EnergieAgentur.NRW
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Combined Heat and Power in Practice
Examples of efficient and environmentally responsible applications

KWK NRW
Strom trifft Wärme

www.klimaschutz.nrw.de

Contents

Setting a good example!

Dear all,

Since the end of 2013 we have been collaborating with a number of companies, research institutes, associations and interest groups under the umbrella of the KWK.NRW – Strom trifft Wärme (CHP.NRW – Electricity Meets Heat) campaign to raise the profile of combined heat and power (CHP) in our country. Because it is only by significantly increasing its share of electricity generation that CHP can develop its potential as a tool for climate protection. As well as its benefits in terms of climate protection, CHP improves the utilisation of primary energy compared to the separate generation of electrical energy and heat.

Have you ever considered replacing the heating system in your company, your institution or your home with a CHP system?

Be inspired by the wide range of usage options for CHP technology: these options range from decentralised mini and micro CHP plants, e.g. for single-family homes, through full energy supply by small-scale cogeneration systems for companies or administrative bodies, to district heating in urban areas.

This brochure contains a range of real examples and aims to encourage you to participate or follow suit.

Margit Thomeczek
Head of the KWK.NRW – Strom trifft Wärme campaign

CHP.NRW – Electricity Meets Heat (KWK.NRW – Strom trifft Wärme)
Coupled for climate protection

Use energy once, benefit twice – this is the principle of combined heat and power (CHP). In the past, electricity and usable heat were usually generated separately, but combined heat and power connects these processes to reduce the overall amount of fuel required.

Combined heat and power is therefore the most efficient way of using fuels to generate energy, regardless of whether the fuel in question comes from fossil or renewable sources. It has enormous potential for the conservation of resources and the protection of our climate. Increased use of CHP can help to lower CO_2 emissions and reduce the amount of primary energy needed. This technology is now available in the form of small-scale cogeneration systems for companies, and to supply individual buildings in larger properties such as care institutions as well as hotels, housing associations and many more.

This brochure includes practical examples of the various fields of application of CHP technology and illustrates how it can be used in an economically and ecologically sound manner.

The aim: 25 percent CHP electricity in NRW by 2020

The federal government of North Rhine Westphalia (NRW) wants to drive forward the 'Energiewende', Germany's transition to sustainable energy, by the expansion of combined heat and power (CHP). The aim is to increase the percentage of electricity generated using combined heat and power plants in North Rhine Westphalia to at least 25 percent by 2020.

The principle of combined heat and power
Producing electricity and heat at the same time

At the moment, electricity and heat generation are usually separate processes. Only in a few cases is the heat produced in the generation of electricity in large power stations recovered and used for heating in local or district heating systems. In conventional power stations that do not recover heat in this way, only 40 to 60 percent of the primary energy used is converted into electricity. This means that 40 to 60 percent is emitted through the cooling tower, unused.

The use of combined heat and power (CHP) allows the total fuel use efficiency to be increased to as much as 80 to 90 percent, allowing savings of up to 40 percent to be achieved compared to the separate generation of electricity and heat.

High requirement for electricity and heat all year round?

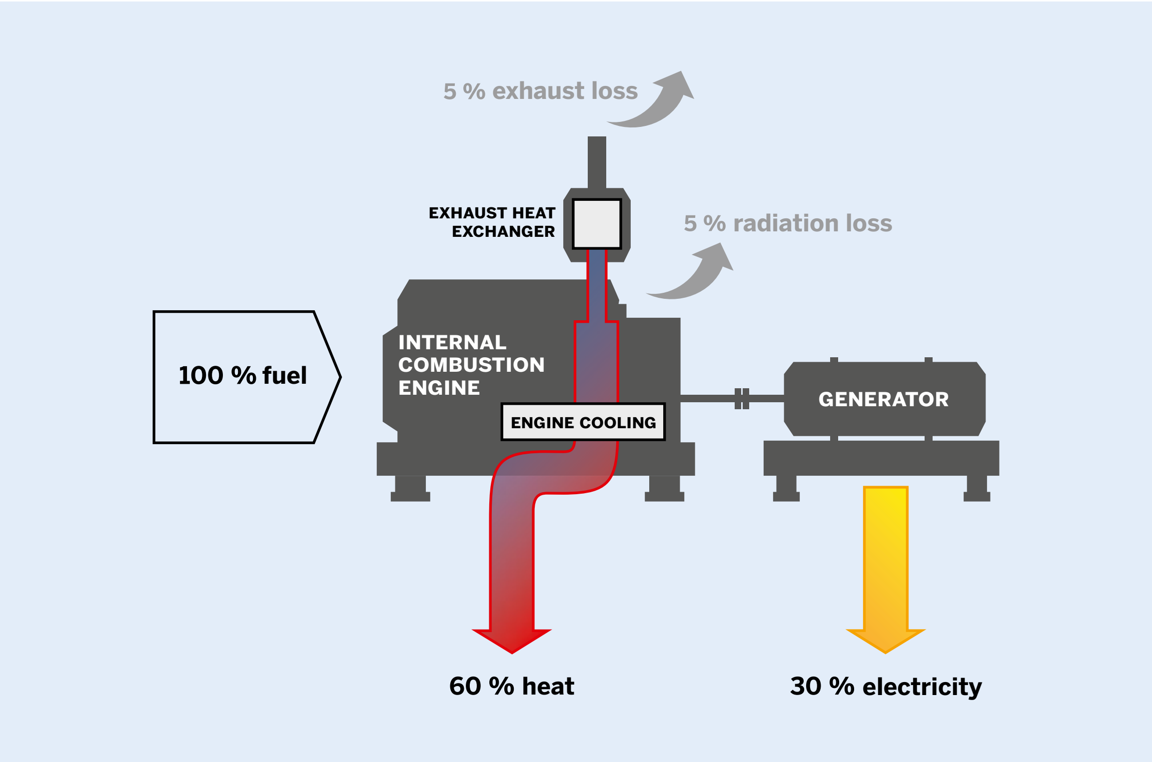
Who might benefit from CHP?

CHP can be advantageous for companies, communities and private individuals that have a continuously high requirement for electricity and heat or cold at the same time – in particular if there is a high thermal baseload due to the need for process heat and hot water.

CHP is even more attractive if as much as possible of the electricity generated is consumed on site. The higher the cost of electricity, the more economically attractive it is for the CHP operator to use the electricity generated by the system.

How does combined heat and power work?

In most cases, combined heat and power is produced by internal combustion engines or gas and/or steam turbines in connection with a generator. However, steam engines, Stirling engines, organic Rankine cycle (ORC) systems and innovative technologies such as fuel cells are also used for the generation of combined heat and power. The illustration below shows a cogeneration unit with an internal combustion engine. This drives a generator, which produces the electricity. The heat from the engine's cooling system and from the exhaust is harnessed in the cogeneration unit. This means that the available heating potential is optimally exploited. Around 30 percent of the fuel is used for the generation of electrical energy.



Energy balance of a cogeneration unit

Modern supply solutions
Using energy efficiently

Thanks to its high efficiency, combined heat and power has an important contribution to make to climate protection and to Germany's energy transition.

Because fossil fuels are in limited supply and cause pollution, it is important to use them more effectively and to supplement and replace them with renewable energies.

Combined heat and power is the right technology for this. It uses existing resources as efficiently as possible. Every small-scale cogeneration unit in industry, the commercial sector or public institutions not only improves the individual energy balance, but also that of North Rhine-Westphalia and Germany as a whole.

