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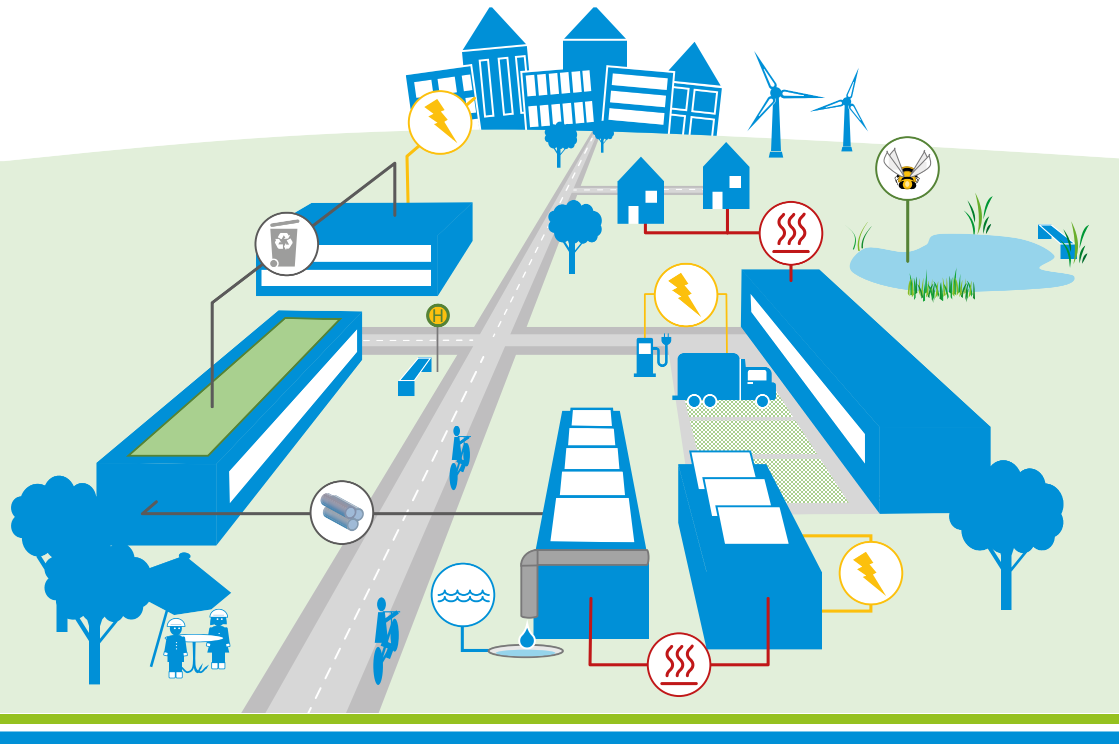
VDI ZRE Publications: Brief analysis No. 22

Resource Efficiency Potentials of Industrial Estates



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VDI ZRE Brief Analysis No. 22: Resource Efficiency Potentials of Industrial Estates

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The brief analysis was prepared within the framework of the National Climate Protection Initiative of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

The brief analyses of VDI ZRE provide an overview of current developments related to resource efficiency in research and industrial practice. They each contain a compilation of relevant research results, new technologies and processes as well as examples of good practice. The brief analyses thus provide a broad audience from business, research and administration with an introduction to selected areas of resource efficiency.

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Resource Efficiency Potentials of Industrial Estates

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LIST OF ABBREVIATION

CHP	Combined heat and power unit
BMWi	Bundesministerium für Wirtschaft und Energie - Federal Ministry of Economics and Energy
CDM	Clean Development Mechanism
CO_2	Carbon dioxide
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen - German Sustainable Building Council
EEEEH	Energy efficiency and use of renewable energies in hall buildings
Oath	Eco industrial development
EiP	ECO-Industrials Parks
EnEV	Energieeinsparverordnung – Energy saving regulation
ICT	Information and communication technology
IT	Information technology
JI	Joint Implementation
CED	Cumulative energy demand
KfW	Kreditanstalt für Wiederaufbau - Credit Institute for Reconstruction
SMEs	Small and medium-sized enterprises
CRD	**Cumulative raw material demand**
LED	Light emitting diode
NAPE	**National Action Plan for Energy Efficiency**
NISP	National Industrial Symbiosis Programs
PUBLIC TRANSPORT	Local public transport
VDI	Association of German Engineers

VDI GEU	VDI Society for Energy and Environment
VDI ZRE	VDI Zentrum Ressourceneffizienz GmbH

1 INTRODUCTION

Resource efficiency plays an increasingly important role in small and medium-sized enterprises. The efficient use of energy, materials, water and surface area not only saves resources, but also costs for purchasing and disposing of waste, residual materials and waste water, for example. Networking businesses in an industrial estate or with the surrounding residential areas offers many opportunities to save resources. Residential areas in particular offer high efficiency potential as heat consumers.

