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L6-4: ASSESSING WASTE HEAT POTENTIAL WITHIN THE CITY BOUNDARIES FOR INTEGRATION IN THE CENTRAL DISTRICT HEATING SYSTEM

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1 INITIAL SITUATION AND MOTIVATION

Energy transition in the Federal Republic of Germany is making high demands of a large number of companies in order to be able to achieve future climate goals. This is leading to a change in thinking in the field heat supply, too. In the process, the area of electricity production represents just a cornerstone of energy transition. The required reduction of harmful emissions cannot be achieved without heat transition. For example, heat applications, with more that 54 %, made up more than half of Germany's energy consumption in 2018. Thus, it quickly becomes clear that efficient use of thermal energy plays a central role (BDEW, 2020).

Due to the announcement of climate emergency declared in 2019 and the aspirations in Leipzig, local authority heat planning is required. It has the goal of complete climate-neutrality in heat supply by the year 2038, meaning even existing infrastructures will have to be reconceived.

Currently, heat supply for homes and businesses in Leipzig, as is mostly the case throughout the Federal Republic, depends on fossil natural gas and coal – he generation of district heating is also of fossil origin, with a combined heat and power ratio of 99.8%. Climate-neutral district heating is being assessed throughout the Federal Republic in specialist circles for climate protection and renewable energies as one of the most important elements of energy transition and, in particular, heat transition.

With the clear goal of the decarbonisation of Leipzig's district heating, various potential sources for the use of renewable energies and the inevitable waste heat, and their integration into the grid-bound heating systems, are under investigation. Thanks to the district heating network, potential available, large local and regional sources of environmental heat are being made usable for the compact urban settlement structures of the city centre and many neighbourhoods. Given the limited sizes of plots of land, extensive individual self-supply usually is not possible for physical and spatial reasons, thus, compactly developed urban residential areas can receive assured, climate-neutral heat supply with the expansion of district heating. District heating makes the complex technologies of Co_2-free heat production manageable as public utility companies guarantee professional, efficient and reliable operation. That way, many building owners are relieved of the considerable technical, financial and organisational effort for individual climate-neutral heat production on their own plots of land. Climate protection needs to pick up speed, firstly, with measures with significant leverage. Thanks to the district heating network, a climate-neutral heat supply can be achieved for large sections of housing stock and many businesses with just a few major measures.

Alongside having a main focus on the incorporation of waste heat into the district heating grid network, integration options for secondary networks, local heat networks and low-ex networks are also being considered. In some cases, this could be the technical and economic approach given the existing technical parameters (e. g. lower heat network temperatures) and due to the spatial environment.

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2 POTENTIAL INDUSTRIAL WASTE HEAT UTILISATION

In future, subjects of energy efficiency, such as sector coupling or the utilisation of synergies, will be ever-present in every value-added chain. The sectors of electricity, heat and cold supply, transport and industry must be regarded as integrated with each other and energetically interlinked.

Above all, the options for coupling the heat supply and industry sectors represent great potential for the use of heat reclamation methods. At 23%, the demand for **process heat** alone makes up almost a **quarter of Germany's energy requirement** (see figure 1).

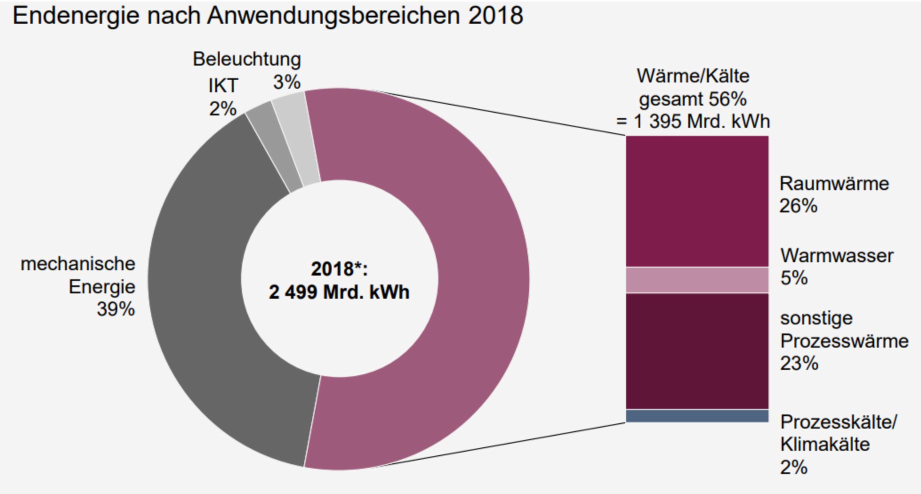

Figure 1: Final energy by areas of application / (BDEW, 2020) - translation in the appendix

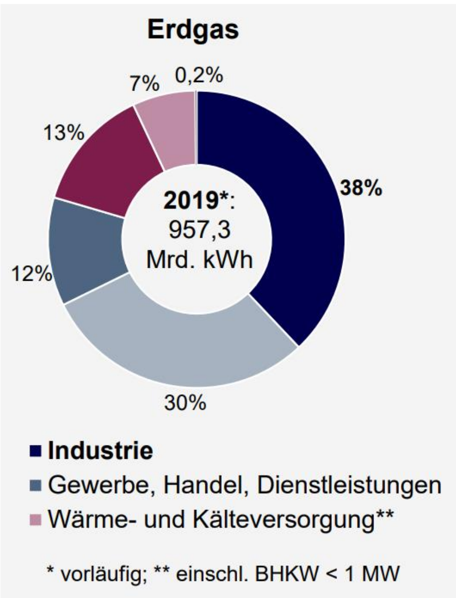

Figure 2: Distribution of natural gas consumption by sectors / (BDEW, 2020) - translation in the appendix

In many areas of industry, this requirement can be located in various production processes. However, the expended energy in form of process heat does not enter completely into the product. The thermal loss generated in the process is a by-product which does not serve the causal purpose of further utilisation of energy, and is released unused into the environment. This is industrial waste heat.

However, this thermal energy loss is not an unknown quantity. A report on the use of industrial waste heat based on the Swedish Enova Study (2009) came to the conclusion that, technically and economically, there is a potential to cover around 12 % of the entire final energy requirement in the German industrial sector with waste heat, if an effective temperature of 140°C is assumed. (ENOVA, 2009)

Presuming that this can be applied for the energy balance of 2018, this would mean potential waste heat of around 67 TWh. In terms of the balance sheet, Germany's entire natural gas-based heat and cold supply (2019) could thus

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be covered.

This estimate makes clear how the use of waste heat plays a major role when it comes to energy savings, and approaches for solutions of synergetic use need to be found.

However, this potential is not yet being exploited Researchers working on the "Abwärmeatlas" (waste heat atlas) research project of the BMWK (Federal Ministry for Economic Affairs and Climate Action) surveyed businesses across Germany on their use of waste heat. The results showed that around half of the surveyed businesses were not using their waste heat at all. The reasons for which waste heat is released completely unused into the environment, and is not re-used or reclaimed, can vary. For example, flows of waste heat are often not hot enough in order to be re-used directly in another process. For this purpose, the waste heat first has to be raised to a higher temperature level. In this case, a heat pump may well be the solution. In addition, a flow of waste heat does not always arise at the same time as the corresponding heat requirement elsewhere. Therefore, industry requires heat accumulators in order to be able to use waste heat technically. They allow for utilisation independent of time concerns.

In the most energy-intensive fields in particular, the waste heat available often exceeds the direct requirement. It is thus not possible to utilise it in a practical manner in the same facility. However, it can be economically viable to supply the waste heat to third parties and thus help shape the heat supply more efficiently at the destination. The industrial waste heat can be supplied to buildings or residential areas in the neighbourhood, for example, in order to heat water and supply heating systems. The following chapter describes just how the investigation for the Leipzig area turned out.

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3 POTENTIAL INDUSTRIAL WASTE HEAT SOURCES IN THE LEIPZIG AREA

3.1 Clarification of the requirements and area of application

Before steps can be taken to locate waste heat, and in order to be able to prioritise more exactly, a concrete definition is required of the requirements for use of excess heat which have to be met.

The current supply temperature in the district heating network is between 90 °C in the summer and 120 °C in the winter. The return flow temperature depends on the building structure and ranged from 55 to 65 °C. The return flow temperature is reduced continuously (approx. 0.5 K per year) with the optimisation of the house connection stations and connection of new objects with underfloor heating. Because of the hydraulic conditions of the network and for economic reasons, a reduction of the supply temperature is planned but has not yet been enacted. The transformation of district heat production to 100 % climate-neutral will change the producer's portfolio. The use of potential waste heat sources together with the use of large-scale heat pumps favours the reduction of the supply temperature.

The investigation should not only take into consideration the integration of waste heat into the district heating grid network, but also the residential area approach, i.e. the concept of "neighbourhood heat". While, as already mentioned, district heating requires a flow temperature of 90-120°C, residential areas can be supplied via local heat networks with temperatures of 70-80°C.

A further distinction in the assessment of suitability would be the seasonality of the waste heat. Given that the base load for Leipzig's district heating of around 60-80 MW is to be well covered by the planned waste heat line to Chemiepark Leuna, the integration of further waste heat potential in interim periods and winter months is required. This is discussed in more detail in chapter 5.1.

3.2 Locating Leipzig's potential waste heat sources

Identifying and assessing local potential waste heat sources turned out to be more difficult than initially assumed. In general, there is no generic approach to locating potential sources. Businesses are not obliged to disclose possible heat excesses, and it is not uncommon for them to avoid providing statements in this context. In addition to the fear of a negative external reputation as an inefficient or "wasteful" business when it comes to energy, so far there has also been a lack of economic incentives for modernisation. Most operations do not regard the extraction of waste heat and the associated heat supply as their core business or even urgently necessary.
Therefore, the location process requires multiple indicators in order to be able to identify the realistic potential.

Leipzig is home to around 45,000 businesses and facilities (see figure), which is why the greatest challenges were faced when it came to filtering possible businesses where waste heat could probably be generated.