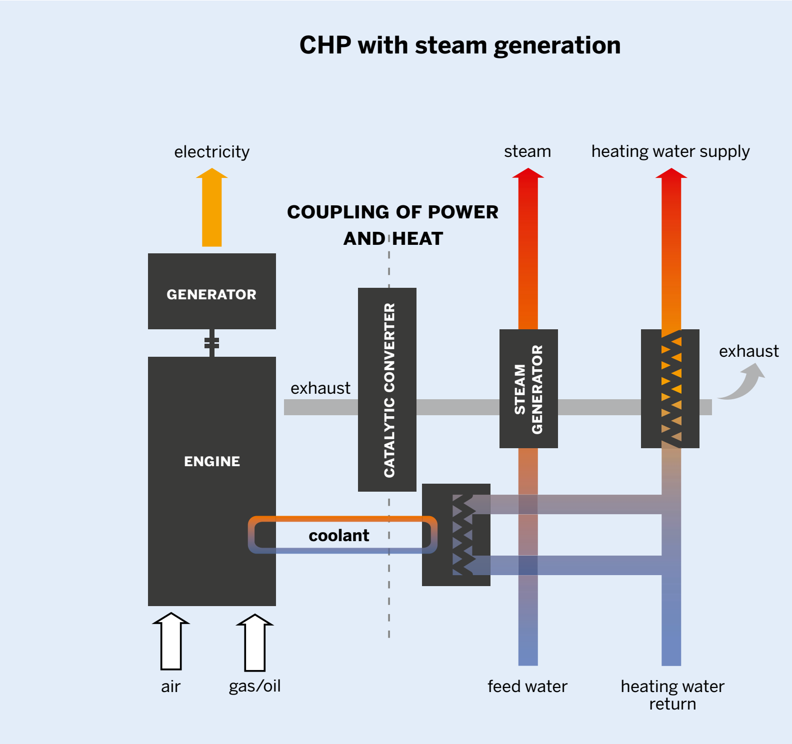
Almost any fuel can be used
Combined heat and power works with almost every fuel. Renewable energy sources such as wood and biogas, as well as fossil fuels, can be converted into electricity and heat. In areas with a federal structure, such as Eastern Westphalia, the Sauerland region or Lower Rhine, numerous CHP plants are operated on the basis of biogas.

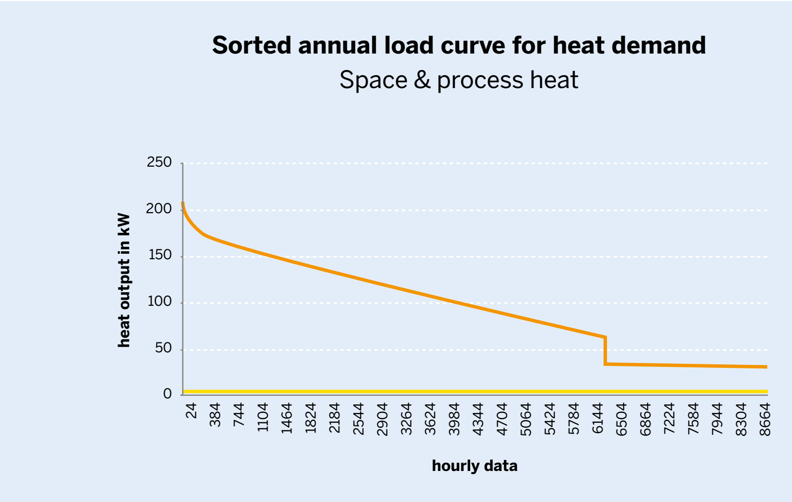
But it's not only when using finite fossil fuels that maximising efficiency is important. The energetic potential of renewables should also be used with care. CHP plants use fuel extremely efficiently. Renewable energies can replace considerably more fossil fuels, and thus save more CO_2, when used in combination with CHP than when used to generate electricity and heat separately.

Excellent decentralised supply of electricity and heat
The expansion of CHP technology can help with the distribution of electricity production. Supplying properties or groups of properties individually means that heat is generated exactly where it is needed.

For economic use, CHP plants should generally be sized to cover the property's thermal baseload. An additional boiler is usually needed to cover load peaks and provide backup for the CHP plant.

The best economic outcome
The right size





An annual load curve represents the (cumulative) power consumption of a supplied property in relation to the annual usage period for this power.

The investment costs for a small-scale cogeneration unit are comparatively high. It therefore needs to clock up a high number of operating hours per year to achieve a good economic outcome. In addition to electricity consumption, heat requirement is a major factor in determining the size of the unit. Finding the right size for the system as a whole calls for careful technical and economic planning of each individual project, taking into account current market conditions and predicted future trends.

Design of electricity supply

The load profile is indispensable when determining the electricity baseload. This data is normally available from the grid operator, since it is needed for the electricity bill.

1. In factories with a 3- or 4-shift system, the cogeneration unit is designed for the daily baseload.

2. Where staff operate in 1 or 2 shifts, it can often be more beneficial to design the cogeneration unit for the baseload during the production period. Outside these times, the cogeneration unit is either run at lower output or switched off.

If the system is designed such that electrical output is lower than the baseload, the electricity generated is primarily used directly on site. In this case, the electricity has the greatest value for the operator.

Design of the heat supply

In factories that require process heat at temperatures up to 90 °C, CHP systems can usually be of a conventional design – the thermal output of the cogeneration unit depends upon the process heat requirement. If a waste heat boiler is placed in the exhaust stream to utilise the waste heat of the cogeneration unit, it is also possible to generate saturated steam at up to 10 bar (see figure above). More complex industrial processes require individual solutions.

When designing a CHP plant, particular attention must be paid to the sorted annual load curve for heat demand. In properties without process heat, the size of the cogeneration unit is based upon the requirement for space heat and service water heating.

Practical examples

Companies


Private customers


General supply

Decentralised energy generation in wholesale store

A packaged cogeneration unit with an output of 250 kW_e provides electricity and heat in Düsseldorf.

Energy efficiency is a subject that has taken on increasing importance for the METRO GROUP in recent years. This is due to rising energy costs and the group's aim of reducing the emissions associated with its business activities. The group's energy strategy takes both these aspects into account. The aim is clear: to reduce the consumption of, and therefore also the costs associated with, CO_2 emissions.

One component of energy management is the trialling of decentralised energy solutions. A good example is the cogeneration unit installed at the METRO market in Düsseldorf. It produces energy directly at the site, allowing the volume of electricity purchased, and the associated costs, to be reduced.

The cogeneration unit has an electrical output of 250 kW and is highly efficient, and heat led. This means that it is used primarily for heating and for the provision of hot water. The need for heat in the market determines the operation of the cogeneration unit – in this sense it is the electricity that is a 'byproduct'.

The cogeneration unit can cover around a quarter of the electricity demand, and the site's entire heat demand for space heating, air conditioning and hot water production. The plant reduces the energy costs at the site and cuts CO_2 emissions by up to 20 percent.

It proved possible to find a long-term cooperation partner for the project in E.ON Connecting Energies. Whilst E.ON is responsible for the design, financing and construction of the plants, METRO Cash & Carry is the operator and generates the electricity.

A potential next step is to combine the decentralised power station at the Düsseldorf site with solar power. Photovoltaic panels have already been installed there and are producing energy with the aid of the sun.