In the industrial estate, the final energy consumption in particular show possibilities for increasing resource efficiency, as this is required in almost every business in the form of heat, cold or electricity. In industry, commerce, trade and services, 44 % of the total final energy in Germany is consumed.[1] In addition, other resources such as materials, water and surface areas are used in large quantities. The geographical proximity of the businesses in an industrial estate is a great advantage for the realisation of many inter-business resource efficiency measures. The attractiveness of a business location is not only an advantage for the businesses when recruiting employees, but also for the municipalities, which want to keep businesses at the location and attract new ones.

In the course of time, the surroundings of industrial estates have also changed. Due to the growth of cities, industrial estates, which were previously located on the edge of a city, have been partially enclosed by residential buildings. This proximity between business and residential use not only creates new challenges for businesses, such as the limitation of commercial space or emission protection for the surrounding residents, but also opportunities. One example is the proximity to consumers and potential employees.

So-called "zero-emission commercial areas" are one way of enabling commercial and residential areas to grow together without any impairment. A holistic approach is required in order to avoid almost any emissions in an

[1] Cf. Deutsche Energie-Agentur GmbH (dena) (2014), p. 13.

industrial estate. To this end, businesses should take both internal and external measures. Resource efficiency measures, such as closed resource cycles, the use of renewable energies and the strengthening of biodiversity, can save and avoid emissions. In the case of the inter-business use of resources, however, it is important to secure the supply in the event of possible outages at the supplier.

This brief analysis provides an overview of the resource efficiency potential in industrial estates. First, resource flows and emissions, including noise emissions (see Chapter 2.1) in the industrial estate, are examined and the concept of 'industrial symbiosis' explained in more detail. The advantages resulting from an increase in resource efficiency for the businesses in the industrial estate are then mentioned. Potentials with regard to energy, material, water and surface area are investigated in the following areas (Figure 1):

a) In the business (Chapter 3)

b) Within an industrial estate (Chapter 4)

c) With residential areas (Chapter 5)

Figure 1: Areas examined in the brief analysis: a) Enterprises, (b) industrial estate and (c) residential estate

Measures from operational practice are presented on the basis of examples. Possibilities for the reduction of supply risks are addressed in this context.

2 RESOURCE EFFICIENCY IN THE INDUSTRIAL ESTATE

The aim of increasing resource efficiency in the industrial estate is above all to conserve resources and avoid emissions. This is becoming increasingly important as residential and industrial estates grow together.

The industrial estate offers a special opportunity to dissolve the linear production of waste and residual materials from the individual businesses and to exploit the potential of synergies in the industrial estate (industrial symbiosis) or even with the surrounding area.

2.1 Resources and emissions in the industrial estate

According to VDI Directive 4800 Sheet 1, **natural resources** are energy resources, raw materials (renewable and non-renewable primary raw materials), water, air, surface area, ecosystem services. [2]

Energy, raw materials, water and surface area are the most important resources for an industrial estate or business. In the following, raw materials and highly processed substances are summarised under the term materials. The potentials of resource efficiency are analysed at the level of businesses, commercial and residential areas.

The most common **emissions** to an industrial estate are noise emissions (air emissions), waste, waste water and those resulting from the production of energy for production.

Emissions are defined as materials and energy flows that leave the system under consideration and

- do not generate any economic revenue, and/or
- will find no further use.

Thermal recovery, composting or similar recovery does not count as further use. [3]

[2] Cf. VDI 4800 sheet 1:2016-02.
[3] Cf. von Hauff, M.; Müller-Christ, G. and Isemann, R. (2012), p. 128.

The objective of **zero emissions** shall be deemed to be achieved when material cycles are closed and/or emissions are prepared in such a way that they no longer have a negative impact on the ecological, economic or social environment. [4]

2.2 Industrial Symbiosis

The **industrial symbiosis** refers to the economic merger of neighbouring enterprises to exchange materials, energy, water and other residual materials (emissions).

The sharing of infrastructures, services and social facilities can also be grouped under the heading of "industrial symbiosis". [5]

- **Neighbouring** enterprises**:** Enterprises in which a merger is ecologically and economically feasible at local and regional level.
- **Residual materials:** Materials for which no further use exists in the producing enterprise and for which no economic revenue can be generated for the enterprise . [6] This includes by-products and production waste.
- **Energy:** Heat, cold and electricity that can no longer be used in your own enterprise.

In industrial symbiosis, the linear system of production is to be broken down in order to exploit the potential of cooperation with other enterprises. The traditional form of production in the linear system means that each enterprise has its own input of resources. On the other hand, both products that generate an economic profit and by-products or waste products such as (Waste) water or energy (usually heat), which usually involves disposal costs (Figure 2).

4 Cf. von Hauff, M.; Müller-Christ, G. and Isemann, R. (2012), p. 130.
5 Cf. Chertow, M.R. (2000), p. 314 - 317.
6 Cf. von Hauff, M.; Müller-Christ, G.; Isemann, R. (2012), p. 128.