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Table 1: Businesses of the Leipzig Chamber of Commerce/City of Leipzig

Businesses of the Leipzig Chamber of Commerce	2019	2020	2021
Total businesses	44 450	44 192	45 483
Of which in the economic sector (classification of economic branches 2008)			
Agriculture, forestry and fishery	73	73	76
Manufacturing industry	1 239	1 291	1 378
Energy supply	648	318	320
Water supply, waste water and waste disposal	108	103	103
Construction	2 080	2 120	2 169
Trade, maintenance and repair of motor vehicles	7 852	7 843	8 113
Transport and storage	1 205	1 181	1 323
Hospitality	2 143	2 155	2 195
Information and communication	3 245	3 383	3 567
Financial and insurance services	2 146	2 164	2 259
Real estate	2 579	2 613	2 736
Freelance, academic and technical services	9 641	9 571	9 725
Other economic services	5 874	5 801	5 811
Education	948	954	996
Health and social care	804	838	924
Art, entertainment and leisure	1 491	1 513	1 576
Other public and private services	2 366	2 263	2 202

A first indication of the likelihood of waste heat is the industry in which the company operates. Especially in companies where materials are produced, processed or refined waste heat with higher source temperatures can be assumed. The following overview shows the distribution of waste heat quantities in the respective sectors and waste heat temperatures for UK industry in 2015.

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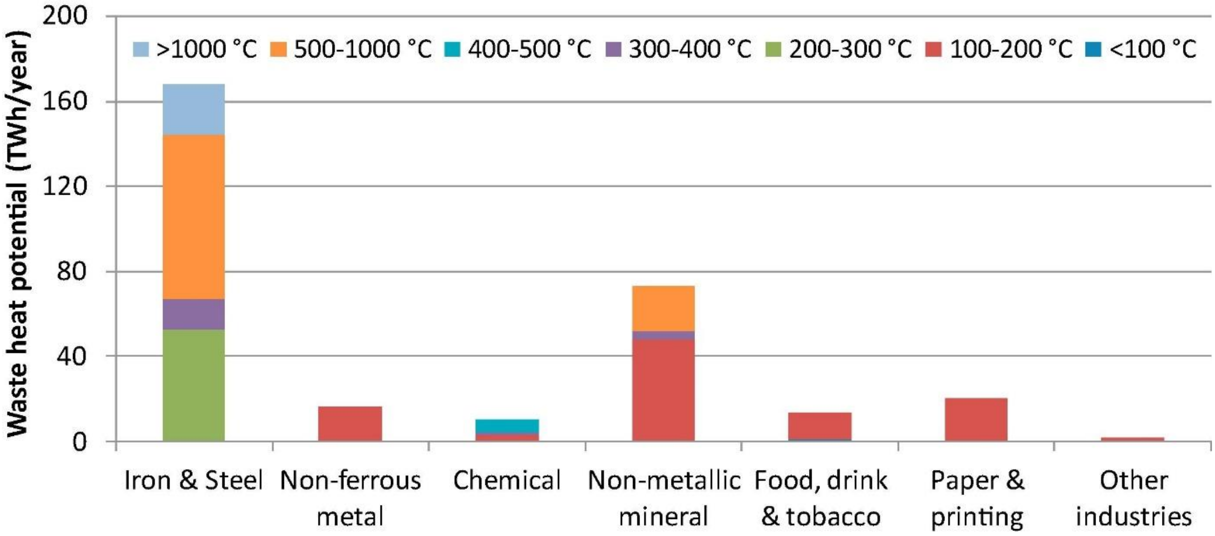

Figure 3: Waste heat potential per industrial sector and temperature level for EU industry in 2015 (Michael Papapetrou, 2018)

The first point of contact when it came to locating sources of waste heat and businesses with waste heat potential was the Leipzig Pollution Control Authority which is where the data on large combustion plants is listed. Other than the combustion plants of the Stadtwerke Leipzig, the only larger combustion plants with an overall combustion power of around 60 MW were those located at the BMW car factory. Due to them being located at a large distance from the district heating grid network and the low synergy effects in the spatial environment, this was not pursued further as a priority in relation to external grid-bound waste heat utilisation.

Using the company register of the Leipzig Chamber of Commerce, it was possible to filter by sector and capacity. In order to achieve an initial narrowing down of the potential businesses, in addition to the criterion of a minimum number of employees of 50, filters were applied to search predominantly for the typical branches for waste heat generation. The following sectors and businesses thus came into consideration:

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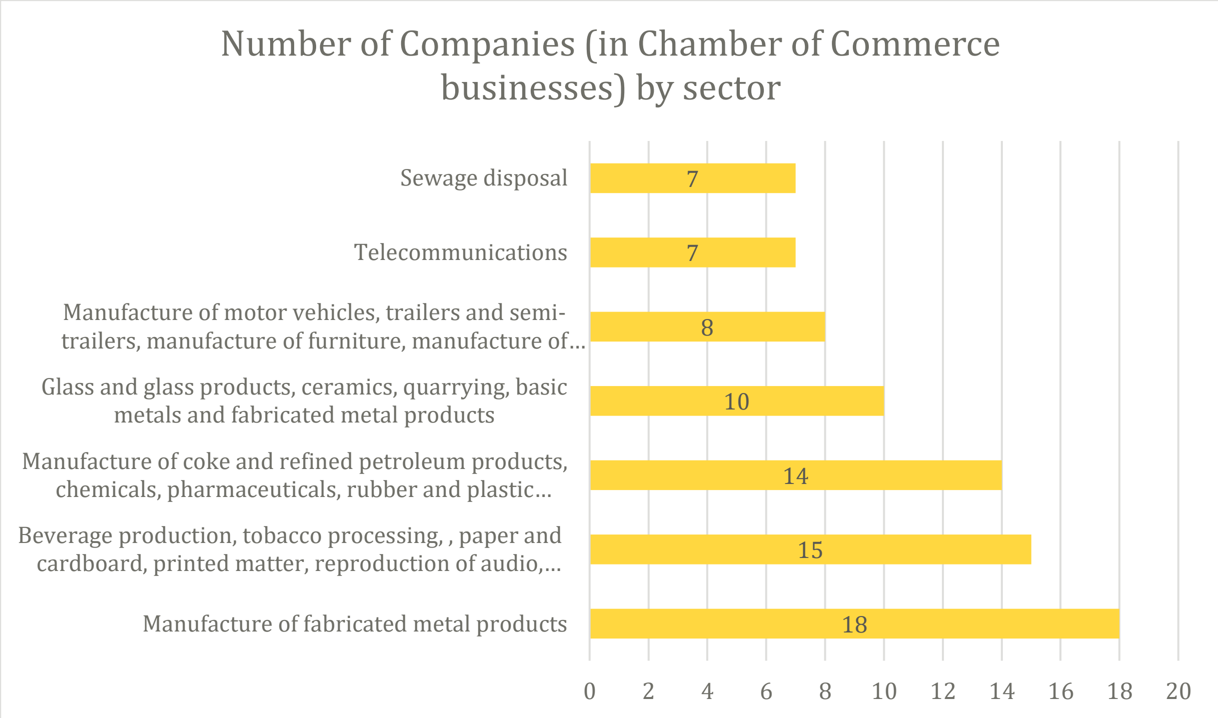

Figure 4: List of pre-sorted Chamber of Commerce businesses

After further research into the concrete activities of the resident companies, it was possible to add further businesses and make more specific statements on the respective business activity, making for a clearer picture of the correlation with sectors:

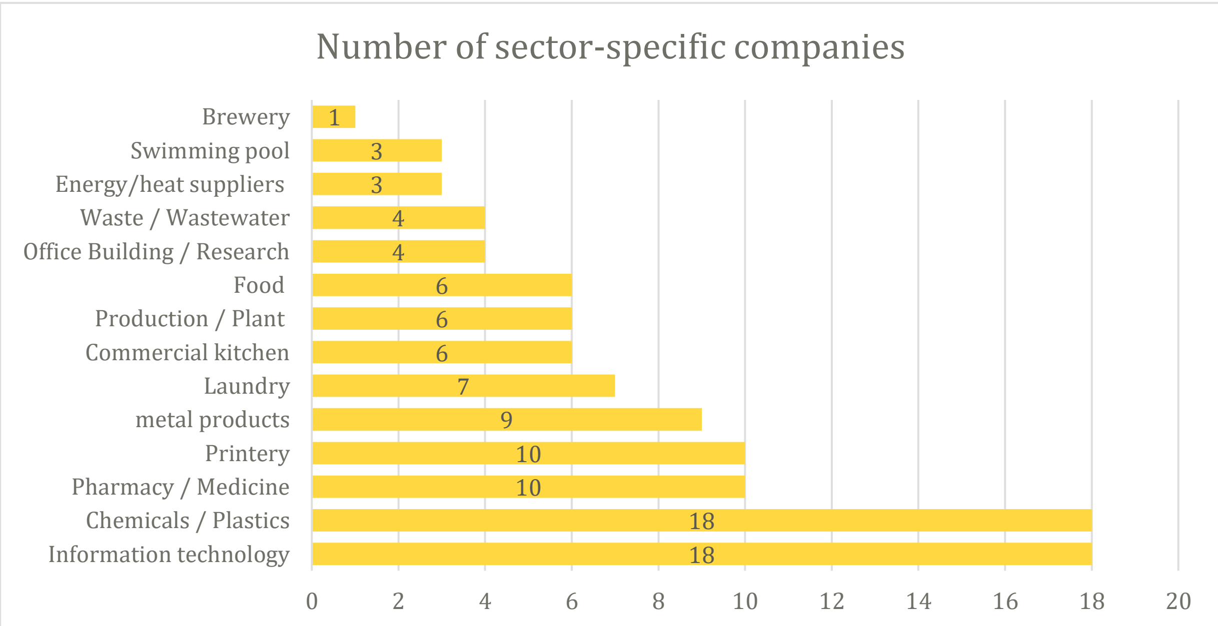

Figure 5: Classification of businesses by sector or area of activity

It is very clear that, with 18 businesses, the information technology sector heads the list of more than 100 businesses with possible waste heat. This also correlates with a targeted focus on data centres.

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Given that an individual assessment has to be carried out in order to determine the explicit waste heat potential, a further narrowing down by priority using factors of influence was implemented, e. g. Sector activity, business fields, Proximity to the district heating grid network, waste heat indicators (recooling plants, media lines, flues, chimneys etc.).

The companies were evaluated with a point system, which provided for the following logic:

<u>Industry classification:</u>
Materials processing industry +3
Electricity/heat generation +3
Data processing centre +2
Food industry+2
Chemical industry +2
Research, printing, (waste) water +1

<u>Proximity to heat infrastructures:</u>
Distance < 100 +3
Distance < 250 +2
Distance < 500 +1

<u>External indications of waste heat occurrence:</u>
Many / Large recooling units, large chimney +3
Average number of cooling units + 2
Isolated small recoolers +1

Figure 6: Map of potential businesses with waste heat/own illustration based on Google Earth

As a result, the next step was to then address businesses directly, contacting around 70 businesses and providing them with a guide and checklist on external waste heat utilisation (see appendix).