Project data

- Operator: Metro Cash & Carry Deutschland GmbH
- Cooperation partner: E.ON Connecting Energies GmbH
- Location: Düsseldorf
- Plant: 2G Agenitor 306
- Power: 250 kW_e, 265 kW_{th}
- Commissioned: 7/2013
- Fuel: natural gas
- Electricity generated: approx. 1.0 million kWh/y
- Heat generated: approx. 1.16 million kWh/y
- CO_2 reduction: 280 t/y
- Investment costs: 475,000 euros

As of 6/14

Deliciously efficient brewing at Früh

A steam cogeneration unit at the Früh brewery achieves over 94 percent fuel utilisation by the systematic use of all heat sources.

Since May 2014, "Früh Kölsch" beer has been produced not only according to traditional brewing methods, but also using a highly efficient CHP.

The installed SOKRATHERM GG 198 compact cogeneration module generates 200 kW of electric power using a generator coupled to a turboengine.

The heat that is produced at the same time is used for various purposes: a steam waste heat boiler takes the exhaust heat from the cogeneration unit to generate saturated steam with a thermal output of 121 kilowatts, which is then fed into the brewery's steam network. The heat from the engine cooling water, including the first stage of the mix cooling (totalling 120 kW), is used to heat the brewing water from 15 to 85 °C. Twenty kilowatts of low-temperature heat (approx. 40 - 46 °C) is recovered from the 2nd stage of mix cooling for the same purpose, and up to 45 kilowatts of heat from a condensing heat exchanger installed downstream of the steam generator is also used.

The use of all four heat sources as well as the electricity allows the cogeneration unit to extract a total of up to 506 kilowatts from 538 kilowatts of fuel, thus achieving a total efficiency of up to 94.1 percent. The electrical output of the cogeneration plant was selected such that the generated electricity could be used on site throughout the entire year.

The amount of steam generated is sufficient to compensate for all line losses in the steam network outside production time, meaning that the inefficient steam boiler can be dispensed with during this period.

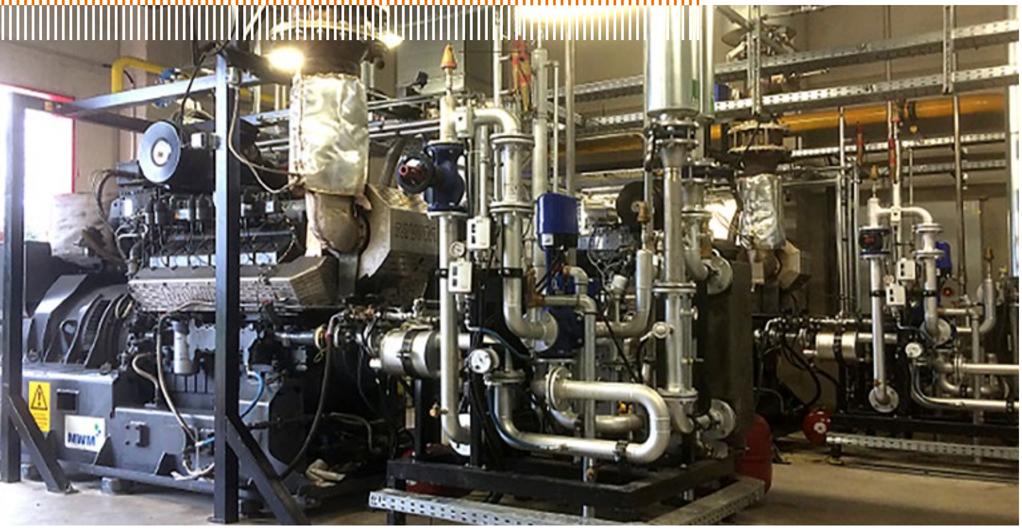
The manufacturer installed the cogeneration unit on the premises of the brewery as a full service package including the supply of the ready-to-connect cogeneration unit, operating building and waste-heat boiler. The brewery's engineering department was responsible for connecting the unit to company's systems and regulating the consumers.

The plant ran for approx. 6000 operating hours in its first year of operation, of which over 98 percent was at full load. All of the electricity generated was used in the brewery, and the electricity bill fell accordingly. The investment, including all peripheral works and the connection of the cogeneration unit, will thus pay for itself in around three years. "As expected, the cogeneration unit is running well", sums up Axel Spelzhaus, the brewery's head of operations technology. And the project is also benefiting efforts to protect the climate: the CO_2 emissions of the brewery have fallen by 840 tonnes per year thanks to the highly efficient energy production.

Project data

- Operator: Cölner Hofbräu P. Josef Früh KG
- Plant: SOKRATHERM GG 198
- Location: Cologne-Feldkassel
- Output of cogeneration unit: 200 kW_e / 306 kW_{th}
- Commissioned: 05/2014
- Fuel: natural gas
- CO_2 reduction: 840 t/y
- Investment costs: 430,000 euros
- Amortisation: approx. 3 years

As of 1/16



Logistics specialists with a cool head

Products in an Essen warehouse are being cooled efficiently with the aid of a combined heat, cooling and power (CHCP) system.

Logistics specialists in the field of chilled and frozen food have a high energy demand. Because of this, Logistic Services Essen (LSE) took various measures to save energy. One of these was the commissioning of a combined heat, cooling and power (CHCP) system in a warehouse.

The integration of an ammonia/water absorption chiller was out of the question because mixing the coolants from the absorption chiller (2-component coolant) was not compatible with the ammonia cooling circuit in the warehouse. Moreover, such chillers reach temperatures in the normal chilling range between 0°C and + 10°C. Since LSE specialises in the deep-freeze range, with temperatures as low as -25°C, a different solution had to be found.

The solution was to have the coolant circuit completely separate from the absorption plant cold water supply and return using heat exchangers. On one side all the liquid ammonia from the coolant circuit is piped through a heat exchanger that is cooled at a cold water temperature of approximately 6 to 8°C from the absorber. The extracted heat load no longer needs to be removed via the chillers.

This precooling takes a great deal of the load off the chiller and, despite the operation of water and lithium bromide circuits and vacuum pumps, leads to a net saving in terms of electricity of 550,000 kilowatt hours per year.

In the Essen cold store, an exhaust gas-fired lithium bromide absorption chiller uses the waste heat load from the two cogeneration units with 8 and 12 cylinders that drive generators with electrical outputs of 400 and 600 kilowatts respectively. The exhaust heat and the engine heat from the cogeneration units is used to evaporate the water from the lithium bromide salt solution, which then generates cold water via a condensation and vacuum process.

Taking into account the purchase costs for electricity and gas, the maintenance fees, the increased water consumption by the evaporator, the depreciation and interest for machines and the building erected and the repayments for natural gas tax and CHP allowance, a clear saving has been achieved in 2013 to 2018 by the operation of the CHCP plant compared to the purchase of all electricity. With a total investment cost for machines and buildings of around 2.73 million euros, the resulting payback time is 5.5 years.

Project data

- Operator: Logistic Services Essen GmbH & Co. KG
- Location: Essen
- Freezer volume: 196,500 m³
- Output of cogeneration units: 1,000 kW_e, 1,081 kW_{th}
- Installed capacity of chiller: 3,600 kW
- Commissioning of CHCP plant: June 2012
- Fuel: natural gas
- Electricity requirement: approx. 7,500 MWh/y
- Cold generated: 27,100 MWh/y
- CO_2 reduction: 848 t/y
- Investment costs: 2.3 million euros
- Payback time: 5.5 years

As of 1/15

Modern heating technology for historic mill

The system for supplying heat and electricity to a listed building had to be renewed on an urgent basis. A cogeneration unit and a condensing boiler now provide heating and electricity to the hotel and restaurant business.