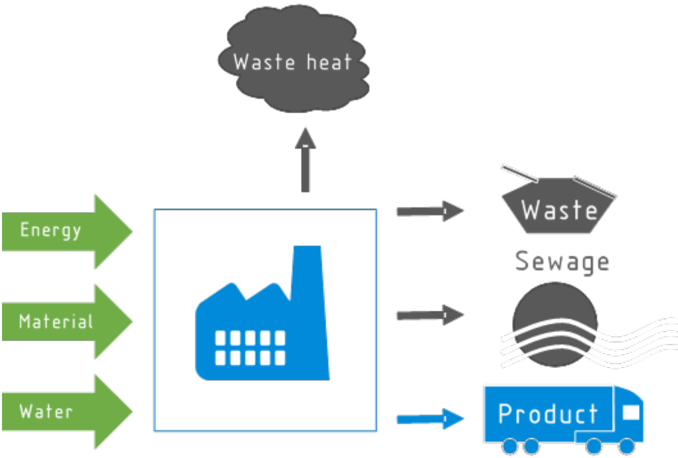

Figure 2: Linear Production

The opening of these system boundaries makes it possible to use the by-products of production in other enterprises as their new resource inputs. The result is a branched material/energy flow and ideally a closed material cycle (Figure 3). [7]

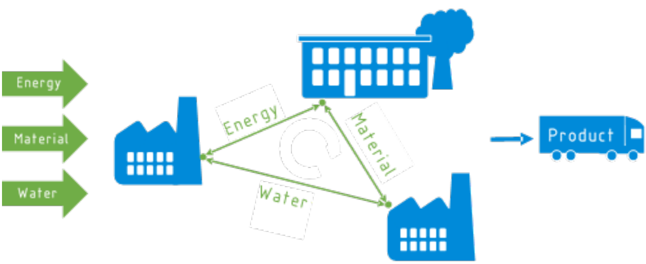

Figure 3: Circulation or further use of by-products

The expression of the industrial symbiosis was coined by the Kalundborg industrial estate in Denmark, which was one of the first industrial estates to

[7] Cf. Johnson, I. et al. (2015), p. 21.

use materials and energy for inter-business purposes. Their concept is explained in more detail in Chapter 4.5.2.

In German, the term "Verwertungsnetzwerk" is often used for industrial symbiosis. Eco-industrial networks and Eco-industrial Development (EID) are also synonyms for industrial symbiosis, although they are not very widespread in Germany. [8]

In other concepts, industrial symbiosis is only one component, as in ECO-Industrials Parks (EIP), which mainly increase their efficiency through the principles of industrial symbiosis. [9]

The present brief analysis also speaks of networking to simplify matters.

2.3 Networks, Certification and Research

In many countries, e.g. Scandinavia, Great Britain and Germany (GET.Min [10]), **networks** (Waste and Resources Action Programme, NISP [11]) have emerged in recent years, which provide enterprises nationally and internationally with knowledge and support for the realisation of industrial symbiosis.

The **DGNB** (Deutsche Gesellschaft für Nachhaltiges Bauen - German Sustainable Building Council) certifies sustainable industrial estates that take particular account of ecological, economic and socio-cultural aspects. For this purpose, the user profile office and commercial quarters was created. The certification includes various aspects: Life cycle evaluation, urban climate, water cycle management, land efficiency, adaptability, quality of open space, emissions, resource management and mobility infrastructure. [12]

The Federal Institute for Research on Building, Urban Affairs and Spatial Development launched the **project "Sustainable Development of Industrial**

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[8] Cf. Gleich, A.; Gößling-Reisemann, S. (2008), p. 350.

[9] Cf. Indigo Development (2016).

[10] More information can be found at www.getmin.de

[11] For more information, see www.nispnetwork.com

[12] Cf. DGNB GmbH (2016).

Estates" in 2014. [13] In nine pilot projects, concepts, instruments and procedures are being developed and tested throughout Germany. The aim is to work out a transferable procedure for the sustainable further development of industrial estates.

The **National Action Plan for Energy Efficiency (NAPE)** of the Federal Ministry of Economics and Energy (BMWi) should also be mentioned here. [14] The action plan deals not only with the energy efficiency of buildings but also with that of enterprises and industrial estates. Topics include waste heat utilisation, energy efficiency managers for industrial estates and energy-efficient waste water treatment. The Action Plan provides information, influences regulatory law and develops financial incentives.

2.4 Ecological advantages of networking

- **Conservation of natural resources:** As enterprises consume fewer (primary) resources through industrial symbiosis, natural resources are conserved. Kalundborg (see Chapter 4.5.2) can save, among other things, approx. 3 million m^3 of water and 150,000 tonnes of natural gypsum annually through industrial symbiosis measures. [15]

- **Contribution to climate protection:** The cascading use of resources both saves raw material and reduces waste. As a result, Kalundborg was able to reduce CO_2 emissions by 240,000 tonnes. [16]

2.5 Economic and social benefits of networking

- **Cost reduction:** The mutual use of by-products results in economic advantages for all parties involved. The enterprises save costs for raw materials, energies, disposal and - in the case of shared use - also for infrastructure and services.

