Utilization of Waste Heat in the Data Center

A white paper by NeRZ in collaboration with eco – Association of the Internet Industry

Authors:

Tobias Funke

Dr. Ralph Hintemann

Prof. Dr.-Ing. Christoph Kaup

Christoph Maier

Steffen Müller

Sören Paulussen

Dr. Jürgen Süss

Ulrich Terrahe

NeRZ
Netzwerk energieeffiziente Rechenzentren

DIGITALE INFRASTRUKTUREN
WIR SIND DAS INTERNET

eco
ASSOCIATION OF THE INTERNET INDUSTRY
WE ARE SHAPING THE INTERNET.
YESTERDAY. TODAY. BEYOND TOMORROW.


SERVERWORLD
SERVERWORLD
FRISCH GEMÜSE
WE'RE USING THE WASTE HEAT FROM OUR DATA CENTER

Content

Dr. Béla Waldhauser
Spokesperson for the Alliance for the Strengthening of Digital Infrastructures in Germany

1. Foreword

Dear Readers,

The general public is slowly becoming aware of how important digital infrastructure has become for our private and professional lives. Not a day goes by without just about all of us sending an email, using an app, or simply using a variety of social media. Keywords and key phrases such as Cloud, Internet of Things (IoT), Smart Home, Smart City, Smart Factory, and Industry 4.0 are on (almost) everyone's lips. Not to forget the new mobile standard 5G – which is just around the corner – but also autonomous driving, which will certainly gain traction in the coming decade.

All of this requires large and reliable bandwidths, powerful Internet hubs such as DE-CIX, and of course data centers of all sizes. Data centers in particular have recently suffered criticism for consuming large amounts of energy. This is justified on the one hand, because the electricity consumption of data centers in Germany is now over 13 terawatt hours (TWh) per year. It is important to note, however, that the large data centers in particular are very energy-efficient and now only require a fraction of the electricity consumed for cooling, for example. The other side to this is that the demand of the German population for digital applications is so great and increasing so steadily that the energy consumption for digital applications will continue to rise significantly.

Now, we data center operators have been committed to sustainability for a long time, and not just since the Fridays for Future demonstrations. As those responsible for a large number of data centers in Germany, we want to meet the immensely high demand for digital infrastructure on the one hand, and make it as environmentally friendly as possible on the other. Therefore, in our data centers, we ensure consistent separation of cold and hot aisles, for example. The temperatures in a modern data center today have nothing to do with the "refrigerators" of the past. And we use the latest technologies to make our services as energy-efficient as possible.

Nevertheless, there is potential for improvement, which in Germany currently lies more or less untapped; namely, making use of the waste heat from our data centers. When we compare Germany with Sweden, for example, we can learn a lot from our Scandinavian colleagues. In contrast to Germany, the use of waste heat there is an integral part of energy policy concepts and is supported by a broad majority of the population.

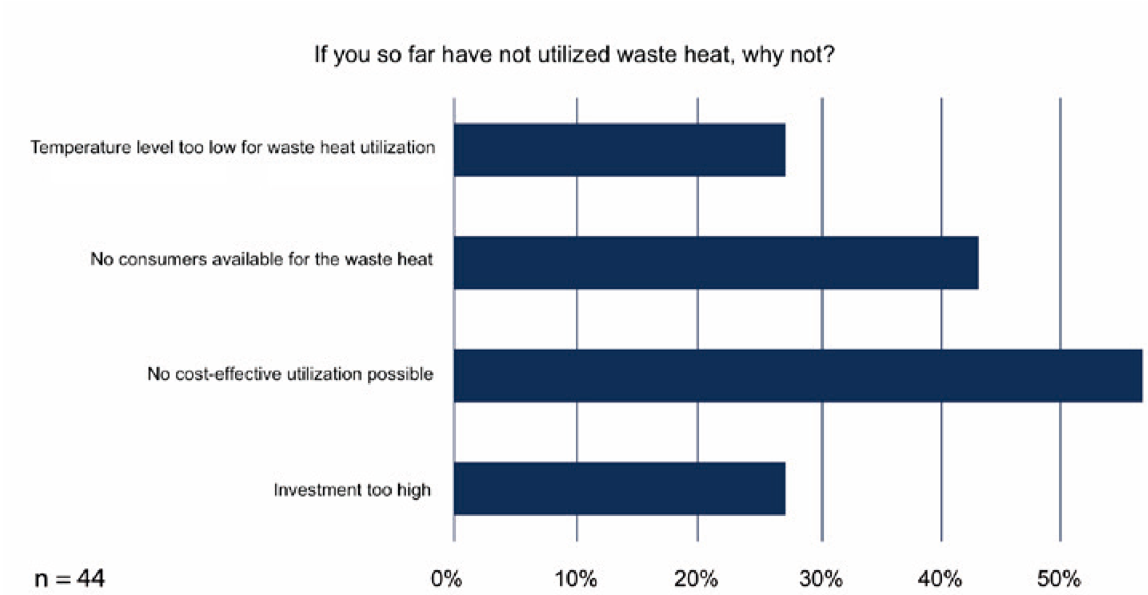
The following white paper is intended to help ensure that the utilization of waste heat also becomes socially acceptable in Germany and is implemented whenever possible. Unfortunately, there are still only a handful of flagship projects in our federal republic. I am therefore pleased about each and every willing reader of this white paper, who subsequently gives thought to where the existing concepts of waste heat utilization can be implemented.

I wish you an enjoyable and insightful read!

Dr. Béla Waldhauser
Spokesperson for the Alliance for the Strengthening
of Digital Infrastructures in Germany

Fig. 1

Reasons why waste heat is not used in data centers
Source: NeRZ - Survey of data center operators 2017



2. Introduction

Industry 4.0, autonomous driving, artificial intelligence, social networking, video streaming – more and more and increasingly powerful applications require more and more computing power in data centers. The demands are growing to such an extent that, despite significant advances in the energy efficiency of information technology and data center infrastructure, the power requirements of data centers are increasing continuously. In 2017, data centers in Germany needed 13.2 billion kilowatt hours (kWh) of electricity. This corresponds roughly to the total electricity needs of a city the size of Berlin. And in the data centers, this electricity is converted into heat which is almost always released unused into the environment.

If climate protection is to be taken seriously, waste heat from data centers should be utilized sensibly. Many national and international examples already demonstrate that this is possible. There are a wide variety of possible uses for waste heat from data centers. They range from the use of waste heat for adjacent office buildings, to the connection of data centers to local and district heating networks, through to its use for greenhouses and "vertical farming".

Many data center operators have already recognized the future significance of waste heat utilization for data center operations. In a NeRZ survey, 50% of data center operators in Germany stated that they see medium to very high savings potential through the utilization of waste heat (Hintemann, 2017). In data centers, IT is usually cooled with air. As a rule, the heat is then transferred to a water system using circulating-air cooling units equipped with cold water registers, and transported away. Typically, this results in cold water return temperatures of 18 to 30 °C. The waste heat can already be utilized at this temperature level, as the examples in this white paper show. If a higher temperature level is reached – for example, through liquid cooling of the IT components – the possibilities of using the hot water increase significantly. A heat pump can also be used to raise the temperature level. However, here – especially in Germany – the cost of the electricity required to operate the heat pump significantly reduces the cost-effectiveness of waste heat utilization. No wonder, then, that more than half of those surveyed in the NeRZ survey cited the lack of cost-effectiveness as the reason why no waste heat has been utilized to date. Slightly more than 40% did not see any suitable consumers for the heat (Figure 1). This white paper is intended to present possibilities for utilizing waste heat from data centers in Germany cost-efficiently. This is intended to help overcome the challenges currently faced by data center operators.