The ageing oil-fired boiler in the old water mill in Wegberg was using a lot of energy. The energy supply system for the over 1,000 square meters of floor space in the property had to be replaced. The historic building houses a hotel and restaurant that extend over two floors. The old system has now been replaced by a modern liquefied gas-fired cogeneration unit with a thermal output of 12.5 kilowatts and a condensing boiler with an output of 60 kilowatts for periods of peak heat demand. The new technology saves 8,900 euros in energy costs per year, which is 28 percent of the energy costs of the previous system. Most of the electricity required is now produced using the cogeneration unit, which feeds any excess energy generated into the public grid. This is paid for at the applicable rates. A total of over 160,000 euros will thus be saved within 15 years. This calculation is based upon estimated inflation rates of five percent.

The conversion from oil to liquefied gas means an additional saving of around 15 to 20 percent on the energy purchase costs. Moreover, liquefied gas does not endanger the groundwater in the event of floods or other damage because it evaporates on the surface leaving no residue. Liquefied gas is therefore an appropriate solution for conservation areas like the one in which the old water mill stands.

Thanks to the cogeneration unit and condensing boiler technology, CO_2 emissions have now been reduced by 30 tonnes per year. Together, the two devices cover the operation's annual requirement of 100,000 kilowatt hours of electricity and 1,200 litres per day of hot water. The owner decided upon a contracting solution from german contract for the financing and development of the project.

This meant that all services – from planning, through the removal of old technology, to the installation of the new system, regular maintenance and an emergency service – are covered by a monthly rate over a service life of 15 years.

Project data

- Operator: gc Wärmedienste GmbH (german contract)
- Fuel supplier: PRIMAGAS Energie GmbH & Co. KG
- Fuel: liquefied gas
- Location: Wegberg
- Output of cogeneration unit: 5.5 kW_e, 12.5 kW_{th}
- Output of condensing boiler: 60 kW_{th}
- Commissioned: 2013
- Electricity requirement: approx. 100,000 kWh/y
- CO_2 reduction: 30 t/y
- Investment costs for contracting: approx. 50,000 euros

As of 8/15

MEDICE generates its own electricity, heat and cold

Pharmaceutical company banks on CHCP

MEDICE is a medium-sized pharmaceutical company with its registered offices and production site in Iserlohn. As one of the top 50 pharmaceuticals manufacturers in Germany, the company takes Germany's energy transition very seriously and has put in place some measures to use resources sparingly and responsibly. In 2011, this sense of responsibility led the family-run company to the decision to install a cogeneration unit to generate its own electricity. In addition to electricity it also supplies heat and cold.

A comprehensive analysis of the energy consumption by the local municipal utilities yielded various recommendations for MEDICE regarding the optimisation of energy management. A natural gas-fired cogeneration unit with a high utilisation factor was implemented. The cogeneration unit has an electric output of 240 kilowatts and therefore covers the company's baseload electricity demand.

Since cold is equally indispensable for the sensitive production processes at MEDICE, the cogeneration unit was combined with a modern absorption chiller. This combined technology is known as combined heat, cooling and power (CHCP) generation.

The production of cold results in better utilisation of the cogeneration unit, particularly in the summer months when there is no need for space heating in the company. Since cold is needed for the production process even in the winter, the heat exchanger of the absorption chiller is used for free cooling during this season.

The company has an annual electricity demand of approximately 4 million kilowatt hours, so the cogeneration unit was supplemented by the installation of photovoltaic panels with a total output of 213 kilowatts on the company's roofs. The company generates around half of its annual electricity demand from the photovoltaic panels and the first cogeneration unit.

MEDICE saw even more potential, and in December 2013 installed a further cogeneration unit with an output of 140 kilowatts. In total, the company now generates around 75 percent of its electricity demand itself. In addition, around 300 tonnes of CO_2 emissions per year have been avoided.

Project data

- Operator: MEDICE
- Location: Iserlohn
- Output of PV plant: 213 kW
- Output of 1st cogeneration unit: 240 kW_e, 375 kW_{th}
- Commissioned: 11/2012
- Output of 2nd cogeneration unit: 140 kW_e, 220 kW_{th}
- Commissioned: 12/2013
- Fuel (cogeneration unit): natural gas
- Output of absorption chiller: 400 kW_{th}
- Output of free chiller: 400 kW_{th}
- Saving of heating oil: > 300,000 l/y
- Saving of electricity: > 500,000 kWh/y
- CO_2 reduction: > 1500 t/y
- Investment costs (total): approx. 1.8 million euros

As of 12/13

Cogeneration unit and local heat network create efficiency

Electric motor manufacturer backs CHP

Groschopp AG, which has its registered offices in Viersen, is currently one of the world's leading companies in the field of electric drive technology. Its range of services encompasses the development, production and sale of motors, gearboxes and regulators of various designs.

For this energy-intensive company it makes sense to give some thought to ways of increasing efficiency in the provision of energy. The particular challenge was to coordinate the required process heat with the existing three heating systems.

In collaboration with EnergieConzept GmbH (EC), these considerations gave rise to a cogeneration unit. EC developed an overall concept that guarantees the central supply of the four heating systems and production in a heated area of 7,216 square metres, using a CHP plant combined with a local heat network in the form of a closed circular pipeline system.

The cogeneration unit has an electrical output of 142 kilowatts. An annual fuel use efficiency of 88 percent is the aim. Currently, 753 megawatt hours of electricity are being generated per year. The high fuel use efficiency was primarily achieved by also connecting four buffer tanks with a storage volume of 5,000 litres each. The remaining two boilers therefore only rarely need to be brought online for the provision of heat.

The ovens that bake the housings for the electric motors and dry their paintwork are preheated using the local heat network. The overall heat network extends over a length of 400 metres.

The cogeneration unit has also been fitted with a condenser and a heat recovery system, which has turned out to be a particularly effective measure.

The cogeneration unit and the local heat network have led to CO_2 savings of 108,000 tonnes of per year. The cogeneration unit alone will pay for itself in less than two years.

Project data

- Heated area: 7,216 m²
- Useful energy: 2,436 MWh/y
- Electricity consumption: 1,188 MWh/y
- Heat-led cogeneration unit: MP 150 duoWRG
- Installed capacity: 142 kW_e, 207 kW_{th}
- Efficiency: 40 %el, 58 %th
- Electricity generation: 753 MWh/y
- Heat generation: 1,097 MWh/y
- Full load hours: 5,299 h
- Savings realised: approx. 100,000 euros/y

As of 10/15

Three cogeneration units ensure a cosy atmosphere

For more than 10 years restaurant Lippeschlösschen has been generating its own energy using thre cogeneration units.

Just outside the town of Wesel lies the tradition-steeped restaurant Lippeschlösschen. The restaurant has space for 160 guests. An efficient and environmentally friendly energy supply was always something that was close managing director Ulrich Langhoff's heart.

In 2000 he had the first cogeneration unit installed in the cellar of his restaurant so that he could generate energy for himself. Today, three cogeneration units from SenerTec supply the restaurant with electricity and heat, meeting the building's entire heat requirement. In total, they supply around 1,200 square metres of managed catering and residential area. Around two-thirds of the electricity generated is consumed on the premises. The rest is fed into the public grid.