[13] More information can be found at www.gewerbeexwost.de

[14] More information can be found at https://www.bmwi.de/Redaktion/DE/Artikel/Energie/nape-mehr-aus-energie-machen.html

[15] Cf. Kalundborg Symbiosis (2016).

[16] Cf. Deffke, U. (2009).

- **New sales market:** Another economic advantage is the new sales market for the enterprises own by-products. Although the enterprises in Kalundborg have spent a total of approx. US$ 60 million on the expansion of the new (materials) infrastructure, the annual revenue is estimated at about US$ 10 million. [17]

- **Competitive advantages:** Cost savings, a new sales market and an improved image create competitive advantages over conventional businesses.

- **Reducing market dependence:** As businesses need fewer primary resources, they are less dependent on fluctuations in raw material prices on the external market.

- **Opportunities for innovation:** The transition from a linear system to a circular economy offers the opportunity for innovation, as a working environment is created that offers undreamt-of opportunities. A study of 154 projects in the National Industrial Symbiosis Programme (NISP) has shown that 70 % of the symbioses implemented contain innovations. 19 % led to new research and technology developments. These were mainly the result of the exchange of knowledge between different sectors. [18]

- **Network:** The network created by the collaborations makes it possible to get to know other enterprises better and to exchange information (also in higher-level networks, such as GET.Min). [19] Enterprises can benefit from the experience and expertise of other enterprises.

- **Image improvement:** With the help of the industrial symbiosis, the sustainability of the enterprise and the industrial estate can be increased and thus the external impact as an environmentally friendly production site can be improved.

- **Initiation of analyses and monitoring of material flows:** A basic prerequisite for symbiosis is the exchange of data on the material and energy

[17] Cf. Schön, M. et al. (2003), p. 13.
[18] Cf. Lombardi, R.; Laybourn, P. (2012), p. 32.
[19] Cf. Lombardi, R.; Laybourn, P. (2012), p. 32.

flows of the individual enterprises. If these are missing, they are determined by analyses and measurements. The experts of the GET.Min project were thus able to eliminate previously undiscovered defects that led to increased energy consumption. [20]

[20] Cf. Drießen, H. (2015).

3 INCREASE IN RESOURCE EFFICIENCY IN THE ENTERPRISE

In addition to considering the increase in resource efficiency in production in enterprises, the construction and technical building potentials must also be taken into account. The potentials are only shown by way of example, since the detailed studies, short analyses and online tools of the VDI ZRE [21] can be used if required. In addition, the VDI Directive 4800 Sheet 1 defines product-related resource efficiency strategies and measures.

3.1 Energy

Industry in Germany accounts for a considerable share of final energy use: In 2014, it consumed about 29 % of the total final energy consumption in Germany; trade, commerce and services together accounted for a further 15 %. [22] The Federal Government estimates the economic savings potential in the realisation of energy efficiency measures for industrial enterprises alone at € 10 billion per year. [23]

Energy conservation measures are subdivided into four areas below: Energy conservation, substitution of fossil fuels by renewable energies, intelligent energy management and compensation measures.

3.1.1 Conservation

Reduction of the energy requirement for room temperature control

In Germany, approx. 420,000 industrial and commercial buildings consume 15 % of the final energy for heating all buildings. [24] The demand for cooling in the industrial sector is significantly higher than in residential buildings and has risen further in recent years, partly due to higher heat loads from IT

[21] The free information and aids can be found on the homepage of the VDI ZRE (www.ressource-deutschland.de).

[22] Cf. Federal Ministry of Economics and Energy (2017a).

[23] Cf. Federal Ministry of Economics and Energy (2017b).

[24] Cf. BINE Information Service (2015).

equipment. Savings potentials already arise during the planning of a production hall [25]: The compactness of the building, the orientation of the building, the proportion of window area, the shading and the construction method are among other things factors that influence the consumption of heat and cooling energy at this point. The insulation properties of the exterior components are decisive: These can also be improved retrospectively during an energetic renovation, whereby thermal bridges must be avoided. When planning an energy-efficient building envelope, the required interior temperature control and building technology must always be taken into account. When designing the temperatures in the individual zones, the often high internal heat loads in production must be taken into account. The internal heat loads can be reduced by insulating the pipes and equipment. It should be noted, however, that a reduction in internal loads reduces the cooling requirement, but in return can increase the heating requirement in the winter months. [26]

In addition to losses from external components, heat losses from ventilation (through infiltration and exfiltration) contribute to high energy losses in many buildings in the manufacturing industry. Airlocks, dock shelters and shorter opening hours can reduce heat losses. [27]

Ventilation and air conditioning systems

Most production facilities are equipped with a ventilation system and a ventilation system. The ventilation systems can fulfil several tasks:

- The removal of polluted air as a result of sources of moisture, pollutants and heat,
- Fresh air supply and

[25] When planning or renovating a building, the entire life cycle should be considered. The resource requirements in the production of building products play just as important a role as a concept for the dismantling of buildings (recycling-friendly construction).