The first guide was intended to motivate the businesses and clarify some positive effects of waste heat utilisation. The accompanying checklist was intended to provide the surveyed business with an estimate and indication of the waste heat lines and quantities available within the scope of an investigation.

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Unfortunately, the desired results were not achieved, with only two businesses returned completed check lists.

With expert support and further focusing on the 20 prioritised companies, we continued and continue to repeat the approach. Through direct contact with the technical managers of the companies, the level of interest has risen and is still rising. After initial technical discussions, the theoretical potential of a further 6 companies was identified. Overall, the following general interim assessment can be made of the status quo:

- Total waste heat output/power = 8.2 MW
- Total waste heat quantities = 31.2 GWh

The theoretical potential of waste heat from the Rosental sewage treatment plant is currently still being examined and is not yet considered here.

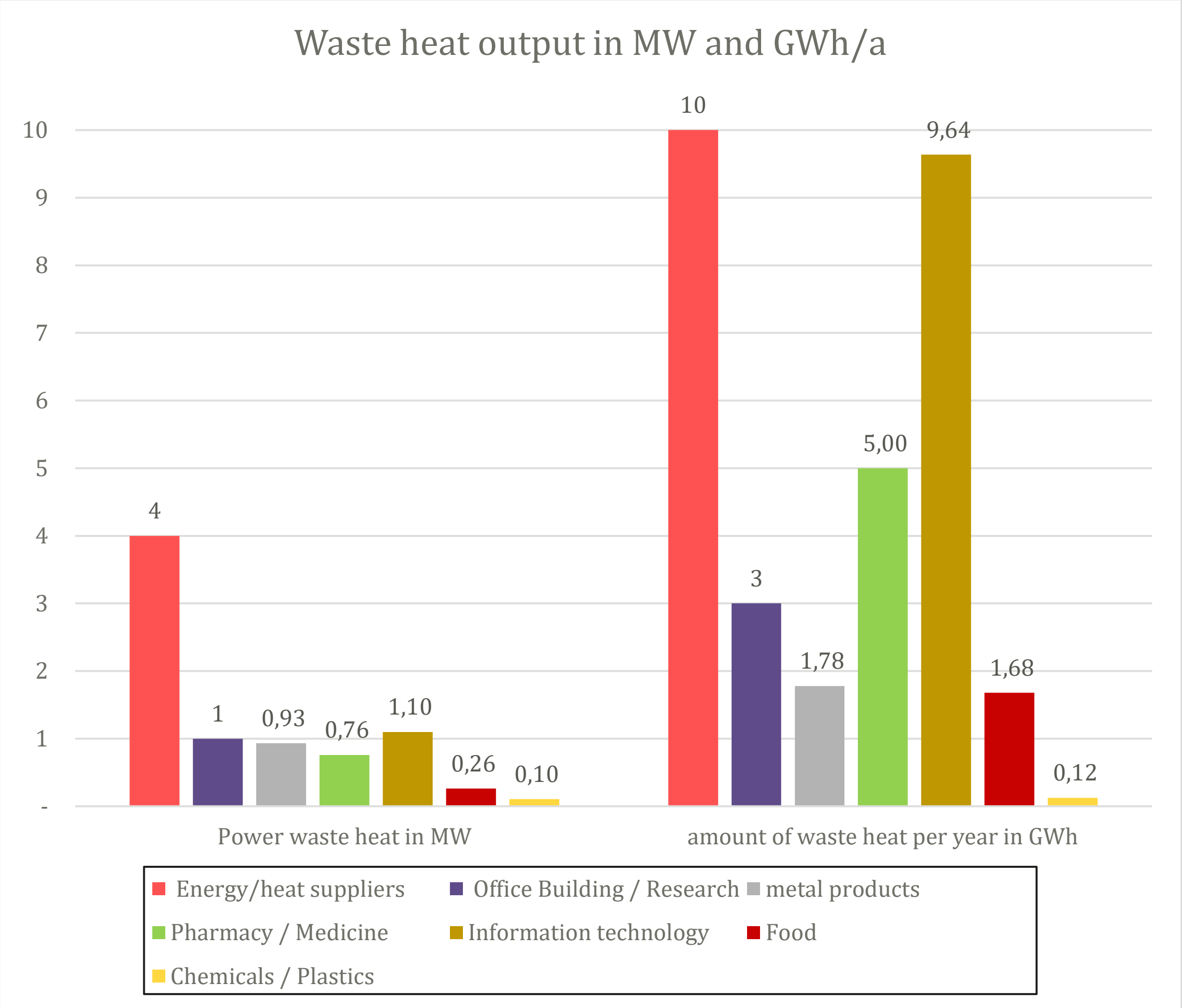

Figure 7: Assessment of the sector-specific waste heat output of the surveyed businesses

With the current findings and estimates, the more than 100 companies were evaluated on the basis of their industry activity, company size, proximity to district heating and, if applicable, available data on consumption, emissions or waste heat. Consequently, these were categorised into 4 basic categories regarding the occurrence and usability of waste heat. Although there is

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clear waste heat potential in the urban area, only a small proportion of it could be used realistically and in terms of technical and economic viability.

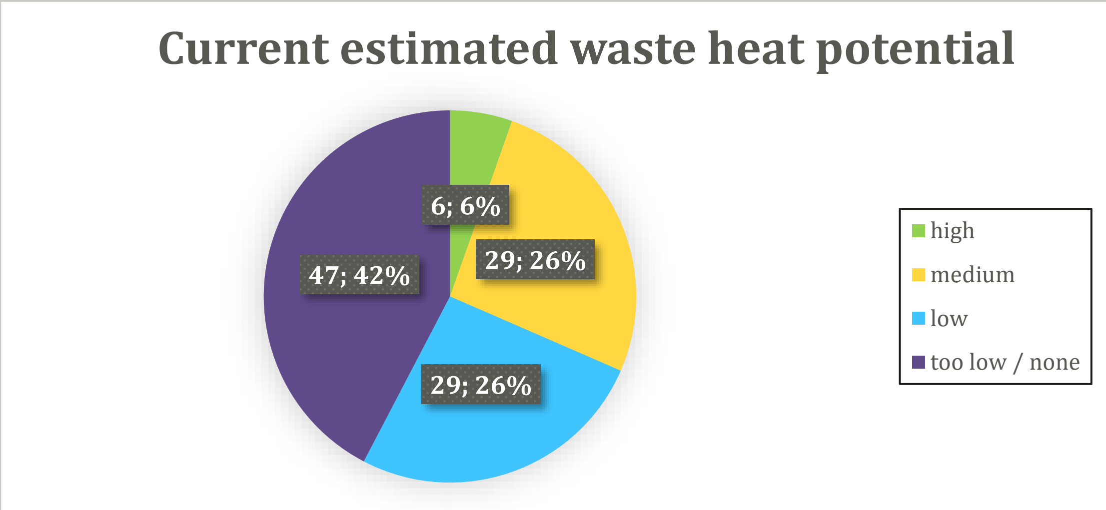

Figure 8: Assessment of the businesses by usability of potential waste heat

In the current situation, it is true to say that there is only a high potential for external waste heat utilisation for 6%. Around a quarter of companies actually have waste heat from their production processes available, but they have either already been ruled out due to technical requirements or the waste heat quantities are already being reclaimed internally and used for in-house purposes. Another quarter of the businesses, there are indeed (very probably) potential sources of waste heat but they are generally plant sizes <100 KW or potential sources of waste heat with low flows of exhaust air or waste water with low temperatures.

The remaining 42% of businesses have only low waste heat potential or none at all which could be used for thermal reclamation.

The municipal utilities will continue to prioritise and investigate inner-city potentials in the sense of the municipal heat transition - both in the area of centralised district heating integration and decentralised use in neighbourhoods or secondary heating systems.

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4 WASTE HEAT FROM DATA CENTRES

An important milestone on the way to heat transformation could come from the use of waste heat from data centres, as an interface between heat supply and the constant growth of digitisation with cloud applications, IoT, smart homes, Industry 4.0 or the new 5G mobile communications standard. All these technologies require large and reliable bandwidths, high-performance internet nodes and, of course, large-scale data centres. The electricity consumption in data centres in Germany already stands at more than 13 terawatt hours (TWh) per year, with an upward trend. At the same time, the large data centres carry out their tasks with a high level of energy efficiency, and only require a fraction of the consumed electricity, e.g. for cooling.

However, there is potential for improvement which is currently more or less lying fallow in Germany, i.e. the use of waste heat from our data centres. If we compare Germany with Sweden, for example, our Scandinavian colleagues are really leading the way. Unlike in Germany, the use of waste heat there is a firm part of energy policy concepts, and is upheld by the broad majority of the population.

Using Leipzig as an example, we currently have an established potential of almost 2 MW. This value must be regarded as being part of an upward trend as existing data centres are already planning further stages of expansion.
The IT at the data centres is usually air-cooled. The heat is then generally transferred to a water system in circulating air conditioners equipped with cold water accumulators, and evacuated. This typically produces cold water return flow temperatures of between 18 and 30 °C. The waste heat can already be used at this temperature level.
If, for example, a higher temperature is achieved with the liquid cooling of IT components, the options for utilisation of hot water grow significantly. A heat pump can be used to increase the temperature level.

However, in this case – above all in Germany – due to the costs of electricity required for operation of the heat pump – the economic viability of waste heat utilisation is reduced significantly. This was confirmed in a NeRZ survey from 2017 in which more than half of the parties surveyed listed a lack of economic viability as the reason for having not yet used waste heat. A little more than 40 % considered that there were no suitable consumers for the heat (see figure 8).