The three cogeneration units run on fuel oil. Each unit has an overall fuel use efficiency of 89 percent. This means that 89 percent of the energy in the fuel is converted into electricity and heat. Each cogeneration unit has an electrical output of 5.3 kilowatts and a thermal output of 10.5 kilowatts.

The three cogeneration units are connected in a cascade arrangement. This allows them to be be switched on sequentially, depending upon the energy requirement. As a result, the three units run for a total of around 13,400 operating hours in a calendar year.

Furthermore, two hot water tanks of 500 litres each store excess heat. Owner Ulrich Langhoff also installed an e-bike charging station in front of his restaurant in September 2014, where visitors can charge their e-bikes from the cogeneration unit free of charge.

Project data

- Operator: Restaurant Lippeschlösschen
- Location: Wesel
- Plants: 3x SenerTec Dachs HR 5.3
- Output of cogeneration units: 5.3 kW_e, 10.5 kW_{th} each
- Commissioned: 02/2000, 10/2003, 01/2013
- Fuel: oil
- Electricity generated: approx. 78,000 kWh/y
- Heat generated: approx. 122,145 kWh/y
- Operating hours of cogen units: approx. 13,400 h/y
- Oil consumption: approx. 24,000 l/y
- Capacity of hot water tank: 2x500

As of 11/14

Liquefied gas-fired micro gas turbine in Brühl

Germany's first liquefied gas-fired micro gas turbine is producing electricity, heat and cold and serving as a backup electricity supply.

Rheingas, in collaboration with Aachen technical college, has developed Germany's first liquefied gas-fired micro gas turbine in Germany. The key goal of the project was to demonstrate the functionality of the micro gas turbine with liquefied gas and to make it available on the market as an alternative to the cogeneration technology that was already available.

The liquefied gas-fired micro gas turbine has been on the energy supplier's roof since May 2009 and supplies the company with electricity and heat. The addition of an absorption chiller means that the turbine can now take over the cooling of the server room and the office rooms in the main building. In the event of a power cut, the turbine switches to stand-alone operation and supplies exclusively the server room with electricity.

The micro gas turbine is an environmentally friendly CHP plant with an electric output of 30 kilowatts and a thermal output of 68 kilowatts.

Thanks to its compact, lightweight and low-vibration design, the micro gas turbine is used mainly in decentralised energy supply systems.

Due to its physical properties liquefied gas is an ideal fuel for this field of application.

Liquefied gas is easy to transport and available virtually everywhere. Since it is delivered at pressures of 3-5 bar, the micro gas turbine does not require an internal fuel gas compressor for operation. This improves its electrical efficiency by 2 percent compared to natural gas.

Similar plants such as the one in the Hegau Ost service station have a payback time is 3.5 years.

Project data

- Operator: Propan Rheingas GmbH & Co. KG
- Project participants: Aachen technical college, department of energy technology, Institut Nowum-Energy
- Location: Brühl
- Output of micro gas turbine: 30 kW_e, 68 kW_{th}
- Commissioned: 05/2009
- Fuel: liquefied gas
- Electricity generated: 109,069 kWh/y
- Heat generated: 247,223 kWh/y
- Investment costs: 128,000 euros

As of 7/14

Fuel cell for semi-detached house

As part of the "100 CHP plants in Bottrop" project, the old oil-fired heating system was modernised by installing a fuel cell and a gas-fired condensing boiler. The property has several buildings with a total area of around 400 square metres. The fuel cell's 600-watt thermal output can be connected to the heat supply for the property throughout the entire year. In addition to the thermal output, the fuel cell produces around 1.5 kilowatts of electric power on a continuous basis.

Due to the high baseload of around 15,000 kilowatt hours per year, the majority of the electricity generated can be used internally. This is an advantage for the economic viability of the fuel cell.

Property data

- Property type: semi-detached house
- Area: 400 m²
- Year of construction: 1987
- Residents: 6 persons
- Age of heating system: 11 years
- Energy consumption: approx. 4,500 l of oil/y

Conversion

- Plant: CFCL BlueGen inc. additional heater
- Manual work: Smit GmbH
- Installation: 15.08.2014

Since installation of the plant

- CHP electricity produced: 3,783 kWh
- Proportion of electricity used internally: 79 %
- CO_2 saving: 1.2 t CO_2

Stirling engine for terrace house

The first plant in the "100 CHP plants in Bottrop" project was installed in an end-of-terrace house dating from 1956. Before this, the 120-square-metre living area of the three-person family was supplied with heat by a 20-year-old gas heating system. This has now been replaced by a CHP system with a Stirling engine and integrated condensing boiler to cover peak loads and a large buffer tank for the heating system and the provision of hot water.

The system was installed in a highly confined space in this property.

Property data

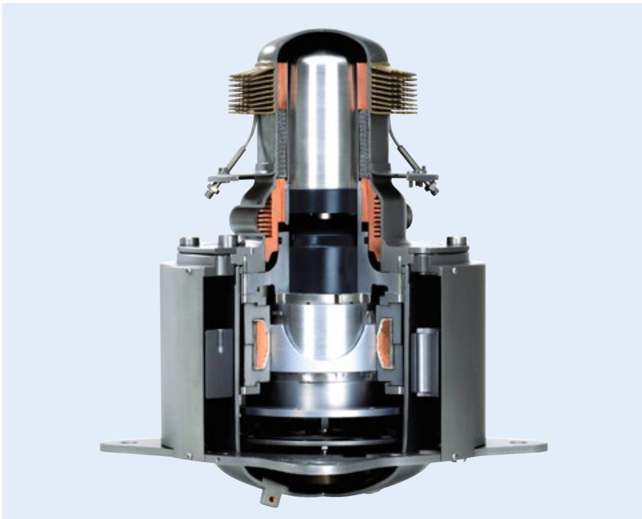
- Property type: semi-detached house
- Area: 120 m²
- Year of construction: 1956
- Residents: 3 persons
- Age of heating system: 20 years
- Energy consumption: approx. 32.000 kWh of natural gas/y

Conversion

- Plant: Brötje EcoGen WGS 20.1
- Manual work: Uwe Pyschny GmbH
- Installation: 12.12.2013

Since installation of the plant

- CHP electricity produced: 2,650 kWh
- Proportion of electricity used internally: 62 %
- CO_2 saving: 1.9 t CO_2



From coal to natural gas

The residential property dates from 1919. It has a living area of 160 square metres, and two people live there. The semi-detached house was an previously supplied with heat by a 24-year-old coal-fired heating system. As part of the project, the heating system was replaced by a CHP plant with a Stirling engine.

The conversion to natural gas has made it possible to increase user comfort enormously. The CHP system in this property consists of a system package with integral peak-load water heater and a buffer tank for the buffered heat supply.

- **Property data**
- Property type: semi-detached house
- Area: 160 m²
- Year of construction: 1919
- Residents: 2 persons
- Age of heating system: 24 years
- Energy consumption: 5-6 t coal/y

Conversion

- Plant: Viessmann Vitotwin 300 W
- Manual work: Smit GmbH
- Installation: 07.03.2014

Since installation of the plant

- CHP electricity produced: 1,695 kWh
- Proportion of electricity used internally: 34 %
- CO_2 saving 2.1 t CO_2

From oil to natural gas

The detached house dating from 1981 with a living area of around 133 square metres was previously supplied with heat by a 25-year-old oil-fired heating system. The heating system has now been modernised by a gas internal combustion engine with an electrical output of 1 kilowatt.