In what contexts cost-effective utilization of the waste heat from a data center is possible, and which consumers are worth considering for the waste heat, naturally depends in each individual case on the specific underlying conditions and the technology employed for the waste heat utilization. This white paper presents various ways of utilizing waste heat from data centers, outlines innovative technological approaches, and discusses the opportunities and challenges. The possibilities for utilizing waste heat from data centers are first presented in Chapter 3. Chapter 4 deals with the possibilities of using a heat pump. Chapter 5 then presents innovative technological approaches to waste heat extraction from data centers. This white paper closes with a short summary and a conclusion in Chapter 6.

A few facts about waste heat utilization

- *More than 13 billion kWh of electricity are currently being converted into heat in the data centers in Germany, which is released unused into the environment.*
- *Many facilities require heat all year round, such as swimming pools, laundries, and greenhouses. The heat requirement for hot water generation in Germany alone was over 120 billion kWh in 2015.*
- *More than 50% of the data center operators surveyed by NeRZ see high potential for the future through the utilization of waste heat. Over 30% of respondents already make use of waste heat.*
- *Currently, the high electricity prices in Germany are still a challenge for the cost-effectiveness of heat pumps for waste heat recovery from data centers.*

3. Possible uses for waste heat from data centers

3.1 District and local heating

An obvious option for utilizing waste heat from data centers is to feed the heat into existing or newly-installed local and district heating networks. The distinction between local and district heating networks refers to the spatial dimensions of the networks. While local heating networks are mostly installed within smaller residential or commercial areas, district heating networks usually span entire cities and even conurbations such as the Ruhr Region. In addition, local heat usually works at a slightly lower water temperature. The temperature in district heating networks is usually between 80 and 130°C. The boundary between local and district heating is fluid.

In Sweden in particular, waste heat from data centers is already being utilized intensively, through being fed into district heating networks. There are already 30 data centers that feed in their waste heat. Examples include Ericsson, H&M, Interxion, Bahnhof, and Digiplex. The district heating network in Stockholm spans approx. 2,800 kilometers. 10,000 households are already connected, 95 percent of them in the heart of Stockholm (Ostler, 2018). In the future, the network is to be significantly expanded. By 2035, the waste heat from data centers is expected to meet one tenth of the metropolis' heating requirements (GTAI, 2018).

Currently, a colocation data center with a maximum power consumption of 21 megawatts (MW) is being built in Stockholm. At this data center, district heating pipes direct the waste heat to the Värtaverket biomass cogeneration plant, after the temperature level has been raised by means of heat pumps. There, the temperature of the waste heat is raised to the level of the district heating network. In this way, all the waste heat from the data center can be recovered and fed into the district heating network of the city of Stockholm. The approx. 112 million kWh of heat energy harnessed in this way corresponds to the heating requirements of a small city of around 20,000 inhabitants (Ostler, 2016).

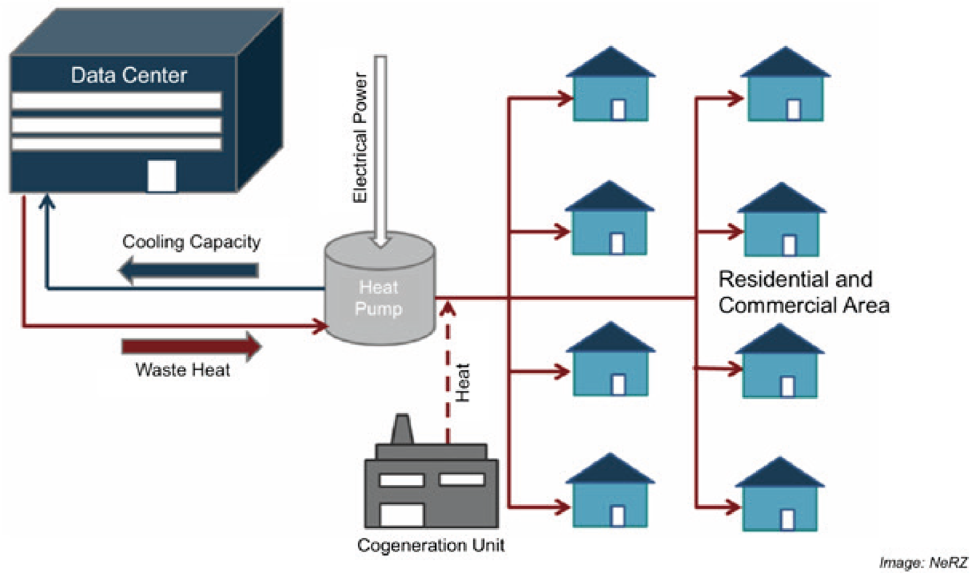
A similar approach is taken in a concept developed by the Technical University of Darmstadt, which won the German Data Center Award in 2017 with its project "Data centers as a building block for energy transition at the neighborhood level". In the project, a coupling of the university's own heat network with the waste heat of a high-performance computer with return temperatures of 60°C is planned. A heat pump is used to provide 70°C hot water for the heating network (Weis, 2017).

In Braunschweig, VW Financial Services commissioned a data center in 2018 whose waste heat is used for an adjacent residential and commercial area (Stachura, 2018). Figure 2 shows the principle of how waste heat utilization from data centers can be built up in a local heating network. In the case shown, the residential area is supplied with heat on the one hand by the waste heat from the data center, and on the other hand by a cogeneration plant. The waste heat from the data center is brought to the required temperature level for the local heating network with the aid of a heat pump. At the same time, the heat pump serves as a cooling unit for the data center.

The University of Greifswald is also currently planning a data center with waste heat recovery. This data center is scheduled for completion in 2019. The waste heat from the data center will be used for a new seminar and administration building, and a local heating system pipe will also supply heat to a neighboring research building (Koschinsky, 2018).

Fig. 2

Basic structure of a local heating network with integration of a data center and a cogeneration unit



The utilization of waste heat in local and district heating networks poses a number of challenges. District heating networks in particular are typically planned and implemented over very long time-scales. If no suitable district heating network is available in the immediate vicinity, then the connection of data centers is usually out of the question in the short term. This requires forward-looking planning for the future expansion of local and district heating networks and the location of new data centers. Here, too, the example of Sweden illustrates a possible approach. There, what are known as data parks are being established. Data center operators are able to build their data centers within these parks. In the data parks, not only is the secure and redundant power supply of the data centers and the connection to the dark fiber network guaranteed; it is also ensured that the data centers can feed their waste heat into the district heating network.

3.2 Utilization of waste heat from data centers in neighborhood facilities

If it is not possible to feed the waste heat from the data center into a local or district heating network, it may be possible to use the waste heat from the data center in facilities in the neighborhood. These include, for example, objects that require permanent heat, such as swimming pools, laundries, and greenhouses. Here, too, the challenge is to provide the heat output at a usable temperature level. In addition, the question of the bilateral design of the heating supply contract must be clarified.

In the Swiss municipality of Uitikon, the waste heat from the data center of an IT service provider is used to heat the local swimming pool. With the help of a heat exchanger, heated water is produced and pumped into the nearby swimming pool. The Uitikon community is supplied with the heat free of charge. However, it had previously assumed a portion of the connection costs. At full capacity, the data center generates around 2,800 megawatt hours (MWh) of waste heat per year (IDG, 2008).