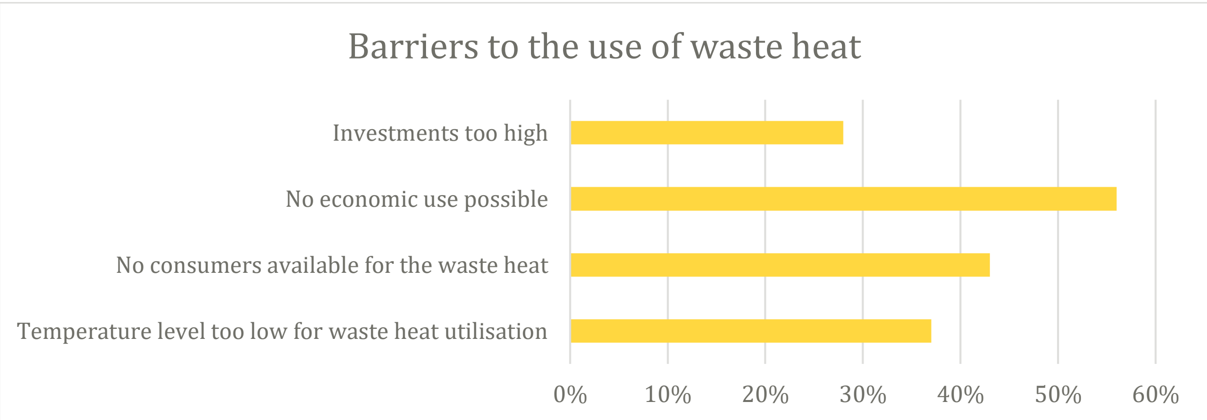

Figure 9: Reasons hindering the utilisation of waste heat from data centres (NeRZ – Netzwerk energieeffiziente Rechenzentren, 2019)

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When an economically viable use of the waste heat from a data centre is possible, and which consumers can be considered, is still of course dependent on the specific framework conditions and the technology used for waste heat utilisation in each individual case.

4.1 Utilisation for district a local heating

An obvious possible use of waste heat from data centres is the integration of the heat into Leipzig's district heating grid network or into new local heat networks which would need to be installed in residential areas.

The supply temperature in local heat networks is significantly lower than district heating. The supply temperature usually depends on the producer's technology and the heat source.

Waste heat from data centres is above all suitable for direct heat utilisation in residential areas with newer buildings. Depending on the temperature of the waste heat, it may be necessary to reheat the supply temperature with heat pumps on the customer's premises for water heating. A large-scale heat pump can also be installed at the source of waste heat itself, thus operating the local heat network at a temperature of 90°C. That way, existing buildings can also be supplied.

The figure below shows the possible basic structure of utilisation of waste heat from data centres in a local heat network. In the case shown here, the residential area is supplied with heat firstly from waste heat from the data centre, and additionally by a combined heat and power plant. The waste heat from the data centre is heated to the necessary temperature level for the local heat network with the aid of a heat pump. At the same time, the heat pump serves as a cooling machine for the data centre.

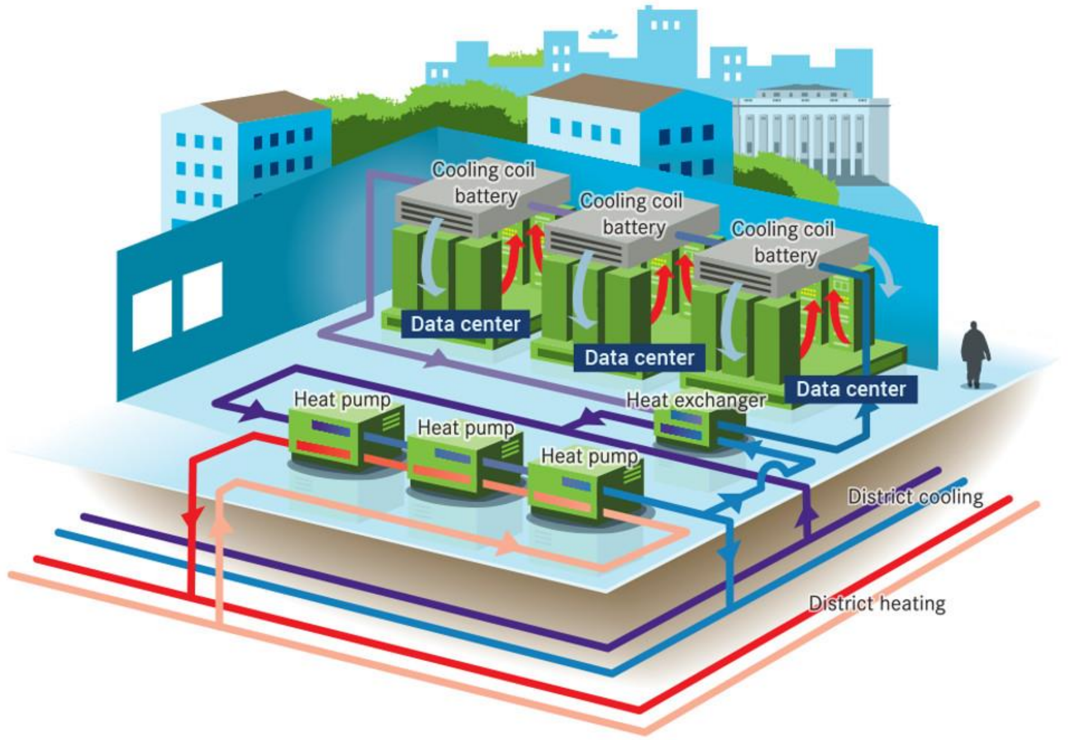

Figure 10: Structure of a local heat network with integration waste heat pump of data centre (Fortum, 2014)

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The waste heat from data centres is now being used intensively, above all in Sweden, where it supplies district heating networks. There are already 30 data centres which supply their waste heat. The references include Ericsson, H&M, Interxion, Bahnhof and Digiplex. Stockholm's district heating network comprises around 2,800 kilometres. 10,000 homes have already been connected, 95 percent of them in the centre of Stockholm. In future, the network is to be expanded significantly. The waste heat from data centres is to cover a tenth of the city's heating requirement by 2035. (Ulrike Ostler, 2018)

A colocation data centre with a max. current consumption of 21 MW is currently being implemented in Stockholm. In the case of this data centre, after the temperature level has been raised using heat pumps, district heating pipes deliver the waste heat directly to the Värtaverket biomass heating plant. On arrival, the waste heat is raised to the level of the district heating network. This way, the entire waste heat from the data centre can be reclaimed and supplied to the district heating network of the City of Stockholm. The heat energy of around 112 GWh utilised in this manner is equivalent to the heat requirement of a small town with a population of approximately 20 000. (GTAI, 2018)

A concept of the Technical University of Darmstadt, which, in 2017, won the German Data Centre Award with the project "Data Centres as a Component of Energy Transition at Residential Area Level", takes up a similar approach. The project plans for the connection of the university's own heating network to waste heat from a high-performance computer with return flow temperatures of 60 °C. With the help of a heat pump, hot water with a temperature of 70 °C is made available for the heating network.
In 2018 in Braunschweig, VW Financial Services inaugurated a data centre, the waste heat of which is used for the adjacent residential and industrial area. (Weis, 2017)

A data centre with waste heat utilisation is also currently planned at the University of Greifswald. This data centre is to be completed in 2019. The waste heat from the data centre is used for a new seminar and administration building, with a neighbouring research building also being supplied with heat via a local heat line. The utilisation of waste heat in local and district heating networks comes with a few challenges. In particular district heating networks are typically planned and implemented with very long timescales. Thus, if there is no suitable district heating network in the direct vicinity, connecting data centres is usually not an option in the immediate future. In this case, proactive planning for the future expansion of local and district heating networks and the siting of data centres is required.
Once again, in this context, when looking for a possible approach, one does not need to look further than Sweden, where what are referred to as data parks are being established. They can be used by data centre operators to set up their data centres. The data parks not only ensure reliable and redundant power supply for the data centres and a connection to the dark fibre network, but there is also a guarantee that the data centres can supply their waste heat to the district heating network. (Koschinsky, 2018)

In order to shape waste heat extraction in the most efficient manner, wherever possible, direct hot water cooling should be drawn upon in order to be able to achieve high usable source temperatures.
Nowadays, IT components in data centres are usually cooled using air as a medium. However, this type of cooling is reaching its physical limits more and more in some areas as the maximum power density of the IT components continuous to increase, thus more and more heat is generated with each server rack. This is firstly due to the fact that the IT components are being packed more and more densely in the servers. Constantly increasing random access memory levels and, in part, the use of graphics processors all leads to heightened energy requirements

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for each server. Furthermore, for some time now, there has again been a notable increase in the maximum power consumption of high-performance processors.
The conveying of heat using water on the other hand is significantly more efficient and could lead to a clear improvement when it comes to waste heat utilisation. Nowadays, water-cooled systems are already being used much in the field of academic applications and for other variants of high-performance computing. Water-cooled IT systems facilitate very good utilisation of waste heat. Hot water with a temperature of 55°C and more is generated directly from the servers. This water can be used very effectively for heating purposes or for hot water heating in residential and commercial buildings. It is also possible to use waste heat for cold production, this process representing the maximum refinement of waste heat utilisation (e.g. HotFlAd project and the Leibnitz data centre in Munich). (NeRZ – Netzwerk energieeffiziente Rechenzentren, 2019)
There are currently two systems for direct liquid cooling of servers:

- Server immersion cooling: This involves immersing the servers in a liquid, causing the liquid to heat up in the process. There are systems with and without phase changes.

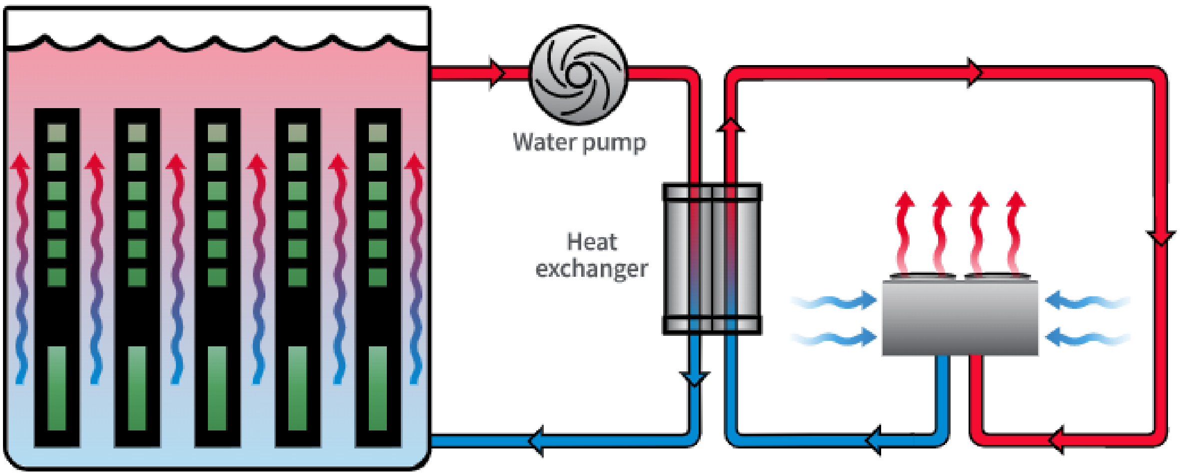

Figure 11: Server immersion cooling (Super Micro Computer Inc., 2022)

- Server liquid/water cooling: In this case, the liquid is delivered to special heat sinks within a closed system, the heat sinks then absorbing the waste heat from the servers.