[26] First aid for the planning of a factory hall is provided by the guide Energy efficiency and use of renewable energies in hall buildings - new construction and existing buildings (EEEEH) at: http://www.mark.de/wp-content/uploads/2015/11/eeeeh-leitfaden1.pdf

[27] Cf. Müller, E.; Engelmann, J.; Löffler, Th. and Strauch, J. (2009), p. 247.

- possible additional services such as heating and air conditioning.

Optimising ventilation systems can save up to 25 % of energy in addition to improving the indoor climate.[28] The costs of most measures to increase the efficiency of systems pay for themselves after several years, and according to the German Energy Agency (dena) even within two years.[29]

Examples of measures to increase the efficiency of air conditioning systems are[30]

- **Use of heat recovery systems:** The outside air is preheated in a heat exchanger using the exhaust air from the heated building.

- **Separation of ventilation and thermal conditioning:** This reduces the required air volume flow.

- **Variable volume flow control:** The required air volume flow is regulated according to air quality and demand.

- **Adiabatic cooling:** The supply air is cooled by evaporation and consumes considerably less energy compared to a compression chiller. However, the cooling capacity depends on the outdoor air humidity.[31]

Lighting

Lighting systems account for approx. 5 % of industrial power consumption, and even up to 15 % depending on the industry. Energy costs can be reduced by up to 70 %. In addition, modern light sources can be expected to require less maintenance and have a longer service life. The potential savings depend to a large extent on the technical condition and age of the lighting system.[32]

[28] Cf. vPRESS. GmbH (2017).
[29] Cf. Deutsche Energie-Agentur GmbH (dena) (2017a).
[30] Cf. EnergyAgency.NRW GmbH (2017a).
[31] Cf. Kabus, M. (2009), p. 8.
[32] Cf. Deutsche Energie-Agentur GmbH (dena) (2015a), p. 16.

Examples of measures to increase the efficiency of lighting systems are: [33]

- reduction of oversized lighting, [34]
- presence detectors and timers,
- daylight utilization and daylight sensors and
- efficient light sources.

Energy efficiency in production

Energy is consumed not only in building operation, but also in production itself. Energy consumption varies from industry to industry. The so-called "energy-intensive industries" have the highest energy consumption. These include, for example, the aluminium, paper, cardboard, glass and cement industries. In addition to process-dependent processes, there are also cross-sectional technologies that play a role in many industries. These are in production, for example, information technology, heat supply for technical processes, refrigeration technology, conveyor technology and motors or drive systems. The savings potential of the individual cross-sectional technologies is very high. [35] compressed air, for example, offers considerable potential for energy savings. By eliminating leaks in the line and optimizing the compressed air level, up to 40 % of energy consumption can be saved. [36]

Another example of energy conservation is the internal use of waste heat. First and foremost, heat losses should be avoided. In order to avoid waste heat, the control system and the temperature level should be checked, pipes insulated and the systems serviced. Unavoidable waste heat can be used elsewhere to cover energy requirements. For this purpose, the heat flows (sources and sinks) as well as the temperature levels, the heat quantity, the

[33] Cf. Deutsche Energie-Agentur GmbH (dena) (2015a), p. 16.
[34] However, the lighting levels required by the workplace regulations must be complied with.
[35] Cf. Federal Ministry of Economics and Energy (2017c), p. 19.
[36] Cf. EnergyAgency.NRW GmbH (2017b).

medium and the temporal availability/demand must be identified. This results in various possibilities for using the waste heat, as shown in Figure 4 using the example of the temperature level.

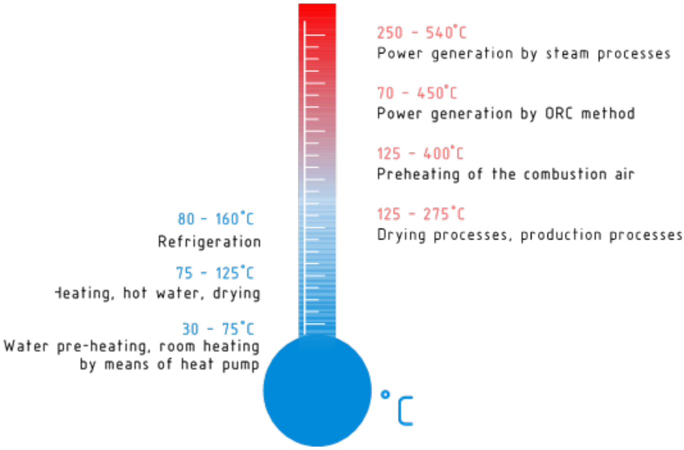

Figure 4: Possible uses of waste heat[37]

The possibilities for using waste heat are manifold: It can be used to generate process heat, space heating and hot water, cooling and, at high waste heat temperatures and quantities, even electricity.[38]

The waste heat calculator of the Bavarian state government, for example, provides an initial evaluation of the existing waste heat potential.[39]

3.1.2 Energy supply and renewable energies

In energy generation, efficiency can be increased with the help of smaller measures, such as the installation of a demand-controlled heating pump or optimisation of the heating system.[40]

A further step is the substitution of fossil energy by renewable energy.

