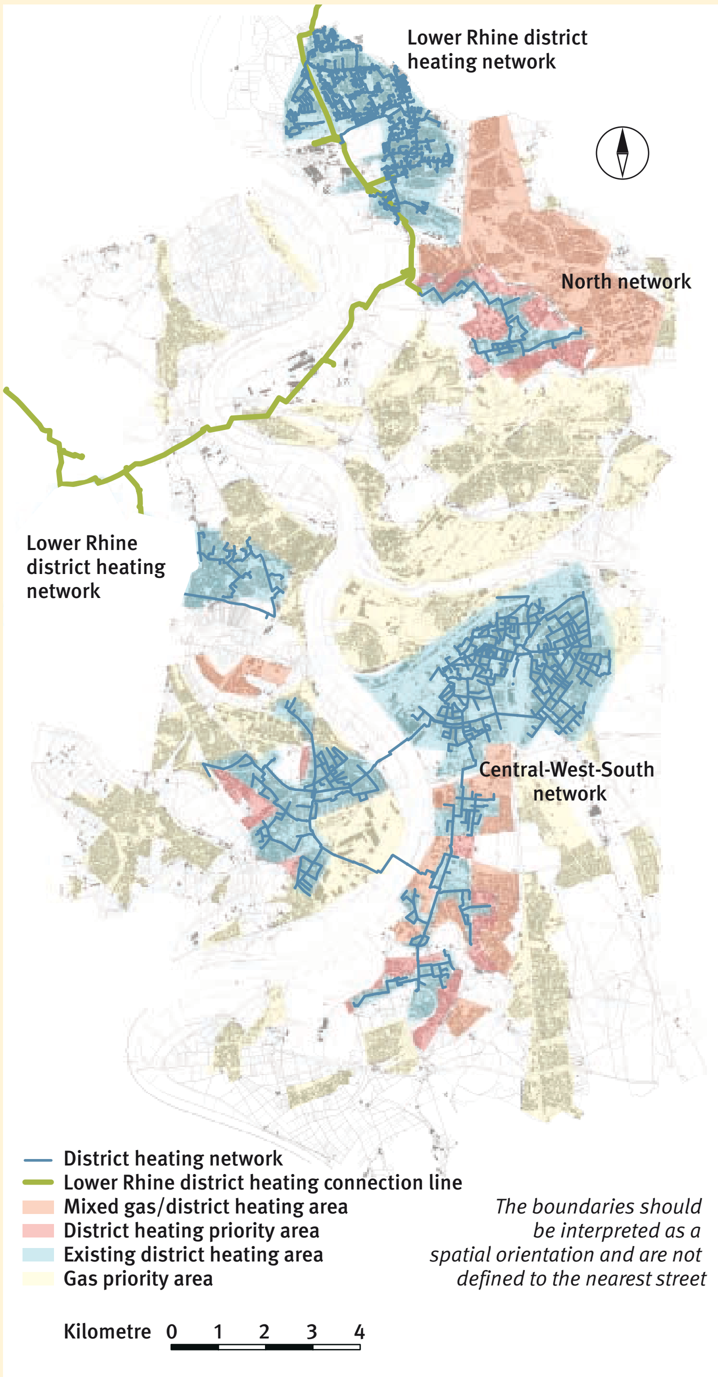

Fig. 3 *In future, the parallel supply with gas and district heating is to be reduced. In an initial design, the experts have demarcated supply areas for this purpose.*

reduce network losses and improve the exergy. The heat supply contracts would have to be adapted to lower temperatures.

Connecting renewables is possible in the long term

The Duisburg district heating network is currently operated at relatively high supply temperatures. This restricts the possibilities for integrating renewables into the heat generation. It is currently possible to use biomethane and woody biomass in cogeneration plants. If the supply temperature in the district heating network were to be reduced in the long term, it would be technically possible to integrate further renewable energy sources within the heat supply. However, calculations have shown that the use of alternative technologies such as heat pumps, micro-CHP and renewables (solar thermal energy, wood pellets) would not make sense if the main priority is given to optimising costs. For their analyses, the experts varied various assumptions and boundary conditions and assumed that no investment support is provided. They assume that a more widespread use of these techniques is only possible if there are financial incentives for this purpose.