An interesting possibility for the utilization of waste heat, especially for the future, is offered by greenhouses. Vertical farming in particular offers good opportunities for this. Vertical farming refers to an urban form of agriculture in which the production of plant and animal products takes place within the city in multi-storey buildings. In the building complexes, fruit, vegetables, and algae are cultivated all year round on several vertically stacked layers. Vertical farming enables much higher yields for the same area than conventional agriculture, and enables local food supply in conurbations. Vertical farming also offers economic advantages over traditional farming: Uniform harvests are achieved through controlled environmental conditions. In addition, the plants grow faster due to the effective supply of nutrients.

One variant of vertical farming is aquaponics. Aquaponics combines fish farming with plant cultivation. The fish are kept inside in large tanks, and their excrement serves as nutrient-rich fertilizer for the plants.

Fig. 3 **Examples of vertical farming**

Photos: Wikipedia, CCBY-SA3.0, CCBY-SA2.0

The combination of vertical farming with waste heat recovery from data centers offers a number of advantages. The waste heat from data centers is well suited for the temperature ranges required in vertical farming and aquaponics. Vertical farming requires heat throughout the year. Spatially, a combination of data center space with buildings for vertical farming is readily feasible.

Vertical farming also requires adequate ventilation, i.e. regular replacement of air to remove unwanted substances and maintain good air quality. If the systems are suitably designed, synergy effects with the systems of the data centers can be achieved here. Vertical farming itself also requires more and more computing power. More and more IT systems are being used to maximize yield, minimize risk, and increase efficiency. A connection of vertical farming systems with data centers is therefore also worthwhile from this perspective.

3.3 Direct utilization in own building

Good conditions are also offered within the data center and the adjacent buildings for utilizing waste heat, for example with the aid of a water/water heat pump. Even today, the waste heat from data centers is very often used to heat the break rooms in the building. However, the amount of heat required for this is usually much less than the waste heat generated in the data center; with such a solution, often only 1% of the waste heat can be utilized (Weis, 2017). Nevertheless, this solution helps at least to operate the heating in the data center building in a very environmentally friendly way.

Significantly higher utilization rates of waste heat in company-own buildings can be achieved by data center operators who, in addition to data centers, operate other properties such as office complexes or production facilities. Aside from large cloud and colocation providers, many operators have their data centers embedded in large properties of this nature. Depending on the specific framework conditions, it is often possible in these cases to utilize large quantities of the waste heat available.

One practical example of the utilization of waste heat in adjacent properties is provided by the former European Central Bank in Frankfurt. In the Eurotheum high-rise building, up to 90 percent of the waste heat from the data center installed in the building is utilized. The heat is discharged directly at the servers via a warm water liquid cooling system. The water, with a temperature of up to 60°C, is fed into the heating circuit of the Eurotheum. When fully expanded, the servers will produce up to 300 kW of waste heat on each of the two floors, which can be used to heat the resident offices, conference rooms, hotels, and restaurants. By using the warm water liquid cooling system for the servers and the associated usable high temperatures, an additional heat pump can be dispensed with, so that no additional electricity needs to be used for waste heat utilization. The annual costs for heating energy in the high-rise can thus be reduced by up to 65,000 Euro. In addition, an additional 95,000 Euro per year in cooling costs for the data center can be saved compared to conventional air cooling (Digitales Hessen, 2018; Ladner, 2017; Ostler, 2017).

Fig. 4

Conventionally cooled compact data center

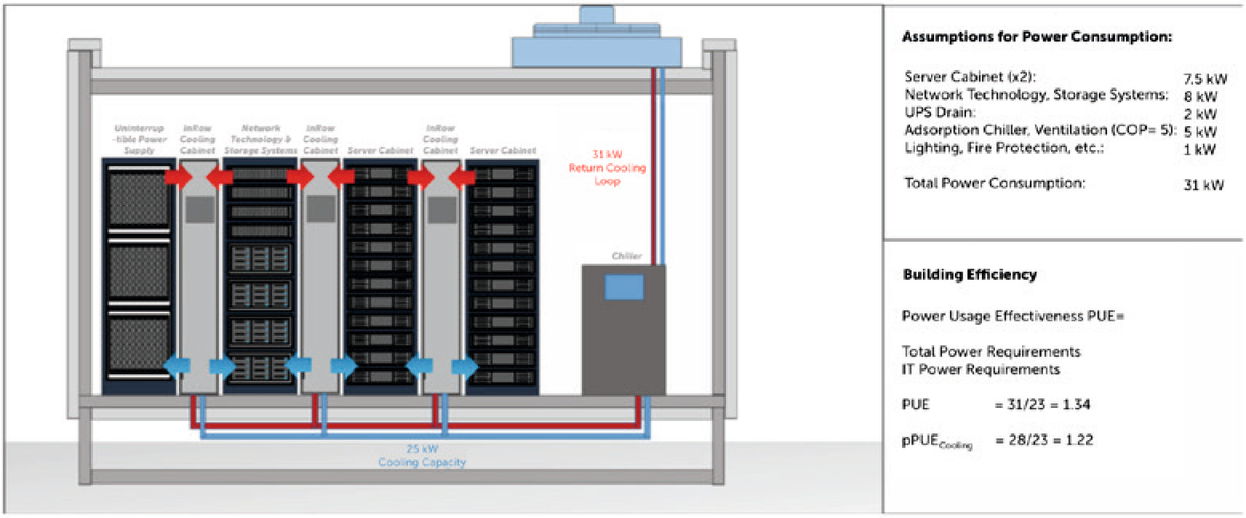


Image: NeRZ

3.4 Potential for refrigeration from waste heat

Heat can also be used to produce cold. Adsorption and absorption chillers are particularly suitable for this purpose. The use of such sorption chillers has many advantages. In particular, this allows refrigeration to be achieved without the use of ecologically harmful F-gases. While absorption chillers are usually operated in power classes greater than 200 kW and require a heat level of 75°C and more for operation, adsorption chillers are also suitable for small outputs of 10 kW and above, and already operate from as low as approx. 55°C.

In combination with the waste heat from data centers, there are a number of advantages. In this way, the heat generated in the data center can be used directly – and especially in summer – to cool other components inside or outside the data center. This allows the waste heat to be used all year round. Such a solution is particularly suitable if the IT systems are water-cooled and if water is thus available at a temperature of 60°C and higher. A corresponding concept is currently being developed and demonstrated within the framework of the research and implementation project HotFlAd ("Waste heat utilization from compact data centers with hot fluid adsorption refrigeration system"), funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) (Borderstep Institute, 2019). In the following, the savings potentials of the planned solution are illustrated on the basis of graphs. Figure 4 shows an efficient data center with traditional technology. In this data center, the necessary cooling is generated by a conventional refrigeration unit. The data center has a very good PUE value of 1.34. The cooling supply requires 5 kW of electricity. The partial PUE value for cooling alone is 1.22. This means that, on average, the data center requires annually 22% of the energy required by IT, in order to cool the IT.

Figure 5 shows a solution for how the waste heat from the servers within the data center can be used to cool other components such as network technology and uninterruptible power supply (UPS), using the HotFlAd concept. In this case, the data center would have a PUE value of 1.15. The partial PUE value of the cooling would be 1.02. Only 500 watts of electricity would be required for the cooling, which corresponds to one tenth of the electricity required for cooling a conventional data center.