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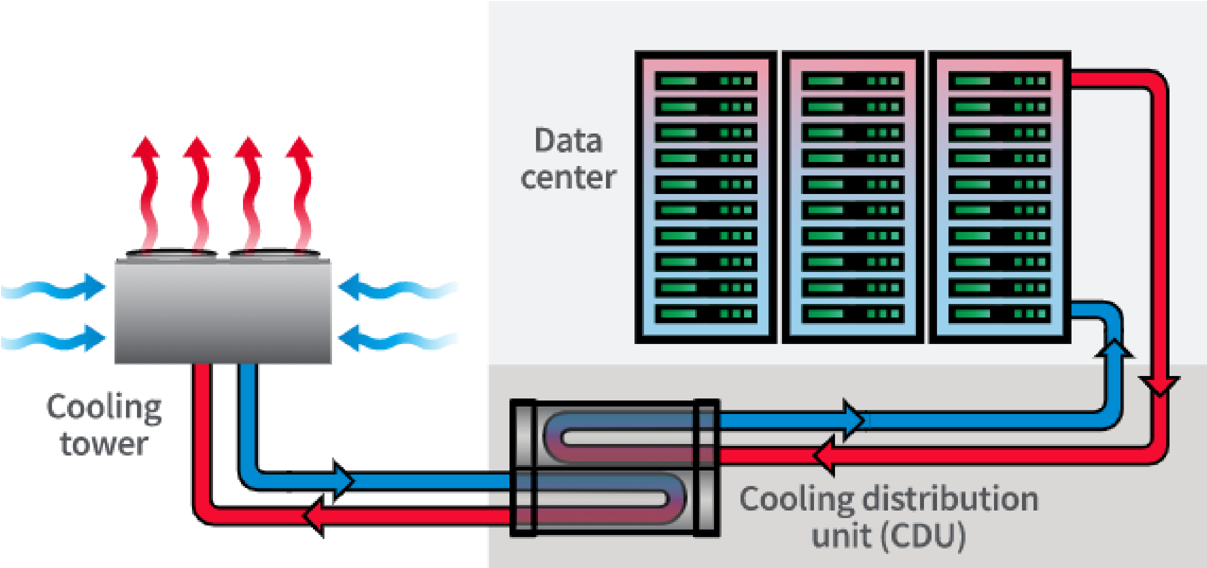

Figure 12: Server liquid - water cooling (Super Micro Computer Inc., 2022)

4.2 Use in systems for the neighbourhood

If it is not possible to use the waste heat from the data centre to supply a local or district heating network, there may also be an option of using the waste heat from the data centre in systems in the neighbourhood. Alongside seasonal heating of residential space and office space, it is above all commercial objects, such as swimming baths, laundries or greenhouses, which also represent constant heat consumers. In this area, too, the challenge is that of providing the heat output with a usable temperature level. If the given temperature level is not sufficient for reclamation in the case of the respective application, the required temperature increase is usually achieved with the use of a heat pump. Furthermore, the question of configuring heat supply contracts bilaterally must also be clarified.

The Swiss local authority in Uitikon uses waste heat from the data centre of an IT service provider to heat the local swimming baths. Heated water is generated using a heat exchanger and then pumped into the nearby swimming baths. The Uitikon local authority receives the heat supply free of charge. However, it first assumed responsibility for a part of the costs for connection. Each year, the data centre generates a waste heat quantity of around 2,800 megawatt hours (MWh) when at full capacity. (NeRZ – Netzwerk energieeffiziente Rechenzentren, 2019)

There is a further utilisation option for waste heat which will be of particular interest in the future, in the field of greenhouses. Above all the area of what is referred to as vertical farming provides very good options for utilisation. Vertical farming refers to urban agriculture which involves the production of plant and animal products in multi-storey buildings in cities and towns. The building complexes are used to grow fruit, vegetables and algae, for example, on multiple vertically arranged storeys.
Vertical farming facilitates must higher yield quantities per area than conventional agriculture, and creates a local supply of food in densely populated areas. Even from an economic point of view, vertical farming offers benefits compared to conventional agriculture. The controlled ambient conditions means constant harvests are achieved.

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Figure 13: The greenhouses of the future thanks to vertical farming/ (Stock, 2022)

One variant of vertical farming is aquaponics. Aquaponics combines fish farming with crop cultivation. The fish are held in large pools and their excretions are used as nutritious fertilisers.

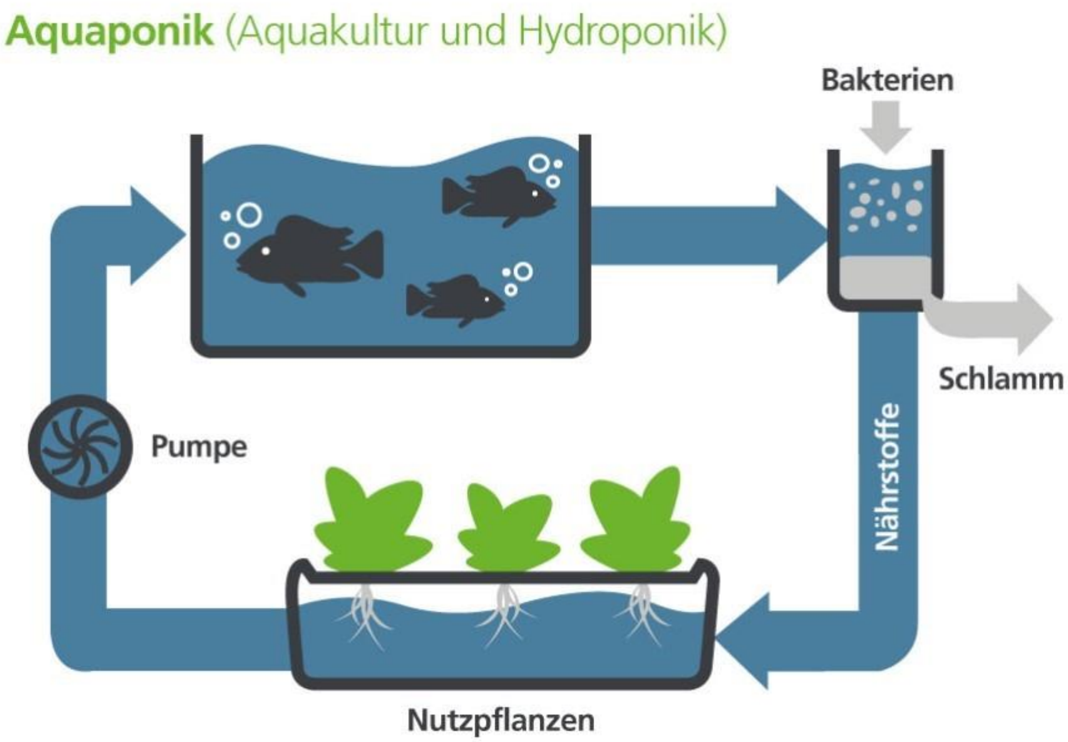

Figure 14: Aquaponics – a combination of aquaculture and hydroponics (Stadtwerke Düsseldorf, 2022) - translation in the appendix

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The combination of vertical farming and waste heat utilisation from data centres provides a whole series of benefits. The waste heat from data centres is well suited to the temperature ranges required in the field of vertical farming/aquaponics. Vertical farming requires a supply of heat all year round. Data centre spaces and buildings for vertical farming can be combined well spatially.

Also, one very important requirement of vertical farming is a regular exchange of air in order to remove unwanted substances and maintain good air quality. If the plants are designed appropriately, synergy effects with the systems of the data centres can be achieved. Vertical farming itself requires more and more computing power every day. IT systems are being used more and more in order to maximise the yields, reduce risks and increase efficiency. Therefore, a connection of vertical farming systems with data centres is practical from this point of view.

4.3 Direct use within the same building

There are good framework conditions for the use of waste heat even within data centres or associated adjacent buildings. The waste heat from data centres is frequently used to heat common rooms in the building. However, the quantity of heat required for this purpose is generally much lower than than the waste heat generated in the data centre; this kind of solution often only utilises 1 % of the waste heat. Nevertheless, this solution does at least help to operate the heating system in the data centre building in a very environmentally friendly manner.

Data centre operators who also operate other properties, such as office complexes or production plants alongside the data centres, can achieve significantly higher rates of use for waste heat. With the exception of large cloud and colocation service providers, the data centres of many operators are embedded into this type of large properties. Depending on the specific framework conditions, in these cases it is often possible to use large quantities of the available waste heat.

The European Central Bank in Frankfurt provides a practical example of use of waste heat in adjacent properties. The Eurotheum high-rise building uses up to 90 percent of the waste heat from the data centre installed in the building. The heat is extracted by a hot water cooling system directly on the servers. The hot water, with temperatures of up to 60°C, is supplied to the Eurotheum's hot water circulation. When fully developed, the servers on each of the two floors produce up to 300 kW of waste heat which can be used to heat the resident offices and conference rooms, hotel and catering facilities. Thanks to the use of the hot water cooling system for the servers and the associated high usable temperatures, an additional heat pump is not required, meaning that no additional electricity has to be used for waste heat utilisation. The annual costs for heating energy in the high-rise building can thus be reduced by up to € 65,000. Furthermore, an additional € 95,000 in cooling costs for the data centre can be saved each year in comparison with conventional cooling. (NeRZ – Netzwerk energieeffiziente Rechenzentren, 2019)

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5 CURRENT REFERENCE EXAMPLES FOR WASTE HEAT UTILISATION AT LEIPZIGER STADTWERKE

5.1 Conveying line for use of industrial waste heat from Chemiepark Leuna

However, in Leipzig itself, the available potential for regenerative energies and waste heat is limited. Leipzig, as a service provider region, has little industry and little space for large renewable energy plants.

The core idea is therefore a **connection line from the industrial location of Leuna** to Leipzig. Pure industrial waste heat as a base load with up to 91 MW of power and a delivery potential of up to 750 GWh at the usable temperature level for district heating is already available in the refinery and the POX/methanol plant. This equates to around 50% of the sales volume of district heating in Leipzig, with which around 10 million square metres of residential space can be heated or 250,000 Leipzig citizens could be supplied, purely in terms of the figures.