The installed system consists of an additional peak-load device and a buffer tank for space heating and hot water. Thanks to the conversion from oil to natural gas, it was possible to use the footprint of the previously installed oil tanks for the installation of the new system.

Property data

- Property type: detached house
- Area: 133 m²
- Year of construction: 1981
- Residents: 2 persons
- Age of heating system: 25 years
- Energy consumption: 3,000 l oil/y

Conversion

- Plant: Vaillant EcoPower 1.0
- Manual work: Huxel GmbH
- Installation: 07.02.2014

Since installation of the plant

- CHP electricity produced: 4,210 kWh
- Proportion of electricity used internally: 34 %
- CO_2 saving: 2.5 t CO_2

Contracting for old people's care centre

In Oberhausen, ASB is banking on energy efficient heat.

An old people's care centre in Oberhausen-Holten is banking on efficiency. Energy supplier Energieversorgung Oberhausen operates a cogeneration unit and a solar-thermal system.

In June 2012, the Arbeiter-Samariter-Bund (ASB) in Oberhausen-Holten opened a new old people's care centre with 64 beds. In addition to general old people's care in the main building, the complex as a whole also houses a centre that is specially set up for the care of people with dementia. The site offers spaces for three sets of ten residents, who are looked after as groups. The ASB also offers twelve day-care spaces.

Overall, the building fulfils the efficiency standard 70, which means that the primary energy requirement is 30 percent below the requirements of the 2009 Energy Saving Ordinance (EnEV) currently in place.

Energy efficiency is an important consideration in the new facility. A natural-gas-fired cogeneration unit, a 42-square-metre area of solar panels and a peak-load condensing boiler provide a highly efficient and environmentally friendly energy supply.

The innovative combination of systems saves 25 tonnes of CO_2 per year compared with a conventional heating system. Due to the way the fuel is used, the Vitobloc 200 cogeneration unit achieves a total efficiency of 96 percent.

The use of such a cogeneration unit is always worthwhile if – as in this case – there is continuous consumption of heat, and the operation periods for electricity generation are as long as possible. Applications that meet these requirements include hotels, residential buildings of 30 to 50 residential units, holiday resorts, swimming pools and in industry, trade (shopping centres) and commerce.

The planning and installation of the heat-producing system was carried out by Energieversorgung Oberhausen AG (evo), which operates the system on a contracting basis and therefore also performs all maintenance and repairs. Evo monitors the operation of the cogeneration unit by remote data transmission.

Due to this external contracting model, the ASB also benefits from lower investment costs and better energy cost planning.

Project data

- Operator: Energieversorgung Oberhausen AG (evo)
- Location: Oberhausen
- Property: old people's care home with 64 beds
- Output of cogeneration unit: 18 kW_e / 36 kW_{th}
- Commissioned: 06/2012
- Fuel: natural gas
- Output of condensing boiler: 240 kW
- Solar thermal system: 42 m² for heating of drinking water and heating backup
- CO_2 reduction: 25 t/y
- Investment costs: 140,000 euros

As of 12/13

Mara hospital

Saving of 200,000 euros over a year thanks to cogeneration unit.

Mara hospital in Bielefeld is banking on a cogeneration unit for its energy supply. The cogeneration unit has a thermal output of 216 kW and an electrical output of 142 kilowatts. The investment of around 750,000 euros is offset by yearly savings of around 200,000 euros.

Due to rising energy prices, and thus rising operating costs, the hospital took the decision to cover part of its energy needs by self-generation after an initial consultation with EnergieAgentur.NRW. The unit installed is based on the principle of combined heat and power generation, producing both heat for space heating etc. and electricity.

Although the cogeneration unit has higher investment costs than a normal boiler, these additional costs can be refinanced by the generation of electricity and heat for internal use. This is only possible, however, if the cogeneration unit clocks up as many operating hours as possible, which is why it is sized to meet property's baseload heat demand. Conventional space heating boilers provide backup to help cover the higher heat demand in the colder season. In the case of the Bielefeld hospital, three space heating boilers are installed in addition to the cogeneration unit.

The cogeneration unit covers 40 percent of the hospital's heat demand and 60 percent of its electricity demand. The main electricity consumers include diagnostic devices, for example the MRI scanner.

To guarantee the efficiency of the cogeneration system in the summer months when there is a lower heat demand, three buffer tanks of 1,500 litres each have also been installed for the interim storage of heat. This allows continuous operation of the cogeneration unit and prevents cycling (continuous switching on and off).

At the same time, the central heating system was also modernised and a hydraulic balancing of the heating system performed, which further improved its efficiency. There are plans to connect a new building to the heating system, which will result in better utilisation and more efficient heat generation.

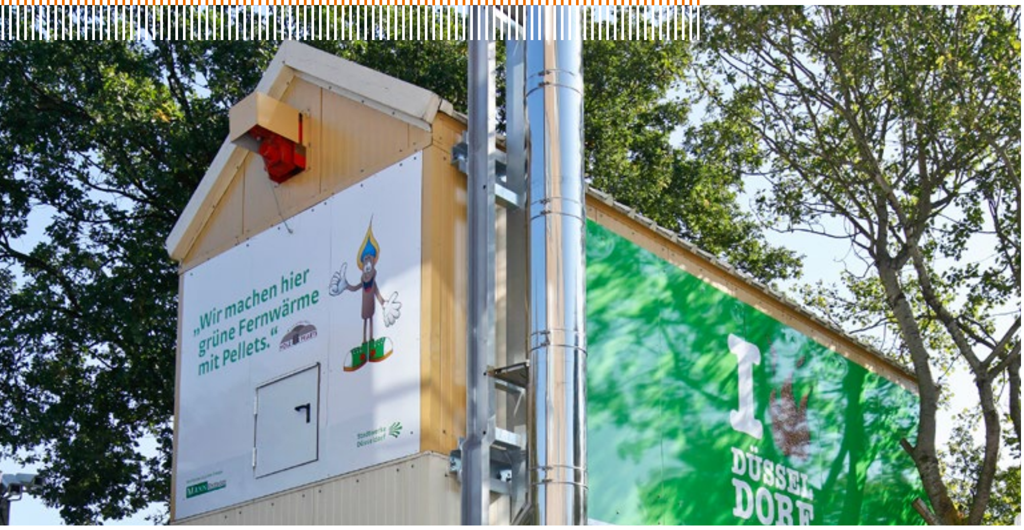
Mara hospital was opened in 1933. It was funded by the v. Bodelschwinghschen Stiftungen Bethel (Bethel Von Bodelschwinghsche Institutions).

The project was planned and implemented by the department of construction/technology/IT of the Evangelisches Krankenhauses Bielefeld GmbH (Bielefeld Evangelical Hospital).

Project data

- Thermal output: 216 kW
- Electrical output: 142 kW
- Operating hours: > 8000/y
- Investment costs: 750,000 euros
- Annual saving: 200,000 euros
- Buffer tank: 3 x 1,500

As of 6/15



Düsseldorf-Garath district heating supply

Wood-fired double act!

In 2007, the municipal utility Stadtwerke Düsseldorf commissioned a wood-fired biomass cogeneration plant on the site of its power station in Garath. The steam generated in the biomass cogeneration plant is piped to a steam turbine with an electrical output of 3.5 megawatts that feeds into the public electricity grid. The condensation heat of 10 megawatts is supplied to the district heat network of the Düsseldorf district of Garath, where it meets the baseload heat demand. Thanks to the biomass cogeneration plant, the proportion of renewable energy in the district heating network has risen to just under 50 percent.