In some cases, the cooling generated by the adsorption process will be significantly greater than that required in the data center itself. Figure 6 therefore demonstrates how the waste heat from the data center can be utilized for cooling adjacent buildings. The PUE value achieved is 1.17. 1 kW is required for the cooling supply. The partial PUE value of the cooling is 1.03. In winter, it is also possible to use the waste heat from the servers to supply the adjacent buildings with heating energy and hot water.

As the calculations show, the HotFlAd concept achieves efficiencies that today only seem possible in very large and optimized data centers. In addition, it is possible to use the waste heat in the form of cooling supply or in the form of heat for adjacent buildings (or parts of buildings). Especially with regard to the current development of EDGE data centers and 5G mobile applications, the use of waste heat in compact data centers is essential for sustainability.

Fig. 5 Compact data center with HotFlAd concept and internal utilization of cooling

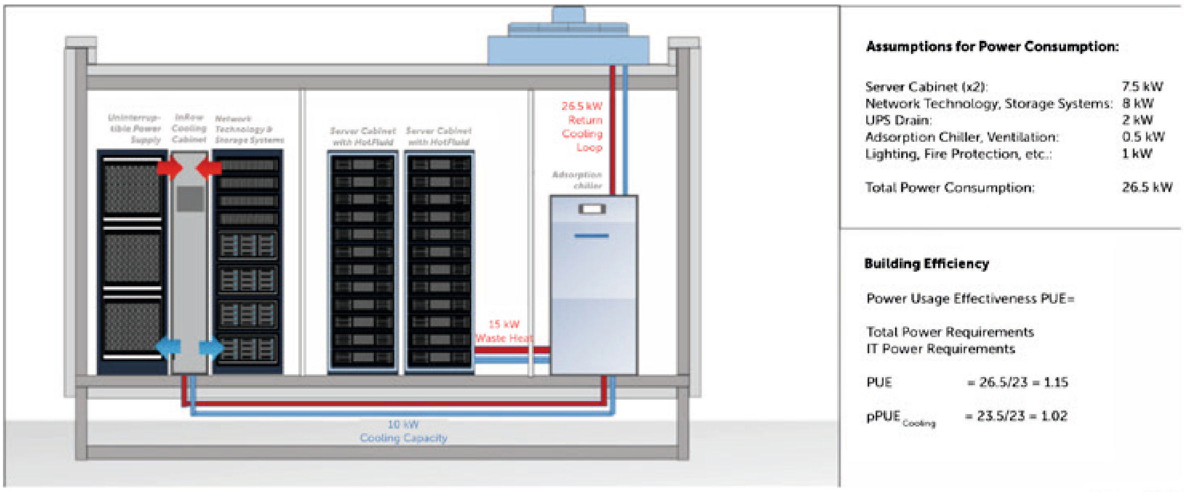


Image: NeRZ

Fig. 6 Compact data center with HotFlAd concept and external utilization of cooling

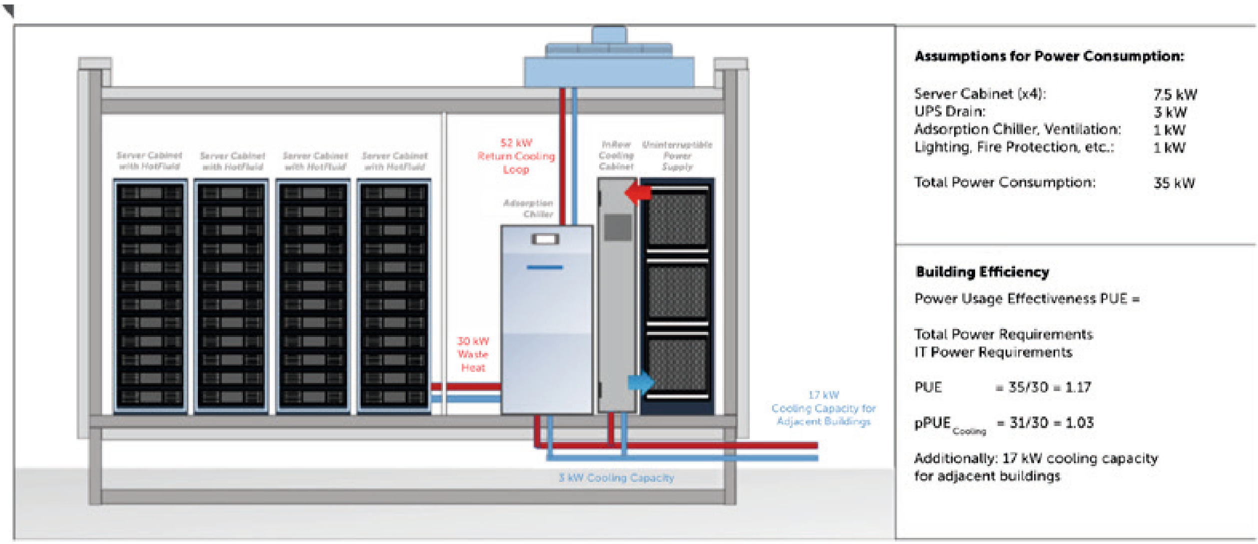


Image: NeRZ

4. Use of heat pumps

For many applications, the waste heat temperature level of between 30 and 40°C often reached in data centers is not sufficient. In these cases, it is advisable to increase the temperature with the aid of a heat pump.

A heat pump uses a technical process to absorb thermal energy from lower temperature sources and transfer it together with the operating energy to a higher temperature system so that the heat can be used for other applications, such as heating rooms. With the help of a heat pump, the waste heat of a data center can be brought to a level of 60°C and higher. Multi-stage heat pumps are also possible, with which a significantly higher temperature level of 150°C or even higher can be achieved.

Whether the use of a heat pump makes economic sense for the utilization of waste heat depends in particular on how expensive it is to operate the heat pump technically. In most cases, this technical process makes use of electricity. Electricity prices are therefore decisive for cost-effectiveness. As a result of the EEG (renewable energy) levy, electricity prices in Germany are so high that the cost-effectiveness of waste heat utilization must be examined on a case-by-case basis.

The practical examples already presented in this white paper show that the use of heat pumps can be worthwhile, even under the conditions that exist in Germany. Another example is the utilization of waste heat from the Hamburg headquarters of Vattenfall Europe AG. Here, the waste heat from the server rooms is used in conjunction with a turbo heat pump to heat approx. 50,000 m² of office space. This saves around 600 tonnes of CO2 every year (Fricke, 2016).

Generally speaking: Assuming a realistic sales price for heat in Germany of 40 Euro/MWh, the costs for operating the heat pump per MWh must be less than 40 Euro for pure waste heat utilization to be cost-effective. With an electricity price of 15 cents/kWh, this means that, with 1 kWh of electricity, the heat pump would have to provide at least 3.75 kWh of heat that could be sold for 4 cents/kWh (equivalent to 40 Euro/MWh). In Germany, the electricity prices mean that the cost-effective operation of heat pumps is ambitious, and in many cases the net result is zero. However, if further advantages of waste heat utilization are taken into account, such as energy savings for cooling or non-monetary effects such as improving the company image, waste heat utilization by means of heat pumps can also be worthwhile in Germany. Irrespective of this, it would be sensible and appropriate from the point of view of environmental policy to abolish the EEG levy on electricity for the operation of heat pumps (Weis, 2017).