[37] Cf. Deutsche Energie-Agentur GmbH (dena) (2015b), pp. 4 - 6.
[38] Cf. Deutsche Energie-Agentur GmbH (dena) (2015b), pp. 4 - 6.
[39] Cf. Bavarian State Ministry of Economic Affairs and Media, Energy and Technology (no date).
[40] Cf. McKenna, R.; Fichtner, W. (2011), pp. 119 - 120.

The most commonly used renewable energy sources are:

- solar energy (solar thermal and photovoltaic),
- wind energy,
- geothermal energy and
- biogas.

A particularly high potential for the use of renewable energies is offered by process heat, which accounts for almost 90 % of heat energy consumption in industry (Figure 5). [41]

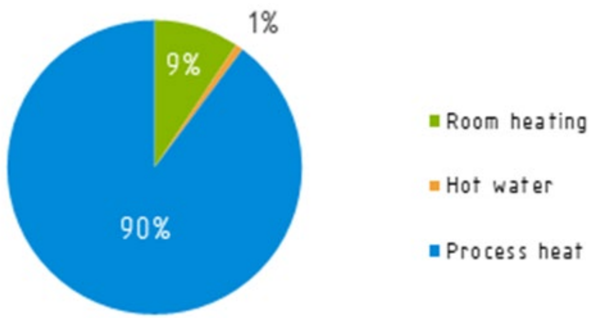

Figure 5: Final energy consumption of industry according to heating purposes in 2015 [42]

However, this value may vary depending on the industry. The heat consumption for the process heat can be partly covered by waste heat as described above. So-called solar process heat can be used for the remaining requirements. This is particularly suitable for temperatures of <100 °C, as it is particularly economical in this case. The food industry requires a large proportion of process heat in this temperature range. The potentials are often not exhausted because the possibilities of realisation and the savings potentials

[41] Cf. Federal Environment Agency (2017).

[42] Cf. Federal Environment Agency (2017).

are little known. In addition, there are rarely standard solutions for their integration. However, various directives and industry concepts have been developed in recent years.[43] Among others, the VDI-Gesellschaft Energie und Umwelt (GEU) is working on the directive VDI 3988 "Solar thermal process heat", which is to be published in 2018. As part of its market incentive programme, the Federal Ministry of Economics and Energy (BMWi) promotes the increased use of renewable energies, including in enterprises.

When calculating the economic efficiency of solar process heat, the low maintenance and operational expenditures with a service life of up to 25 years are positively noticeable. For a typical plant, the payback period is approx. seven years.[44]

3.1.3 Energy and Load Management

According to VDI 4602, energy management is "the foresighted, organized and systematized coordination of the procurement, conversion, distribution and use of energy to meet requirements while taking ecological and economic objectives into account".[45]

The aim of **energy management** is to permanently reduce energy consumption and costs. Both strategic and technical measures are implemented. In an energy management system, the energy flows, i.e. the energy consumption and the generated energy, are recorded and visualized using various sensors and measuring devices. In visualization, there is the opportunity to view the production and energy data not only individually, but also in parallel or as a function of one another. In the live analysis of the processes, errors can be eliminated and potential savings uncovered. Through ongoing monitoring, the goals set for energy management can be constantly checked.

(Operational) **Load management** is an increasingly important energy management measure. Loads can be controlled selectively and flexibly:[46]

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[43] More information on solar process heat can be found at: http://www.bine.info/publikationen/publikation/solare-prozesswaerme/

[44] Cf. Schmitt, B.; Ritter, D. and Giovannetti, F. (2017), p. 10.

[45] VDI 4602 Sheet 1: 2007, p. 3.

[46] Cf. WEKA MEDIA GmbH & Co KG (no date).

- Peak loads can be reduced,
- the load profile can be harmonized and
- the hours of use can be optimised.

This enables a business to optimise individual power grid charges, e.g. through inter-business load management (balancing out fluctuations in electricity generation from renewable energies in the grid).