For years this waste heat from production processes has gone unused and has inevitably been released into the environment via air recoolers. In Leipzig, the required heat has to be produced separately in combustion processes. **Sector coupling** between the cooling requirement and the heat requirements of a major city with a district heating grid system is therefore very practical from an ecological point of view. The additional costs in comparison with the local alternatives also currently being subsidised, such as CHP and renewable energy, would have to be offset by development funds in order to implement an optimised solution which prevents CO_2. In Leipzig alone, with seasonal storage and consideration, a maximum of up to 168,000 t of CO_2 could be saved in comparison to the general heating benchmark. However, realistically speaking, the savings are lower as the planned new production portfolio features further plants, e.g. solar thermal energy, which will be prioritised for supply and, also, Leipzig's heat is better than the German benchmark. When applying the planned district heating CO_2 value and using the Carnot method, the possible overall portfolio of 640 GWh provides **savings of approx. 71,000 t of CO_2** each year, which is equivalent to the emissions of 30,000 passenger vehicles.

In the city of Leipzig there are only very few sources of waste heat, all of which are risky and have low power and a low temperature level, meaning that the search for potential sources of waste heat has to be extended to the **chemicals location of Leuna**.

Given that Total Energies has committed to **climate-neutral production by 2050**, and high investments in **future-proof infrastructure projects** have been planned and in part announced publicly, contact has been established over a longer period since 2017, and the potential for extraction of industrial waste heat has been analysed. A joint visit was made to the reference plant in Karlsruhe which successfully covers approximately 80% of the city's heat requirement, and parallels have been found in Leuna. The significant sources of waste heat are the high-temperature final products which are cooled with **air recoolers**. This permanently available heat potential can be rendered usable using a bypass, **heat exchanger** and a connection line in Leipzig, thus reducing the use of combustibles at the location.

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The industrial sector accounts for around 30 % of energy requirement. The major part of the energy used leaves the areas of use as diffuse or bundled waste heat. Low-temperature waste heat (below 150 °C) is suitable for external use by **supplying it to district heating networks**. The petrochemical industry, with ethylene as the main raw material, can deliver exhaust gas temperatures in the crackers of around 150 °C. The suitability criteria of waste heat quantity, temperature level, simultaneity, duration of use and, taking into account subsidies, even the geographical proximity, are all in place in Leuna.

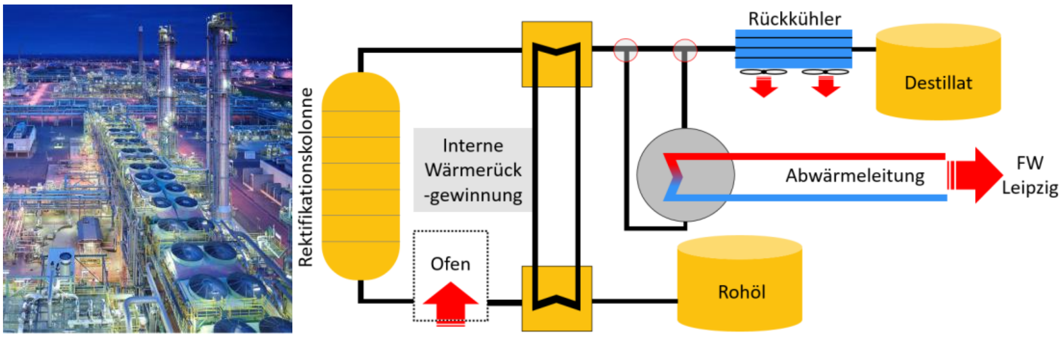

Figure 15: Air recoolers and functional principle with bypass and heat exchanger/Total energies - translation in the appendix

The following diagram shows the various sources of waste heat in Leuna. Regulation is performed in two stages: first by the required supply temperature in the district heating network (throttling of LPG/petrol and SFSG/MeOH), then by heat requirement by additional throttling of the remaining extraction processes.

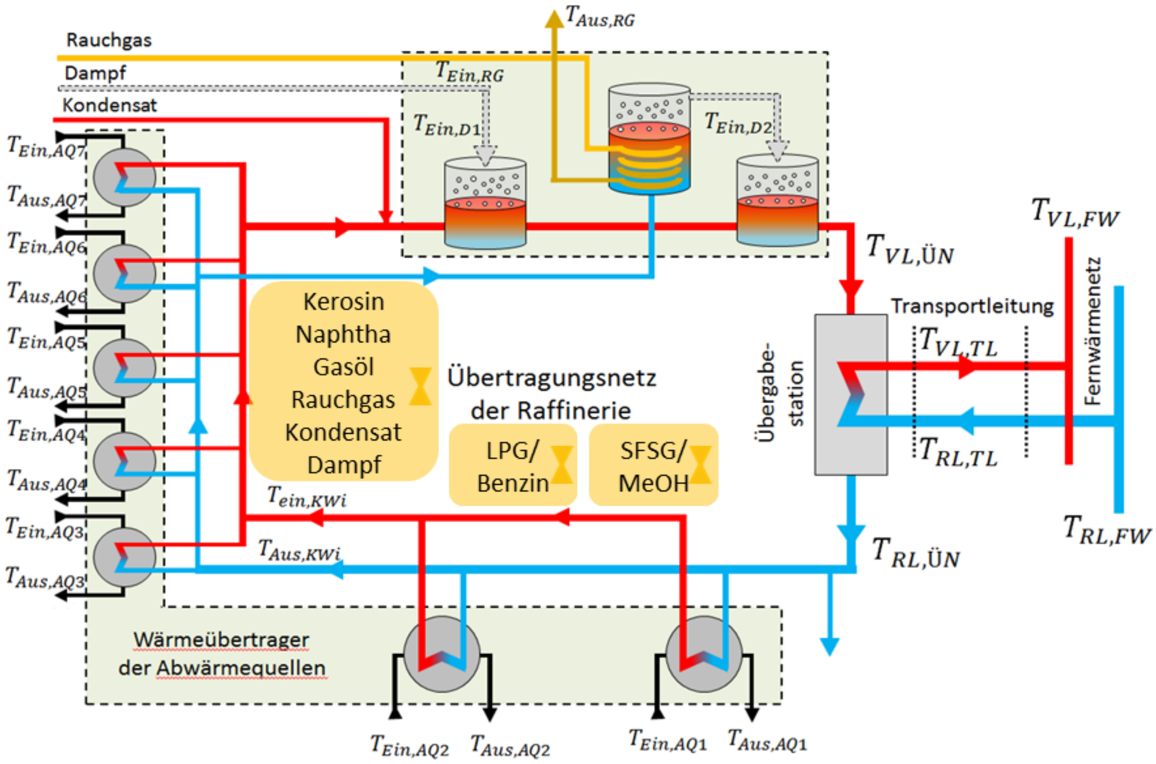

Figure 16: Sources of waste heat and integration diagram/Leipziger Stadtwerke - translation in the appendix

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In future, further sources of waste heat, e.g. from the planned **H_2 electrolysis**, a **biorefinery** or **plastic recycling plant,** will be integrated, thus ensuring that the conveying line will remain viable and suitable for third-party utilisation until 2050 and beyond.

The feasibility study completed in July of 2020 investigated connection lines between the two locations. The ideal solution proved to be a connection between the POX/methanol plant in Leuna and the heating plant in Kulkwitz. The route then predominantly passes through dirt roads of farmland by two cities, crossing river Saale, high-way A9 and the main road. The surveyors consider construction of the line to be technically possible, with the usual construction risks, and in general suitable for approval **within the scope of cross-state planning approval procedure**.

Figure 17: Possible line route from Leuna to Leipzig/GEF Ingenieure

Enlarging the trench by at least 80cm would make it technically possible to **include** a hydrogen line parallel to the district heating line, taking into account the arrangement of the supply & return flow pipes, and would make for synergies in civil engineering.

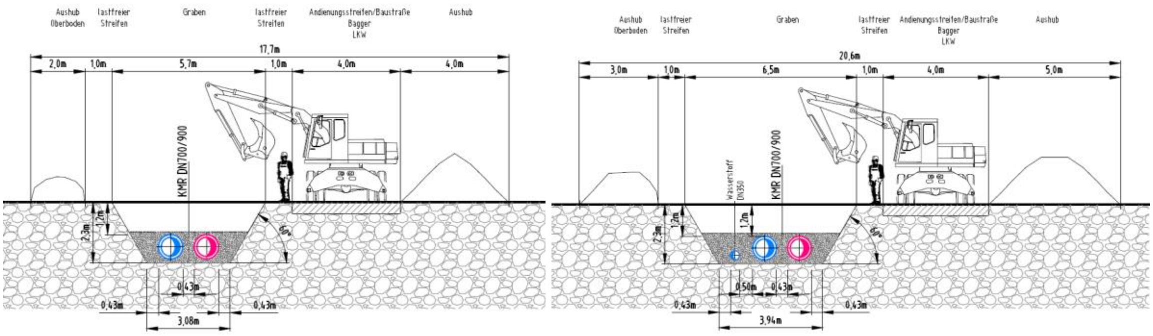

Figure 18: Possible trench profiles with & without hydrogen line/GEF Ingenieure

For technical reasons, the systems are **hydraulically separated** in Leuna. The waste heat is collected using heat exchangers, and is conveyed to the heat transfer station in Leuna within the plant premises via a local heat network. This is where the cold district heating return flow from Leipzig is heated from approximately 65°C to 125°, and delivered back to Leipzig.

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5.2 Innovation centre Alt-Lößnig with integration of inevitable waste heat from the Leipzig Süd heating plant.

In the south of Leipzig, a new combined heat and power plant with a maximum thermal output of 163 MW was commissioned at the end of the year 2022.

Despite the planning of a highly efficient plant configuration for the new CHP plant with a fuel utilisation rate of 93%, recooling of the oil cooling circuit for the lubrication of equipment is technically unavoidable and the waste heat produced cannot yet be reused in an economically sensible way. The neighbouring existing district of Alt-Lößnig could benefit from reclamation of this waste heat by transforming it into usable heat with the use of a large central heat pump.

Such a supply concept would require a grid-bound heat supply from a combination of the utilised unavoidable waste heat and district heating, with a heat quantity ratio of around 50:50. Thus, compared to the original pure gas supply (about 8GWh) of approximately 82 heat generation plants among the properties of LWB in the area, annual savings equivalent to more than 1,000 tonnes of CO_2 would be achieved.