Fig. 7 **Closed loop system with dehumidification circuit and chiller waste heat**

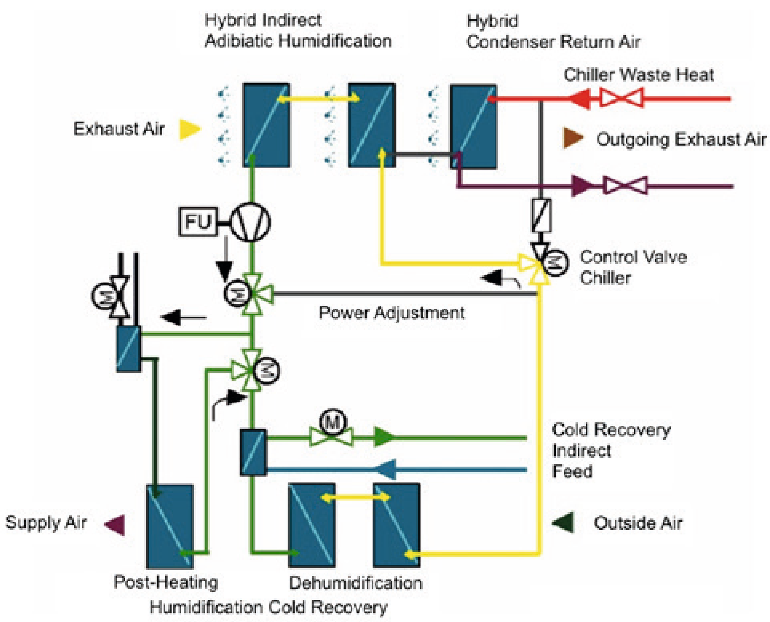


Image: Howatherm

5. Innovative technical approaches to waste heat utilization

5.1 Multifunctional high-performance heat recovery systems

The efficient and effective extraction of heat is an essential requirement for utilizing waste heat from data centers. A very interesting and promising technological approach is the use of closed loop systems. This is briefly presented in the following.

With the closed loop system, a heat exchanger is installed in both the hot and cold air streams. These heat exchangers are connected via pipelines and filled with a heat transfer medium (brine). The warm air from the data center transfers heat to the brine, a pump transports it to the other heat exchanger, where the energy is transferred to the cold outside air.

Closed loop systems have been established for a long time, and have been used very frequently as heat recovery systems with low transfer rates in ventilation and air-conditioning technology. With the appropriate design, closed loop systems can also be used cost-effectively as high-performance systems with a system transfer rate of up to 80%.

The liquid solution (brine) of a high-capacity closed loop system can be used to feed heat or cold into, or extract it out of, the system. The fact that, in such a case, no additional air heat exchanger is necessary increases the cost-efficiency considerably, since on the one hand the investment costs can be reduced and on the other hand the operating costs, caused by pressure losses, can be reduced.

In addition to the input or output of heat, closed loop systems also offer a number of other advantages. In particular, the following extended functions are possible:

- **Indirect or direct post-cooling:** A plate heat exchanger can be used, for example, to feed chilled water into the system (intermediate heat exchanger).

- **Dehumidification:** The closed loop system can also be used to dehumidify the air. For this purpose, cold water is fed into the system between the second and third registers (in air-flow direction). This can be done directly or indirectly. The brine in the intermediate circuit is cooled before entering the second stage so that the air is dehumidified in the two following stages (see Figure 7). This supercooled air is then guided through the third register, seen in air-flow direction. A heat exchange inevitably takes place in the third register, which pre-cools the brine before the chilled water is fed in, and simultaneously heats the air. This pre-cooled brine in turn significantly reduces the cooling capacity to be fed in, and post-heating can be realized without additional primary energy expenditure (dehumidification cold recovery).

Fig. 8

Closed loop system with waste heat extraction (e.g. domestic hot water preheating)

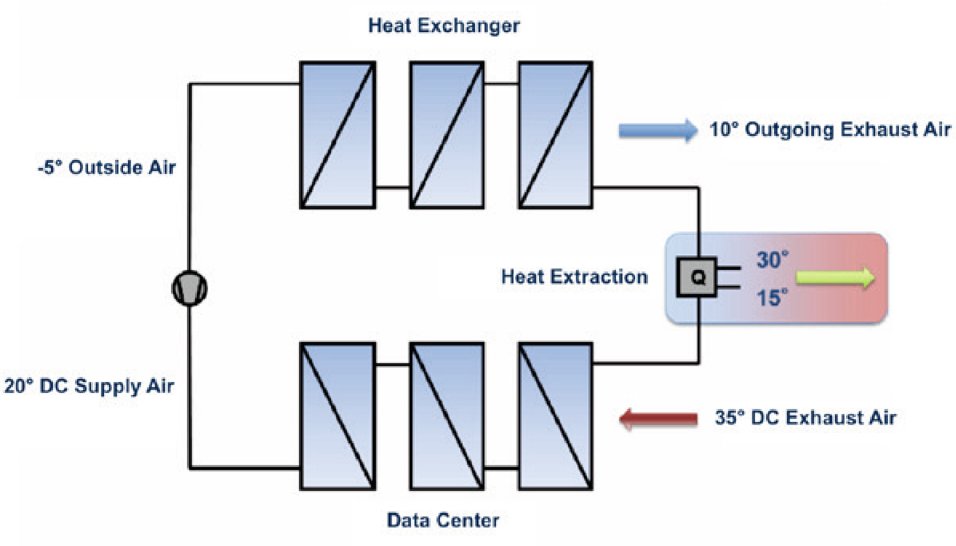


Image: Howatherm

- **Refrigeration unit waste heat:** The waste heat of a potentially necessary refrigeration unit can be discharged into the exhaust air flow via the last register (according to air-flow direction) of the heat exchanger, achieving an energy advantage. For this purpose, the last register from the heat recovery process is decoupled and made available to the chiller cold recovery (see Figure 7), or the chiller waste heat is fed into the return flow via a plate heat exchanger.

- **Waste heat extraction:** Here, more heat can be extracted from the process air flow. In this case, using a plate heat exchanger can extract heat from the liquid solution, e.g. for preheating service water (see Figure 8). The use of waste heat also significantly improves the transfer rate of heat recovery. This waste heat can also be used to heat the supply air of a ventilation system.

With this technique, initial flow temperatures of up to 33°C can be achieved in the data center. If this temperature level is not sufficient, it can be increased through the use of a heat pump. This requires additional energy, which reduces the cost-effectiveness of the overall system.

- **Multi-stage adiabatic evaporation systems:** Adiabatic indirect evaporative cooling has also proven its worth in data centers. The evaporative cooling generated by an adiabatic humidifier is transferred to the process air side via a heat recovery system. The breakdown of the overall system into several stages results in a complex hybrid system. The advantage of the multi-stage system lies in the higher cooling capacity compared to a single-stage system, which results from the fact that the air temperature is lowered again in the subsequent stages, and thus the mean temperature is lower than in a single-stage system. The cooling capacity can be increased by about 25% with this method, without increasing the pressure losses of the system, as the fins – which are required anyway – not only serve for heat transfer, but are also used as an evaporation surface (mass transfer), with the end result called a hybrid system (see Figure 9).