Corporate load management will become increasingly important in the future, as it can support the stable operation of power grids with renewable energies and thus bring conservations for the business. In addition, load management makes it possible to make better utilisation of self-generated heat or electricity from renewable energies. Especially processes that can absorb time shifts by an intermediate storage are suitable for the flexible use of electricity, such as the provision of compressed air and process cooling, the ventilation and air conditioning of buildings.[47]

Load management and a switch from industrial processes to electricity can increase the flexibility of power consumption in the business. This also makes it possible to interlink individual sectors (electricity, heat, mobility) of the energy industry (sector coupling).[48] **Sector coupling** helps to replace fossil fuels with renewables by linking sectors with each other and decentralised storage to compensate for fluctuations in renewable energies.[49] This enables surplus electrical energy from renewable resources to be stored in decentralised batteries and removed again in the event of a shortage, for example in residential buildings, in electric cars or in industrial processes. Other possibilities for sector coupling include "Power to Gas"[50], i.e. the conversion of electrical energy, e.g. into hydrogen, or combined heat and power generation, which produces both electricity and heat.

[47] Cf. Deutsche Energie-Agentur GmbH (dena) (2013), p. 4.

[48] Cf. Paschotta, R. (2016).

[49] Cf. Federal Ministry of Economics and Energy (2016).

[50] More information about "Power-to-Gas" can be found on the page www.powertogas.info to find the right one.

3.1.4 Compensation

If the efficiency measures, such as substitution or efficient energy supply, are exhausted (i.e. technically no longer possible or economically disproportionate), it is possible to offset the remaining emissions through compensation measures and thus - as it is often called in this context - to become climate-neutral. This compensation takes the form of voluntarily acquired **emission certificates**.

An emissions certificate confirms the emissions saved elsewhere through a climate protection project. The holder of such a certificate may sell the right to it so that another person can offset his unavoidable emissions. [51] The climate protection projects on which the certificates are based consist of measures to avoid emissions (e.g. construction of a wind farm) or measures to sequester carbon dioxide (e.g. afforestation). The[52] latter is controversial, however, as, among other things, the durability of the projects can often not be guaranteed. [53]

In order to be able to demonstrate the actual and sustainable avoidance of emissions from a project, strict requirements are set and recorded in various standards. There are the standards of the Kyoto Protocol, which are verified according to the requirements of the Clean Development Mechanism (CDM) and Joint Implemantation (JI). Such certificates are called "Verified Emission Reductions (VER)". An even stricter standard is the Gold Standard. The validation is based on the same requirements as the Kyoto Protocol. However, only renewable energy and energy efficiency projects will be validated and higher requirements made on the sustainability of the projects.

The measure of compensation should only be taken when the possibilities of conservation, efficiency and substitution have been exhausted. This is to prevent the principle of sustainability from being violated and "indulgence trading" from taking place. [54]

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[51] **Cf. German Emissions Trading Authority (DEHSt) (2008), p. 9.**

[52] **Cf. German Emissions Trading Authority (DEHSt) (2008), p. 8.**

[53] **Cf. ifeu – Institute for Energy and Environmental Research Heidelberg GmbH (2010), p. 2.**

[54] **Cf. ifeu – Institute for Energy and Environmental Research Heidelberg GmbH (2010), p. 1.**

3.2 Material

Every manufacturing business needs materials to manufacture its product. The cost of materials was the highest in the manufacturing sector in 2015 at almost 42.2 % of gross production value. By comparison, personnel costs account for just under 18.7 %. [55] The aim should therefore be to produce as little waste as possible and to use materials as efficiently as possible. Through the efficient use of materials, costs can be saved and the competitiveness of a manufacturing industry increased. Depending on the industry, there are various ways to increase resource efficiency. Many of these measures to increase resource efficiency can already be implemented with low investment costs. The challenge in identifying, developing solutions and implementing measures lies in the **comprehensive analysis of the product life cycle**. This path of life is roughly divided into four phases: Raw material production, product manufacture, use and recycling or disposal. [56] Improving resource efficiency in one phase often leads to deterioration in another phase of life. Therefore, an analysis of the entire product life cycle is necessary for an overall improvement of resource efficiency. A primary energy evaluation of products along their life cycle is made possible by the **cumulative energy demand (CED)** method according to VDI 4600. [57] Analogously, the calculation of the **cumulative raw material demand (CRD)** according to VDI 4800 Part 2 can provide an evaluation of the raw material, water and land consumption. [58] With the aid of a **life cycle evaluation** according to DIN EN ISO 14040 or 14044, environmentally relevant effects can be assessed. In addition to the resource efficiency analysis, it also includes other impact categories such as human toxicity.

3.3 Water

The resource water plays a role in all manufacturing businesses. In Europe, for example, approx. 57 % of water consumption is attributable to industry. [59]

[55] Cf. Federal Statistical Office (Destatis) (2017), p. 289.
[56] Cf. VDI 4800 sheet 1:2016-02.
[57] More information can be found in the VDI Directive 4600:2012-01.
[58] More information can be found in VDI Directive 4800 Sheet 2:2018-03.
[59] Cf. Food and Agriculture Organization of the United Nations (FAO) (2016).

The importance of water will increase in the future, as climatic changes already influence the availability of water today.[60] Benchmarking across various industrial sectors revealed a **water savings potential for** industrial water of up to 50 %.[61] In principle, three types of water need to be considered: Drinking water, waste water (grey water, black water and industrial water) and rainwater. However, black water is neglected at this point because of its low incidence.