For this purpose, a local heat network with a total line length of around 3.3 km needs to be set up in order to convey the necessary quantities of heat into the area and distribute it.

Figure 19: Residential area solution Alt-Lößnig with local heating system (yellow line) including waste heat utilisation

Further plant components are required on the heating plant premises for extraction of the waste heat in order to provide the waste heat at a usable temperature level and at the times for fulfilment of demand. Given that the waste heat from the oil recooling plant is available at a temperature of around 50°C, a large heat pump is used to increase the temperature to the

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required 80°C and thus guarantee sufficient temperature control for the residences being supplied.

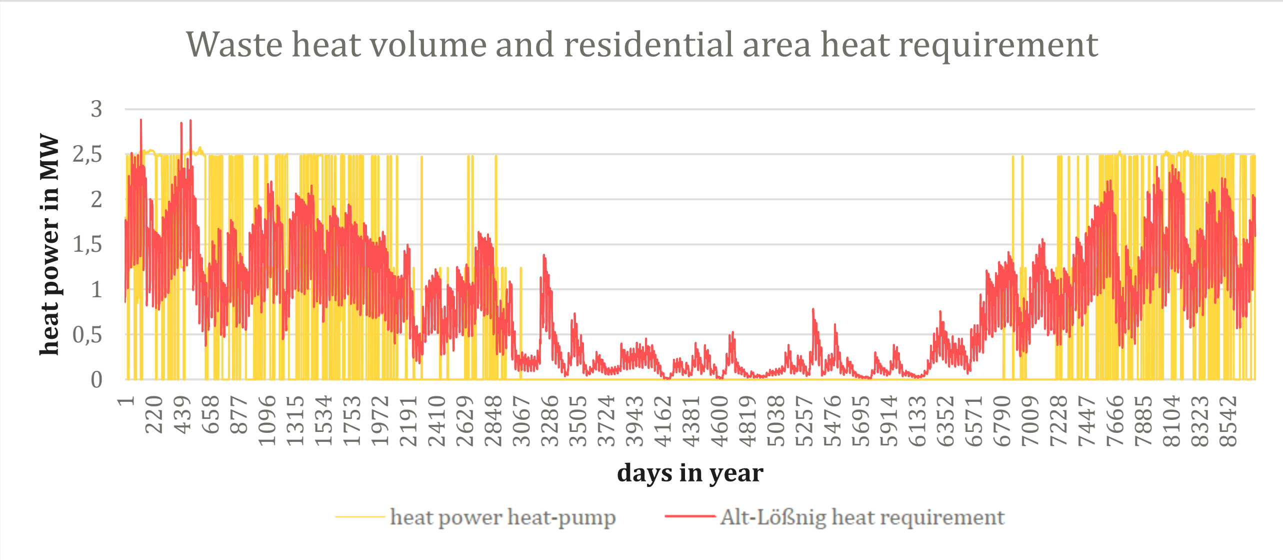

Figure 20: Illustration of the load profile of the large heat pump and heating load curve of the residential area

In addition, a heat accumulator with a heat capacity of up to 10 MWh is required in order to balance operation of the power plant and the associated waste heat production with the heat requirement loads of the residential area.

Leipzig's district heating is added to cover the residual load as it is not possible to cover the entire supply with excess waste heat.

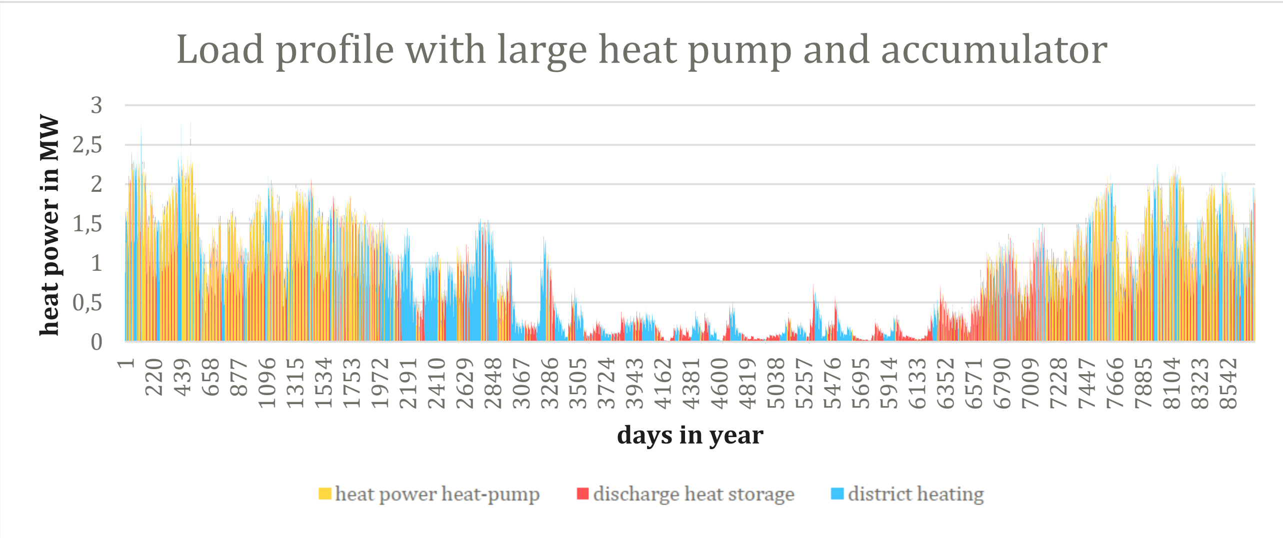

Figure 21: Intersection of waste heat potential and coverage of requirements taking into account the use of a heat accumulator and supplementing with district heating.

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The local heat network is to be completed by the end of 2024. Given that the plant technology for extraction and utilisation of waste heat will not be completed until 2025, in the interim period, the full supply will be covered by Leipzig's district heating.

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6 SOURCE REFERENCE

BDEW. (25. Mai 2020). Entwicklung des Wärmeverbrauchs in Deutschland. Berlin.

ENOVA. (2009). *Utnyttelse av spillvarme fra norsk industrienpotensialstudie.* Trondheim.

Fortum. (2014). *Bahnhof Pionen.*

GTAI. (2018). *GTAI.* Von https://www.gtai.de/GTAI/Navigation/DE/Trade/Maerkte/suche,t=stockholm-will-bis-2040-die-smarteste-stadt-der-welt-sein,did=1856888.html abgerufen

Koschinsky, S. (2018). *Neubau Rechenzentrum.* Greifswald.

Michael Papapetrou, G. K. (2018). *Industrial waste heat: Estimation of the technically available resource in the EU per industrial sector, temperature level and country.* https://www.sciencedirect.com/science/article/pii/S1359431117347919#f0015. Von https://www.sciencedirect.com/science/article/pii/S1359431117347919#f0015 abgerufen

NeRZ – Netzwerk energieeffiziente Rechenzentren. (2019). *Abwärmenutzung im Rechenzentrum.*

Stadtwerke Düsseldorf. (2022). *Von Barschen und Basilikum: Das ist Aquaponik.* Von https://www.swd-ag.de/magazin/was-ist-aquaponik/ abgerufen

Stock, A. K. (2022). *Die Gewächshäuser der Zukunft.* Von https://www.bayerische-staatszeitung.de/staatszeitung/wirtschaft/detailansicht-wirtschaft/artikel/die-gewaechshaeuser-der-zukunft.html#topPosition abgerufen

Super Micro Computer Inc. (2022). *Liquid Cooling Systems.* Von https://www.supermicro.com/en/solutions/liquid-cooling abgerufen

Ulrike Ostler. (04. Juni 2018). *Datacenter in Schweden und in Deutschland - best Practices versus Ignoranz.* Von https://www.datacenter-insider.de/datacenter-in-schweden-und-in-deutschland-best-practices-versus-ignoranz-a-718973/ abgerufen

Weis, T. (2017). *Abwärmenutzung aus Rechenzentren: Möglichkeiten – Potenziale.*

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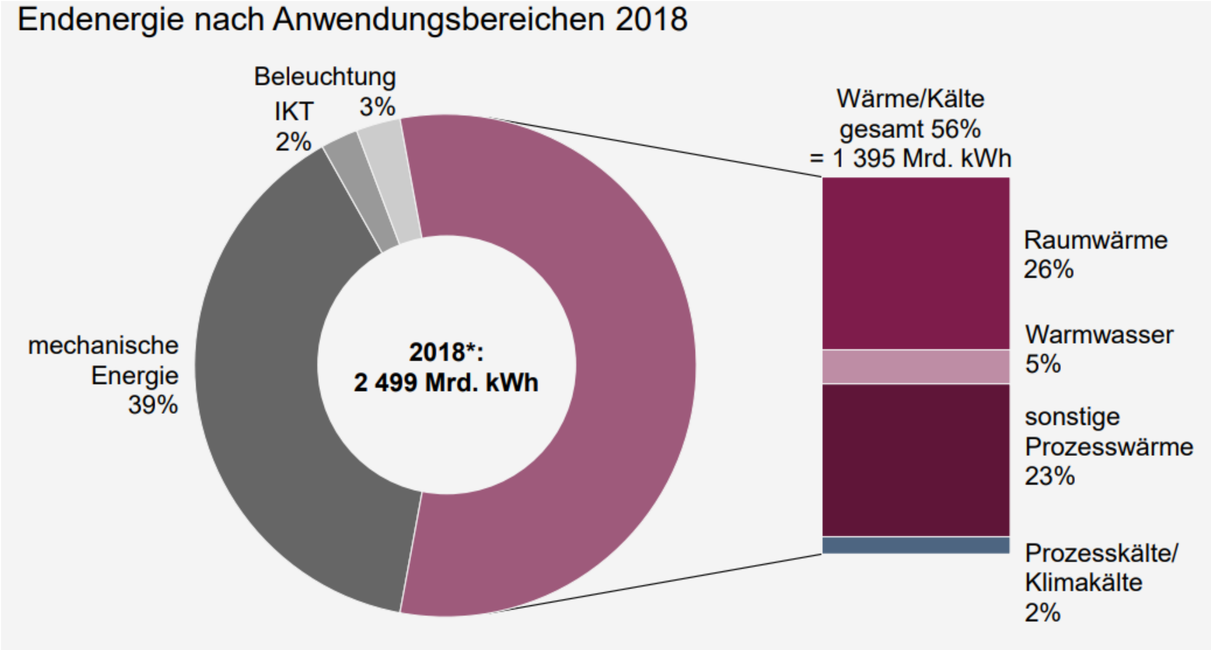
7 ANNEX – TRANSLATION OF ILLUSTRATIONS