In September 2013, Stadtwerke Düsseldorf, along with its partner MANN Naturenergie, also commissioned a mobile pellet boiler house with a thermal output of 0.88 megawatts on the site. The plant, which is fired with wood pellets, supplies the environmentally friendly heat into the district heating network of Garath.

With its heat output of 880 kilowatts, the pellet boiler is mainly used in the transition period and in winter in the power station's medium load range, and produces around 5 million kilowatt hours of heat. This means that the consumption of natural gas can be further reduced over and above the output of the existing Garath cogeneration plant. The Garath cogeneration plant therefore not only helps to provide environmentally friendly heat for the district, but also contributes towards achieving the climate protection goals of the provincial capital of Düsseldorf.

So what are pellets?

Pellets are produced at high pressure from dried, natural residual wood (e.g. wood shavings or sawdust) pressed into cylindrical sticks. A kilo of these pellets, which are up to just under 5 centimetres long and 0.5 centimetre thick, has an energy content similar to 0.5 litres of fuel oil or 0.5 cubic metres of natural gas. Wood pellets are climate neutral because when they are burnt they release exactly the same amount of CO_2 as the tree has bound up during its growth.

Project data

- Operator of biomass cogeneration plant: Stadtwerke Düsseldorf
- Operator of pellet house: MANN Naturenergie GmbH & Co. KG
- Fuel: wood chips & pellets (53 %); natural gas (47 %)
- Construction of cogeneration plant: 1960 / conversion to natural gas operation: 1998
- Conversion to biomass cogeneration plant: 2007
- Commissioning of pellet plant: 09/2013

As of 12/13

The new Fortuna unit

The new combined cycle gas turbine (CCGT) power station has already saved 600,000 tonnes of CO_2 in its first year of operation alone.

The city of Düsseldorf has set itself the goal of becoming climate neutral by 2050. It has achieved a significant milestone on this journey with the new "Fortuna" natural gas-fired unit at its Lausward power station.

The power station uses natural gas to produce climate-friendly electricity and heat. This, along with its high level of flexibility, makes it the ideal companion to the renewable energies that are becoming ever more significant. In this context, the power station's technical properties are particularly important. Thanks to the simultaneous generation of district heat by the cogeneration process, fuel utilisation is increased to up to 85 percent.

In parallel to the construction of the new gas-fired unit, the district heat supply in the city was significantly expanded. District heat has an important contribution to make towards achieving climate goals, because the majority of energy used in urban areas is in the form of heat.

Clean and safe energy for Düsseldorf

The CCGT power station is geared towards the most efficient use of gas possible. It produces energy using a combination of gas and steam turbines, with additional heat use.

When it was commissioned at the start of 2016, the power station, which has an efficiency of over 61 percent, set a new world record in pure electricity generation. Its additional use for the district heating network of the city of Düsseldorf increases its efficiency to 85 percent. This means that 85 percent of the fuel used is converted into electricity and heat.

The combined cycle gas turbine

The gas turbine lies at the heart of a combined cycle gas turbine. Natural gas is burnt at high temperatures in its combustion chamber. The hot combustion gases flow through the turbine and cause the rotor to rotate. This rotary motion is transmitted to a generator, which produces the electricity. After this first task, the still-hot combustion gases have two further tasks to perform. They generate steam from water in a waste heat boiler, which drives the steam turbine that in turn drives the generator, and finally they heat the water in the district heating pipes. The gas and steam turbines are mounted on a single shaft, which minimises generator losses and increases electrical efficiency.

The gas-fired unit is supplemented by a district heat store with a capacity of around 35,000 cubic metres. This allows the natural-gas-fired power station to temporarily store up to 1480 megawatt hours of heat and supply the town of Düsseldorf with heat over a period of several hours to several days – depending upon weather conditions.

Project data

- Electrical output: 595 MW
- District heat output: 300 MW
- Total efficiency: > 85 %
- CO_2 saving: > 2.5 million t/y
- Construction time: approx. 32 months
- Commissioned: 2016

As of 4/16

Energy for the future of a region

The "Powertrain", a special combination of gas turbine, steam turbine and generator, makes the Niehl 3 cogeneration plant one of the most efficient in the world.

The new and highly efficient Niehl 3 combined cycle gas turbine power station is located on the Niehl harbour right next to the Niehl II cogeneration plant. It commenced normal commercial operation at the end of April 2016.

Niehl 3 will permit savings of an extra 500,000 tonnes of carbon dioxide in Cologne every year. In addition, the plant's flexibility means it will help to ensure security of supply at a time when Germany is transitioning to more sustainable energy sources: it takes only 15 minutes to get the plant up to full power from standby. This way it can easily smooth out power fluctuations caused by the use of solar and wind energy. In addition, the output can be increased by over 100 megawatts, or dropped back down again, within a few minutes, if required.

The maximum fuel use efficiency of the plant is over 89 percent. This makes the power station one of the most efficient and flexible power stations in the world and an important building block in Germany's energy transition.

In cogeneration operation, Niehl 3 generates over 450 megawatts of electricity for a million households, and around 265 megawatts of district heat for around 30,000 households. In the long term, this heat output will make it possible to connect new service areas to the district heating network. Even today, the Niehl site is supplying the inner city area, including Deutz, with locally produced emission-free district heat.

A new Rhine crossing to Mülheim is securing the long-term supply of climate-friendly district heat to the right bank of Cologne, and will, in the future, open up new areas to district heating. In total, locally produced, emission-free district heat can replace 35,000 individual heating systems, some of them very antiquated.

The province of North Rhine Westphalia will back the new district heating infrastructure with EU funding.

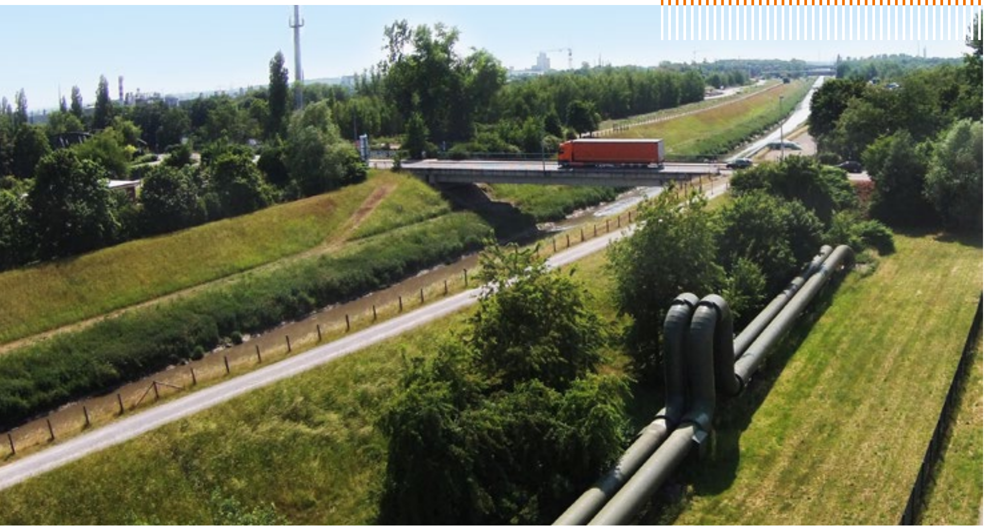
In addition to taking the district heating pipes from the Niehl site, a newly created 650-metre-long underwater crossing of the Rhine tunnel (Düker) also carries the 110 kV electricity cables that connect Niehl 3 to the Kalk substation. There, the electricity is fed into the regional grid, thereby strengthening local security of supply. Nationally, Niehl 3 also secures short-term needs by a connection to the supra-regional 380 kV extra-high voltage grid. With a length of 9 kilometres, the 380 kV cable laid for this connection is the longest of its type in Germany.