  Hybrid systems reduce electrical energy costs, since the pressure losses of the humidifiers (multi-stage) are eliminated and mechanical refrigeration can be used much later.

  In summer operation, at 32°C outside air temperature, a supply air temperature of approx. 22°C is achieved.

Especially efficient closed loop systems have heat exchangers with high temperature transfer rates of more than 75%. In addition, evaporative cooling can be improved by post-evaporation. This can be achieved by increasing the hydrophilicity of the surface through the use of a special additive. The additive is only used when additional evaporation is required due to the requirement for a higher cooling capacity. The additive is added in a controlled manner, whereby the required supply air temperature is regulated by the concentration of the additive. As a result, the need for the additive is kept to a minimum.

Due to the greater post-evaporation effect of the humidification water, a degree of humidification is achieved which corresponds to the equivalent degree of humidification of a separate single-stage humidifier of over 100%. The special process also allows the post-evaporation to be adjusted with infinite variability.

Fig. 9

Multi-stage indirect evaporative cooling

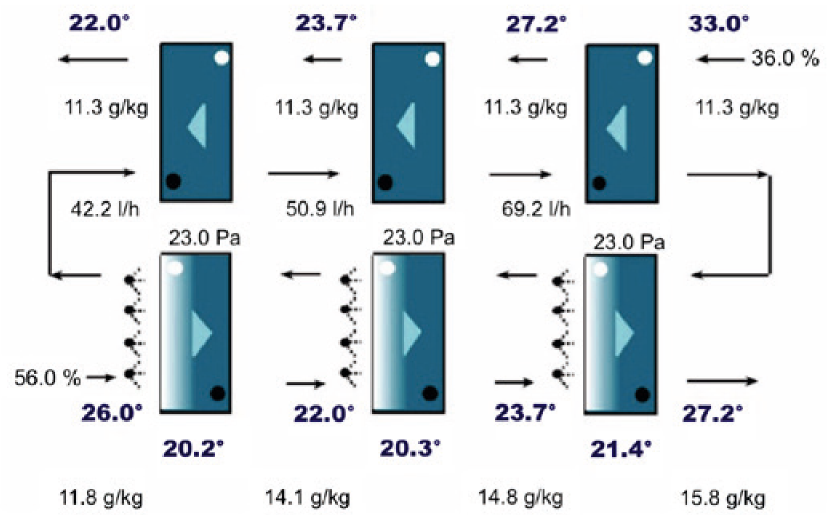


Image: Howatherm

With this new development, a supply air temperature of 19°C can be achieved even at 32°C and 40% outside fresh air condition, and 25°C and 50% exhaust air condition. This was confirmed by validation measurements carried out by DEKRA. The supply air temperature can thus be reduced by up to 3 Kelvin. This new development also has the advantage that additional mechanical refrigeration only needs to be used much less frequently.

5.2 Waste heat utilization with water-cooled IT systems

Today, IT components in data centers are usually cooled through the use of air as the medium. However, this form of cooling is increasingly reaching its physical limits in some areas, as the maximum power density of IT components is increasing, and thus more heat is being generated per server rack. On the one hand, this is due to the fact that the IT components in the servers are increasingly densely packed. Increasing amounts of RAM and the use of GPUs lead to increasing power requirements per server. In addition, an increase in the maximum power consumption of high-performance processors has been noticeable for some time now. While the maximum thermal design power (TDP) of Intel server processors was kept constant at around 150 watts between 2005 and 2013, it is up to 400 watts for high-performance processors in 2019 (Figure 10).

Due to the relatively unfavorable thermal properties of air, IT systems with very high power density require extremely high volume flow rates to guarantee the required cooling capacity, and one that is equally distributed across all points in the data center. This requires a lot of electricity to enable the circulation of air as the heat transfer medium. Large cross-sections of the ventilation systems are also required for the transport. With such systems, the efficient utilization of the waste heat generated becomes technically very demanding.

Heat transport using water, on the other hand, is much more efficient and could lead to a significant improvement in the utilization of waste heat. In the field of scientific applications and other variants of high-performance computing, water-cooled systems are already increasingly being used.

Water-cooled IT systems enable a very good utilization of the waste heat. Hot water of 55°C and more is generated directly from the servers. This water can be used very well for heating purposes or for provision of hot water in residential and commercial buildings. Refrigeration from waste heat is also possible – as the HotFlAd project (see Chapter 4) and the Leibnitz Data Center in Munich (LRZ, 2014) demonstrate – and represents the maximum refinement of waste heat utilization.

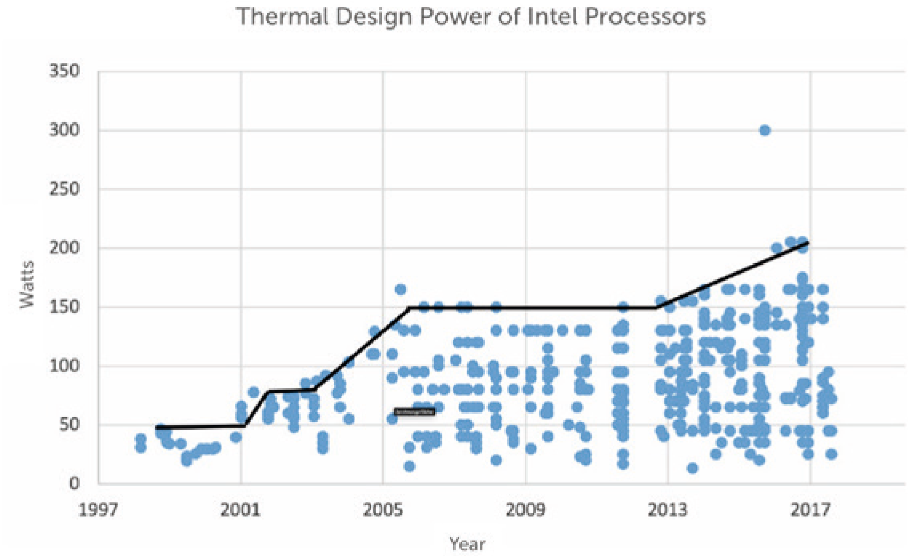
There are currently two systems for direct liquid cooling of servers:

- **Server immersion cooling:** Here, the servers are immersed in a liquid which heats up. This includes systems with and without phase change.
- **Server liquid / water cooling:** Here, the liquid is transported in a closed system to special heat sinks, which then absorb the waste heat from the servers.

In the following, this white paper focuses on server liquid cooling, since in this case the normal processes of a data center's operation do not need to be adapted.

Fig. 10

Developing the maximum power output of Intel server processors



Data: Intel
Image: Borderstep

Fig. 11

Server board (concealed) with heat sink and drip-free connectors (Hot Fluid Concept) by Thomas Krenn

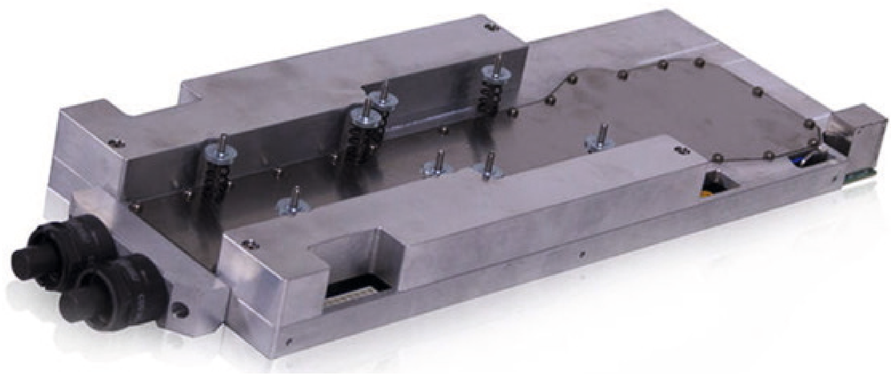


Bild: Howatherm

An elegant solution for direct cooling of servers is the use of a single solid heat sink instead of laying water pipes within the servers. The server board is mounted on this (Figure 11). The heat sink replaces the server housing. By using the solid heat sink, there are no leak-prone connections within the server, but only a drip-free water connection on the back of the server. The heat sink is designed so that it is in contact with all heat-emitting parts of the server board.