Figure 1



Endenergie nach Anwendungsbereichen	Final energy by areas of application
Beleuchtung	Lighting
IKT	ICT
mechanische Energie	Mechanical energy
Wärme/Kälte	Heat/cold
Gesamt	Total
Mrd.	billion
Raumwärme	Room heat
Warmwasser	Hot water
sonstige Prozesswärme	Other process heat
Prozesskälte/Klimakälte	Process cold/air conditioning cold
Mrd.	kWh

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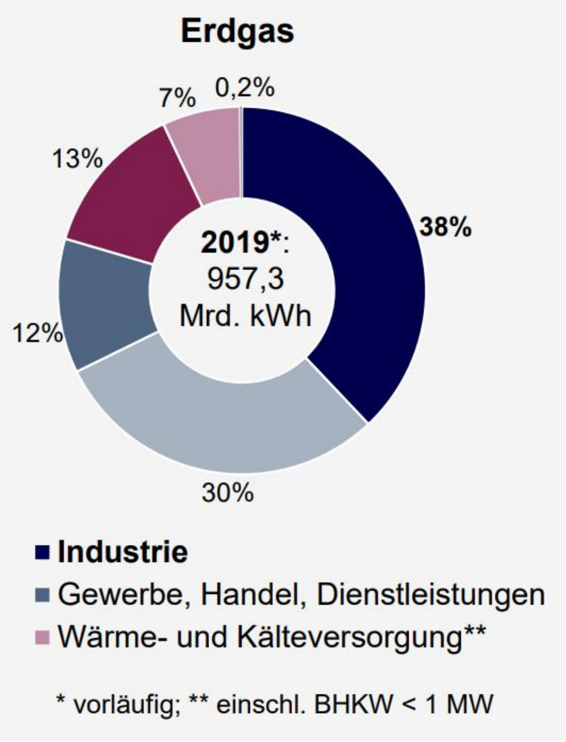
Figure 2



Erdgas	Natural gas
Mrd.	Billion
Industrie	Industry
Gewerbe, Handel, Dienstleistungen	Business, trade, services
Wärme- und Kälteversorgung**	Heat and cold supply**
*vorläufig; ** einschl. BHKW > 1 MW	*provisional; ** including CHP > 1 MW

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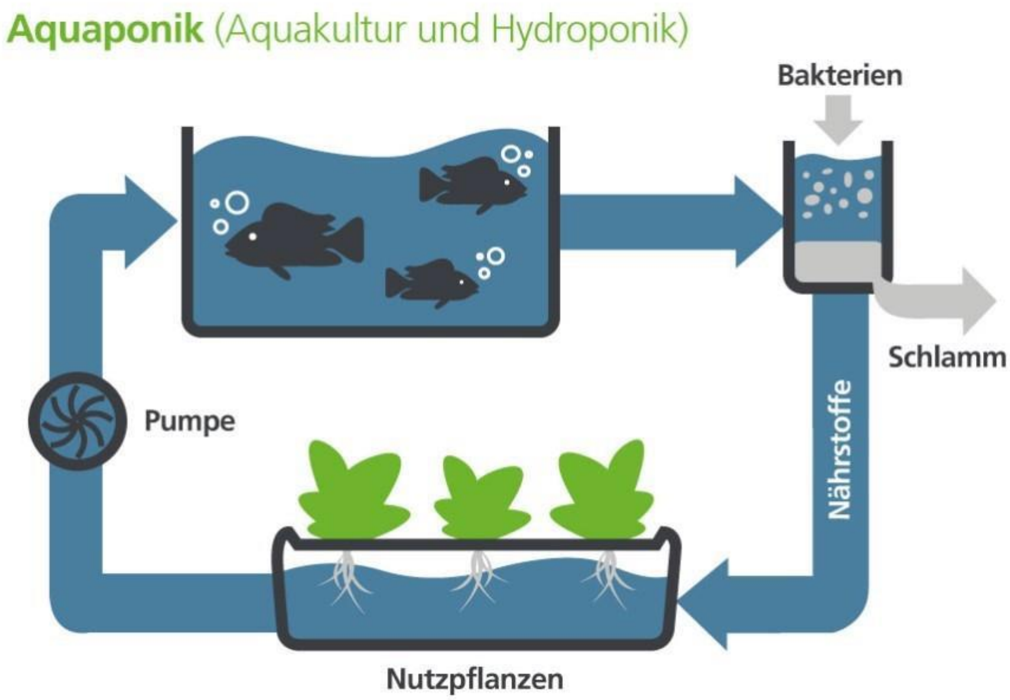
Figure 14



Aquaponik (Aquakultur und Hydroponik)	Aquaponics (aquaculture and hydroponics)
Bakterien	Bacteria
Schlamm	Slurry
Pumpe	Pump
Nutzpflanzen	Crops
Nährstoffe	Nutrients

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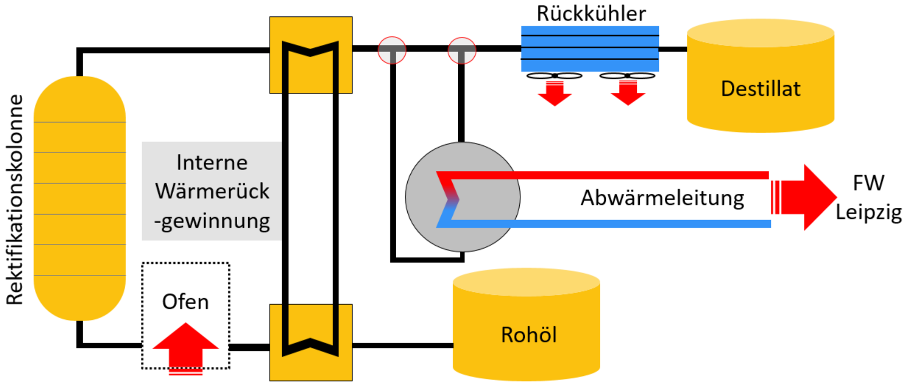
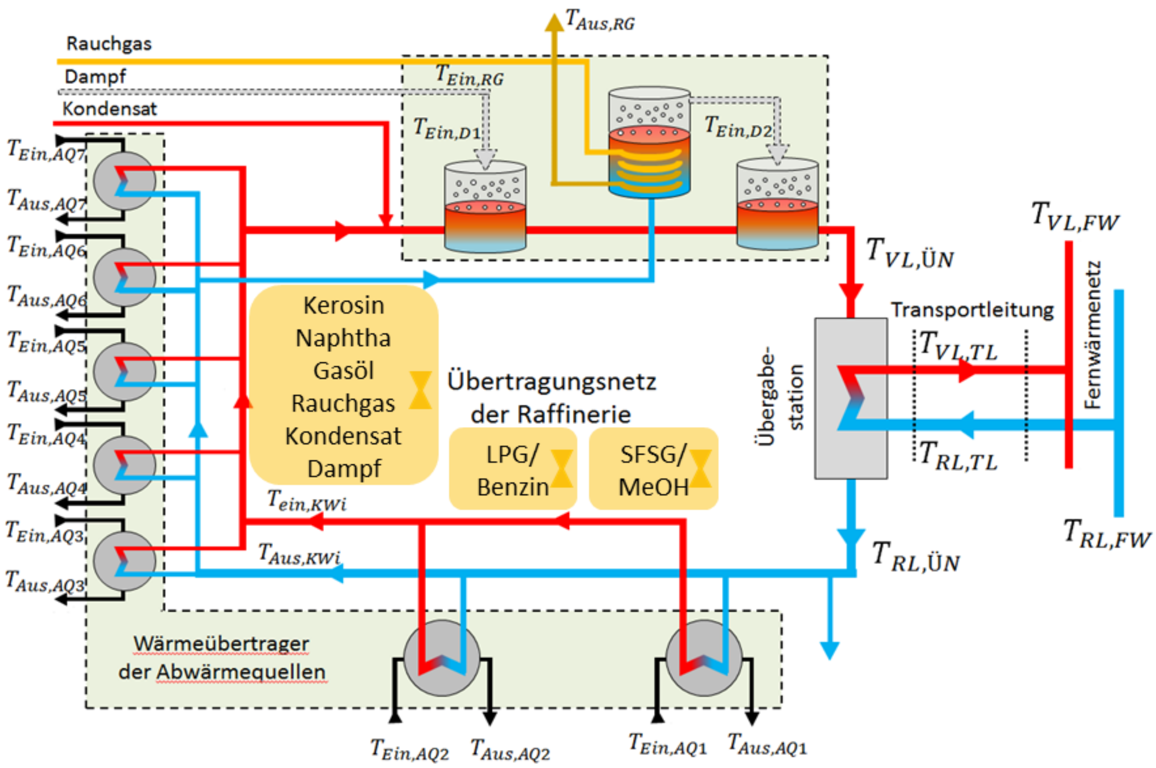
Figure 15



Rektifikationskolonne	Rectification column
Interne Wärmerückgewinnung	Internal heat reclamation
Ofen	Kiln
Rohöl	Crude oil
Abwärmeleitung	Waste heat line
FW Leipzig	Leipzig district heating
Rückkühler	Recooler
Destillat	Distillate

Figure 16



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Rauchgas	Flue gas
Dampf	Steam
Kondensat	Condensation
TAus,RG	TOut,FG
TEin,RG	TIn,FG
TEin,D2	TIn,D2
TEin,D1	TIn,D1
TEin,AQ	TIn,AQ
TAus,AQ	TOut,AQ
Wärmeüberträger der Abwärmequellen	Heat exchanger for sources of waste heat
TEin,KWi	TIn,KWi
TAus,KWi	TOut,KWi
Kerosin	Kerosene
Naphtha	Naphtha
Gasöl	Gasoil
Rauchgas	Flue gas
Kondensat	Condensation
Dampf	Steam
Übertragungsnetz der Raffinerie	Transmission network of refinery
LPG/Benzin	LPG/petrol
SFSG/MeOH	SFSG/MeOH
Übergabestation	Transfer station
TVL,ÜN	TVL,TrN
TVL,FW	TVL,DH
Transportleitung	Conveyor pipeline
TVL,TL	TVL,TL
TRL,TL	TRL,TL
TRL,ÜN	TRL,TrN
TRL,FW	TRL,DH
Fernwärmenetz	District heating network

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