The Niehl 3 cogeneration plant is the cornerstone of conventional energy generation at RheinEnergie.

Project data

- Net output of overall plant: 453 MW
- Net electrical efficiency: over 60%
- Max. net overall utilisation: over 89%
- Max. heat extraction for district heating: 265 MW
- Additional CO_2 saving: 500,000 t/y
- Electricity supply: around 1 million households
- District heating supply: around 30,000 households

As of 4/16



Rhine-Ruhr district heating grid

Efficient, innovative and environmentally friendly heat and security of supply for the Ruhr area.

Based on the results of the feasibility study "Perspektiven der Fernwärme im Ruhrgebiet" (Prospects for district heating in the Ruhr area).

In March 2015, the project company Fernwärmeschiene Rhein-Ruhr GmbH was established to implement this project. The other companies involved were municipal company STEAG Fernwärme GmbH (56.6 %), district heating supplier Niederrhein GmbH (25.1 %) and energy supplier Oberhausen AG (18.3 %).

The objectives of the project company are the planning, construction and operation of the Rhine-Ruhr district heating grid. From 2017, the existing Lower Rhine and Ruhr district heating grid will be connected up incrementally.

This will allow additional industrial and renewable heat sources to be linked into the supply, including waste-to-energy plants, waste heat from industrial plants, gas- and coal-fired power stations and heat from renewable cogeneration. Cogeneration is a particularly efficient process in which the usable heat that is produced during the generation of electricity is used to heat water for district heating.

Creating the largest combined district heating network in Europe

The connection permits the provision of large quantities of CO_2-free heat and cogeneration to all project partners. The Rhine-Ruhr district heating grid thereby makes a significant contribution to the CO_2 and cogeneration goals of the state of North Rhine-Westphalia.

Details

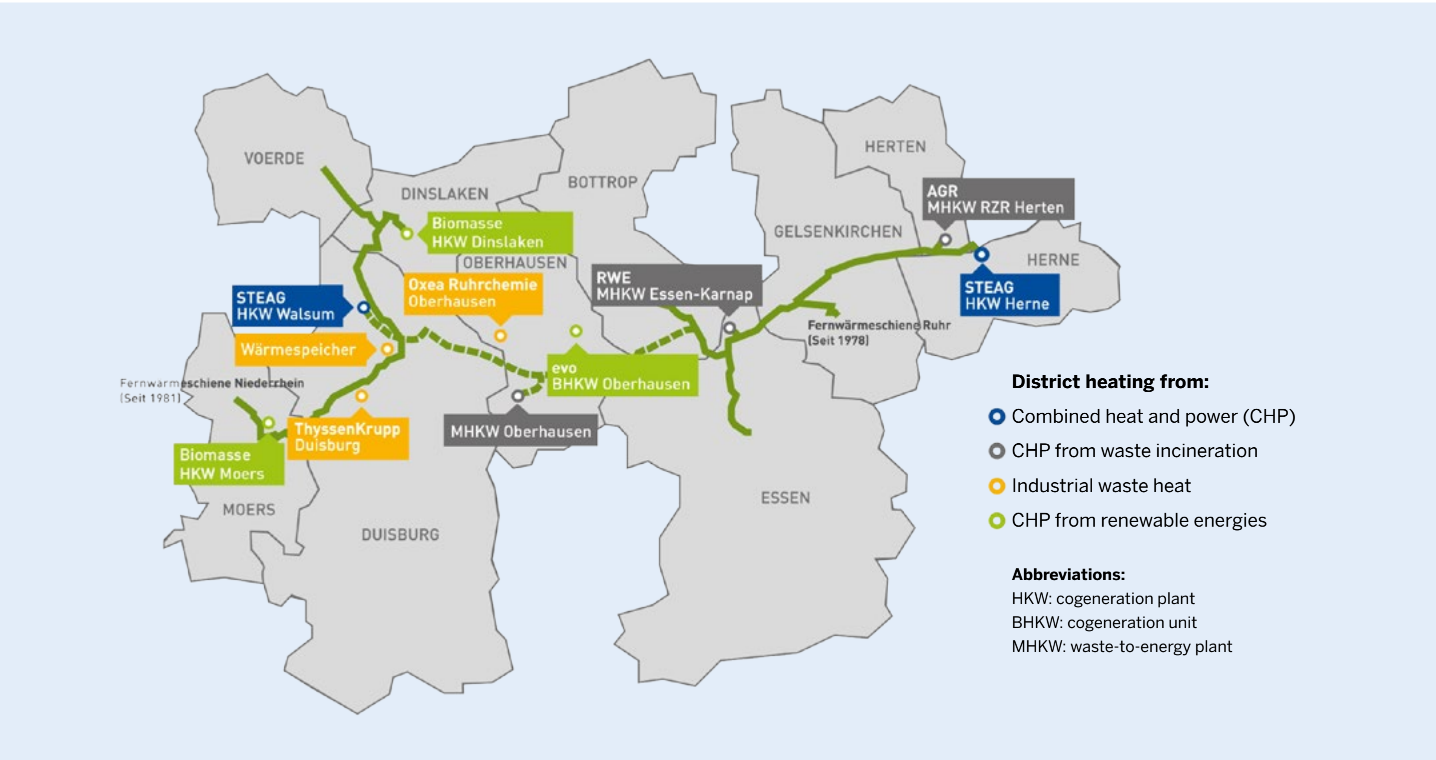
The connection will run from the existing Ruhr district heating grid in the south of Bottrop to the Lower Rhine district heating grid in the north of Duisberg. The start of construction is scheduled for spring 2017. Individual sections will be able to start operation after a construction time of two years – i.e. in 2019. The pipework system will be laid partially above and partially below ground, using existing infrastructure routes where possible.

A European flagship project

Projects like the new Rhine-Ruhr district heating grid mean the Ruhr area is gradually becoming one of Europe's foremost areas for climate protection projects. The industrial area inspires visitors with its green recreation facilities and the high density of leisure and cultural opportunities that are available. The technical expertise that exists in the region has made it possible to bring industrial and residential areas into harmony in an impressive manner.

The project is particularly characterised by the high potential for CO_2 savings and the low cost of CO_2 avoidance.

As has been the case for comparable projects in the past, careful thought has been given to how the Rhine-Ruhr district heating grid could be incorporated harmoniously into the attractive industrial culture and natural landscape of the Ruhr area. The engineering companies commissioned to implement the project has therefore been meticulously planning, metre by metre, the path of the around 25-kilometre route that will connect the existing Lower Rhine and Ruhr district heating grids, thereby creating the largest combined district heating grid in Europe. The Ruhr area will thus gain another international showcase project focussing on climate protection.



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KWK.NRW – Strom trifft Wärme (CHP.NRW – Electricity Meets Heat)
By its "KWK.NRW – Strom trifft Wärme" campaign the EnergieAgentur.NRW supports the expansion of cogeneration in North Rhine-Westphalia (NRW). Together with the relevant groups from business, research, society and administration in NRW, the campaign brings together a range of actions and measures to increase awareness of cogeneration technologies as well as their benefits and fields of application.

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