In order to maximize the efficiency of waste heat utilization, the water flow inside the heat sink is optimized for the respective server boards. The cooler water is first directed to the more heat-sensitive components such as main processors, and then to the less heat-sensitive passive components. In this way, the highest possible water temperature can be achieved.

The current developments – with an increase of high-performance computing for, among other things, the area of artificial intelligence (AI), and clear increases in the electrical power consumption with standard servers – are leading to very favorable conditions for server systems in which heat extraction takes place through liquids and at the same time the heat is available for secondary use. At the same time, the inhibitions regarding the use of water-cooled technologies in the server rooms are being reduced by the use of rear door coolers and side coolers.

6. Summary and conclusion

This white paper on the utilization of waste heat in data centers has shown that many different solutions already exist today for making use of the waste heat from data centers. For reasons of energy efficiency and to avoid environmental damage, the expansion of waste heat utilization is an important challenge for data center operators and also for our society as a whole.

In particular, the following measures are required to promote the utilization of waste heat in data centers in the future:

- Data center operators must be more and better informed about existing possibilities for waste heat utilization.
- Further possibilities for the use of waste heat must be developed, e.g. in the area of agriculture/vertical farming.
- The technical systems for the utilization of waste heat must be further improved.
- And, last but not least, the political, social, and economic framework conditions in Germany must be further improved so that the use of waste heat is promoted more. While the Wärmenetze 4.0 funding program offers a good starting approach, there is a lack of an overall concept in which, on the one hand, the utilization of waste heat is promoted, and on the other hand, the use of fossil energies for heating is fairly priced. The burden of the EEG (renewable energy) levy on powering heat pumps, which is senseless from an environmental perspective, would need to be abolished. Foresighted planning and systematic support for the construction of new heating networks, taking existing heat sources into account, and the creation of incentives to deliver heat are further important fields of action for the future. Germany can learn a lot from Sweden in particular.

We hope this white paper will provide food for thought for data center operators, other industry professionals, journalists, public officials, and political party representatives. Together, we can succeed in making greater use of waste heat from data centers in the future, and in so doing make a significant contribution to the sustainable shaping of digitalization.

7. Links to further information and best practice examples

Utilization of Waste Heat in the new Data Center at the University of Greifswald (German language)
https://www.bbl-mv.de/universität-greifswald-neubau-rechenz-entrum+2400+1025657

Waste Heat Utilization in Sweden
https://www.datacenter-insider.de/fortum-kauft-abwaerme-von-schwedischem-rechenzentrum-a-528335/

https://www.datacenter-insider.de/datacenter-in-schweden-und-in-deutschland-best-practices-versus-ignoranz-a-718973/

Leibniz Data Center in Munich
https://www.lrz.de/wir/green-it/ee-infrastruktur/

NeRZ-Befragung von Rechenzentrumsbetreibern
http://ne-rz.de/wp-content/uploads/2018/04/NeRZ-Kurzstudie-Stand-20180327.pdf

NeRZ Survey of Data Center Operators (German language)
https://www.pctipp.ch/news/firmen/artikel/schweizer-rechenzentrum-beheizt-bad-42931/

Projekt HotFlAd
http://ne-rz.de/2019/02/25/neues-nerz-zur-abwaermenutzung/

https://www.hri.tu-berlin.de/menue/research/research_projects/hotflad/

https://www.borderstep.de/projekte/abwaermenutzung-mit-hot-fluid-adsorptionskaelte-system-hotflad/

Data Center of the former ECB
https://www.datacenter-insider.de/cloudheat-uebernimmt-ehemaliges-rechenzentrum-der-ezb-in-frankfurt-a-613373/

Data Center TU Darmstadt
https://www.ttd.tu-darmstadt.de/ttd/aktuelles_7/archiv_9/archiv__details_264064.de.jsp

Data Center of VW Financial Services in Braunschweig
https://www.braunschweiger-zeitung.de/braunschweig/article215911797/VW-Rechenzentrum-nimmt-den-Betrieb-auf.html

Unterfränkische Überlandzentrale in Lülsfeld
https://www.weick-energietechnik.de/marke_hersteller_produkte/novelan/neuheiten/referenz_rechenzentrum

8. Bibliography

Borderstep Institut (2019)
Abwärmenutzung aus Kompakt-Rechenzentren mit Hot-Fluid Computing. Borderstep Institut. Accessed on 9.5.2019. Available at: https://www.borderstep.de/projekte/abwaermenutzu-ng-mit-hot-fluid-adsorptionskaelte-system-hotflad/

Digitales Hessen (2018)
Frankfurts grünes Rechenzentrum in der ehemaligen EZB. Accessed on 9.5.2019. Available at: https://www.digitalstrate-gie-hessen.de/Cloudandheat

Fricke, M. (2016)
Großwärmepumpen: ein wichtiges Bauteil für Fernwärmnetze. Gehalten auf den Berliner Energietagen. Accessed on 30.5.2019. Available at: https://www.binkert.de/de/ueber-binkert.html?-file=files/binkert/ueber-uns/Fricke_Waermepumpen_Energi-etage2016%202.pdf

GTAI (2018, Januar 25)
Stockholm will bis 2040 die „smarteste" Stadt der Welt sein. Accessed on 8.5.2019. Available at: https://www.gtai.de/GTAI/Navigation/DE/Trade/Maerkte/suche,t=stockholm-will-bis-2040-die-smarteste-stadt-der-welt-sein,did=1856888.html

Hintemann, R. (2017)
Energieeffizienz und Rechenzentren in Deutschland – weltweit führend oder längst abgehängt? – Kurzfassung der Studie. Berlin: Netzwerk energieeffiziente Rechenzentren – NeRZ. Accessed on 28.11.2017. Available at: http://ne-rz.de/wp-content/uploads/2017/11/NeRZ_Kurzstudie_RZ-Markt_Stand-20171129.pdf

IDG (2008, April 4)
Schweizer Rechenzentrum beheizt Bad. PCtipp.ch. Accessed on 8.5.2019. Available at: https://www.pctipp.ch/news/firmen/artikel/schweizer-rechenzentrum-beheizt-bad-42931/

Koschinsky, S. (2018, Dezember 18)
Universität Greifswald, Neubau Rechenzentrum | bbl-mv – Universität Greifswald. Accessed on 5.6.2019. Available at: https://www.bbl-mv.de/universität-greifswald-neubau-rechenzen-trum+2400+1025657

Ladner, R. (2017, Dezember 10)
Cloud&Heat eröffnet grünes Rechenzentrum in der ehemaligen EZB in Frankfurt. Accessed on 9.5.2019. Available at: https://netzpa-laver.de/2017/12/10/cloudheat-eroeffnet-ihr-gruenes-rechenz-entrum-in-der-ehemaligen-ezb-in-frankfurt/