From an economic and ecological point of view it is reasonable to expand the utilisation of waste heat. In addition to the use of district heating, in the Central/West/South supply area it would be economically feasible for customers to switch to individual heating systems based on natural gas. However, district heating provides distinct advantages in primary energy terms.

Creating local heating islands

The experts drew up scenarios for the minimum thermal densities to be expected in the long term in different urban areas in Duisburg. Based on them, they analysed where the development of local heating islands would be feasible. Here, there should be a thermal density of at least 20 – 30 GWh/km^2 and an anchor customer present. This is a customer with a high heating requirement who plays a central role in determining the economic feasibility of a network expansion, such as a school, hospital, nursing home or large residential complex.

Whether the construction of local heating islands is possible in the selected areas also depends on the connection readiness of the adjacent properties. In addition, a production site must be available or feasible. It is expected that the heat provision in the local heating islands will be based on cogeneration plants and boilers powered by natural gas, biomethane or wood.

The experts have drawn up a list prioritising the possible measures for increasing the efficiency of the Duisburg district heating network. According to this, the development of local heating islands would be one of the first measures to be implemented.

Digitally simulating energy systems

The simulations in the “Energy-efficient Duisburg” project presented here are based on the “software package for optimising local infrastructure systems” (POLIS). The software program depicts technologies in individually varying levels of detail. Energy requirements are included in the form of network-specific annual load profiles. It is possible to select either minimised costs or minimised emissions as the optimisation goal. For depicting an energy system, energy sources, networks, conversions and energy sinks are available as components. To build the model, the model components are initially assigned to a prototype. These prototypes define the heat generators, electricity generators, coupled generators, renewable generators and the network, and are in turn defined realistically with individual parameters for the costs and emissions (efficiency, capital costs, operational costs, fuel costs, emissions per remodelled unit etc.). On the demand side, the heating requirement is assigned to individual model networks and depicted in the form of load profiles, for example with an hourly breakdown.

Newly defined district heating

In its Renewable Energies Heat Act, the German Federal Government has set out its aim of supplying 14 % of the heating market with renewable energies by 2020. The transformation of the district heating networks can make an important contribution in this regard. In the “Transformation Strategies for District Heating” study, the ifeu Institute, GEF Ingenieur AG and the AGFW (German Energy Efficiency Association) have investigated how the proportion of renewable energies can be increased in existing district heating systems.

In 2013 the share of renewable energy in district heating networks was around 9 %. Analyses in various energy scenarios assume that this share will continue to rise. Of particular importance for large existing networks are woody biomass, biogas and biomethane. These can also be used with high generator capacities of up to several 100 MW_{th}. In addition, these energy sources enable district heating to be provided at a high temperature level, which is not possible with other renewables. Biomass and biogas/methane can be used in cogeneration plants. A weak point lies in the limited availability of biomass.

Under the current conditions, there are technical limitations restricting the integration of some renewable energy sources into the networks. In order to achieve the highest possible proportion of renewable energy, district heating systems therefore need to be designed so that the pressure and in particular the temperature level are as low as possible. Of the 19 district heating systems investigated in the study, only five networks have short sections that are operated with temperatures below 90 °C. Nationwide, operation modes in a temperature range between 90 °C and 140 °C are the most common.

Using the example of the Jena model region, the researchers have investigated how the transformation strategies can be implemented. Because wood is insufficiently available in Jena as a fuel, the researchers have proposed building a biomethane CHP plant. In the next step, the temperature level of the network would be lowered. It will then be possible to begin constructing additional generation facilities based on renewable energy. These could consist of a second biogas plant, additional biomethane CHP plants and the integration of waste heat from waste water.

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