Ostler, U. (2016, April 5)
Fortum kauft Abwärme von schwedischem Rechenzentrum. Accessed on 8.5.2019. Available at: https://www.datacenter-in-sider.de/fortum-kauft-abwaerme-von-schwedischem-rechenz-entrum-a-528335/

Ostler, U. (2017, Juni 2)
Cloud&Heat übernimmt ehemaliges Rechenzentrum der EZB in Frankfurt. Accessed on 9.5.2019. Available at: https://www.data-center-insider.de/cloudheat-uebernimmt-ehemaliges-rechenzen-trum-der-ezb-in-frankfurt-a-613373/

Ostler, U. (2018, Juni 4)
Datacenter in Schweden und in Deutschland – Best Practices versus Ignoranz. Accessed on 8.5.2019. Available at: https://www.datacenter-insider.de/datacenter-in-schweden-und-in-deutsch-land-best-practices-versus-ignoranz-a-718973/

Stachura, J. (2018)
VW-Rechenzentrum nimmt den Betrieb auf – Braunschweig. Braunschweiger Zeitung.

Thomas Krenn AG (2017)
Server-Kühlung: Wasserscheu ist heilbar – Wie Flüssigkühlung praxistauglich werden kann. DataCenter Insider.

Weis, T. (2017)
Abwärmenutzung aus Rechenzentren: Möglichkeiten – Potenziale – Einsatzgebiete. IKZ Gebäude- und Energietechnik.

9. Authors

Tobias Funke
TOBOL GmbH
t.funke@tobol.de

Dr. Ralph Hintemann
Borderstep Institut für Innovation und Nachhaltigkeit
gemeinnützige GmbH
hintemann@borderstep.de

Prof. Dr.-Ing. Christoph Kaup
HOWATHERM Klimatechnik GmbH
kaup@howatherm.de

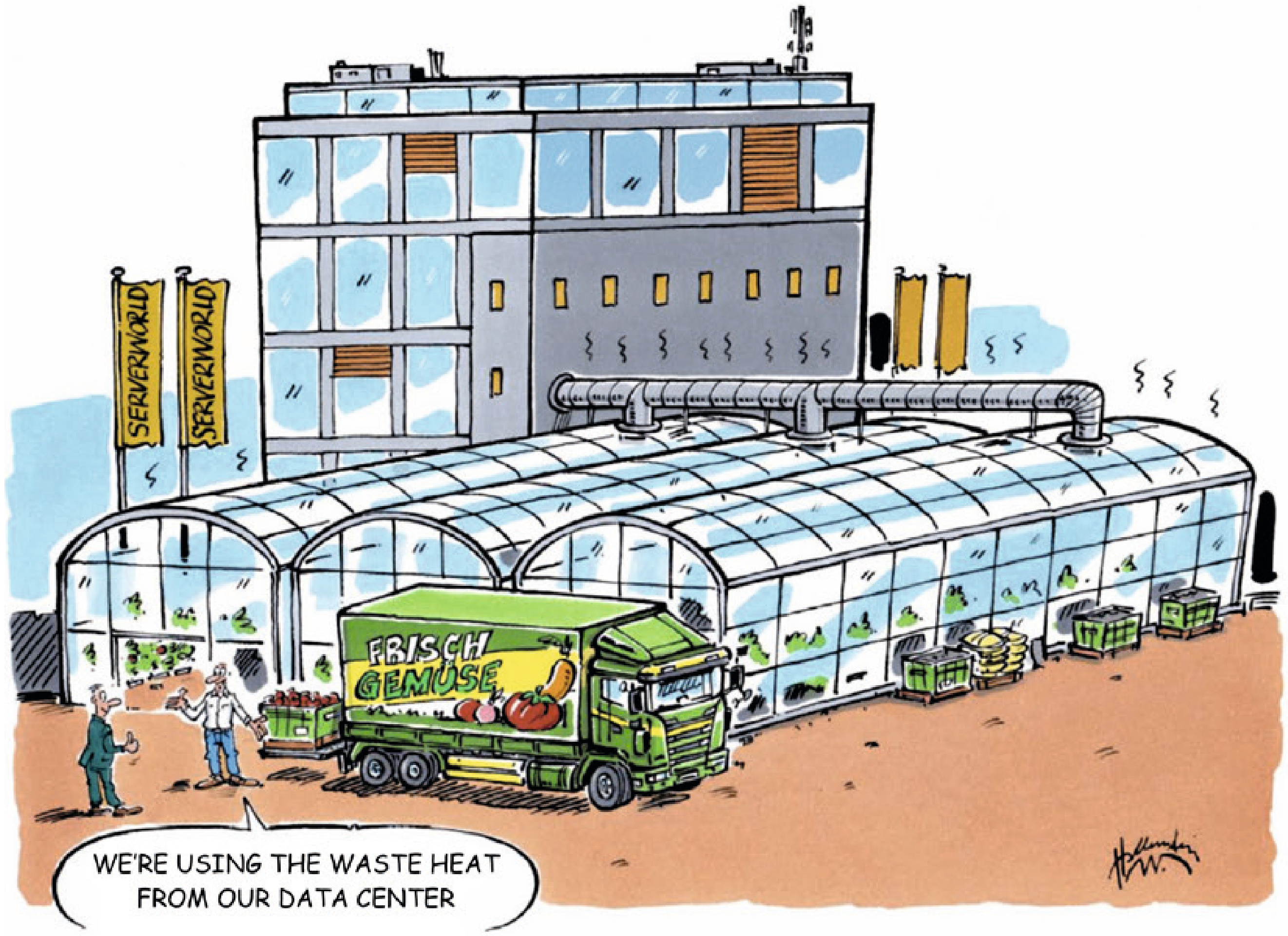
Christoph Maier
Thomas-Krenn.AG
cmaier@thomas-krenn.com

Steffen Müller
geff GmbH
steffen.mueller@geff.de

Sören Paulußen
InvenSor GmbH
soeren.paulussen@invensor.de

Dr. Jürgen Süß
Efficient Energy GmbH
juergen.suess@efficient-energy.de

Ulrich Terrahe
dc-ce RZ-Beratung GmbH & Co. KG
u.terrahe@dc-ce.de



SERVERWORLD
SERVERWORLD
FRISCH GEMÜSE
WE'RE USING THE WASTE HEAT
FROM OUR DATA CENTER

NeRZ – Netzwerk energieeffiziente Rechenzentren
represented by:
Borderstep Institut für Innovation und Nachhaltigkeit
gemeinnützige GmbH
Clayallee 323, D-14169 Berlin, Germany
phone +49 (0)30 306 45 100-5
info@ne-rz.de, www.ne-rz.de

NeRZ
Netzwerk
energieeffiziente
Rechenzentren

DIGITALE
INFRASTRUKTUREN
WIR SIND DAS INTERNET

eco – Association of the Internet Industry
Lichtstr. 43h, D-50825 Cologne, Germany
phone +49(0)221/700048-0
fax +49 (0)221 / 700048-111
info@eco.de, https://international.eco.de
@eco_de, @ecoverband

eco
ASSOCIATION OF THE
INTERNET INDUSTRY
WE ARE SHAPING THE INTERNET.
YESTERDAY. TODAY. BEYOND TOMORROW.