Drinking water

Drinking water has the highest quality among the three types of water. The enterprises purchase drinking water from external waterworks that extract it from the natural water cycle and treat it. A reduction in drinking water consumption leads not only to a conservation of water resources, but also of the energy required to provide drinking water. Options for reducing consumption include replacing drinking water with treated grey water, industrial water or rainwater, installing more efficient sanitary facilities or switching to dry processes or more water-efficient production facilities. By implementing the efficiency measures and substitution, costs for drinking water can also be saved.

Grey water

Grey water is slightly polluted waste water free of faeces. It is mainly used in households and offices, for example when showering, washing hands or washing machines. The grey water treated as process water can be reused for toilet flushing, plant irrigation or for the washing machine without any loss of comfort or hygienic risk. In addition, the heat from the waste water can be used to preheat cold drinking water.

Industrial waste water

Depending on the industry and the process water quality required, the industrial waste water is very different, so that there are no standardised solutions. The first measures to reduce industrial waste water include the efficient use of water and the optimisation of production processes. For example,

[60] Cf. World Business Council for Sustainable Development (WBCSD) (2017), p. 2.
[61] Cf. Andrews, M.; Berardo, P. and Foster, D. (2011).

water can be saved by switching to dry processes, e.g. dry painting, closed water circuits or multiple use or cascading use (Figure 6).

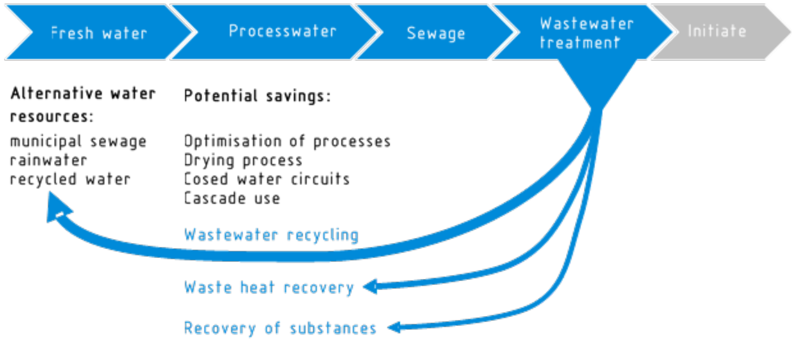

Figure 6: Possibilities for conservation process water

In order to further reduce the demand for fresh water, the industrial waste water can be treated and used as process water again. With the preparation of industrial waste water, there is not only the opportunity to reduce the amount of waste water and thus the costs for waste water disposal, but also to recover waste heat and substances from the industrial waste water.

The use of waste heat from industrial waste water is obvious, as the amount of waste water is quite constant and the average temperature is 60 °C.[62] The prerequisite for the installation of a heat recovery system is a precise analysis of the boundary conditions. In the event of increased pollution of waste water, technical precautions should be taken to ensure efficient and smooth operation.[63]

In addition to thermal energy, materials can also be recovered. The recovery of material resources can save primary raw materials and thus also raw material costs. However, the expansion of the required infrastructure and technology is associated with effort and costs. Phosphorus, ammonium and metals, among others, can be recovered from the waste water. Depending on the material, the effort, but also the conservation, varies. In a potential analysis

[62] Cf. Urbansky, F. (2016).
[63] Cf. Boots, R. (2017), p. 140.

the possibilities and saving potentials can be estimated in the run-up to realisation.

Rainwater

The use of rainwater occurring on the property should be prioritised as follows: evaporate, use, seep away, discharge into the public sewer. [64] Local authorities often now have regulations that only permit the discharge of rainwater into sewers in exceptional cases. In addition, the less water that is discharged into the sewer, the lower the waste water charges. A green roof, for example, can increase evaporation by storing water in the green area. Furthermore, rainwater can be used to reduce the consumption of fresh water in the building, e.g. for flushing toilets, irrigating plants, as cooling water or as fire extinguishing water. The rainwater from sealed property areas or the overflow of the rainwater utilisation system can be seeped away in two ways: Either paved surface areas are designed in such a way that they are open enough for direct rainwater seepage (unsealing, e.g. lawn grid stones) or the collected water from the sealed surface areas is fed into a seepage system. Measurements on grass pavers showed that only 1 % of the precipitation flows off as surface water, while 53 % evaporates and 46 % seeps away. [65]

3.4 Surface area

The surface area consumption results from the areas of the building, e.g. for production and the required traffic routes for flowing and stationary traffic. The development plan issued by the public administration presents some values for land use. This usually includes the arrangement and height of the buildings as well as the location and width of the streets.

Nevertheless, there is a possibility of using the surface areas more efficiently. With the help of a **surface area requirement determination** in the planning phase, production and logistics processes can be analysed and the existing surface areas can be used efficiently and the operational processes in the business can be optimized. Flexible floor plans and the possibility of

[64] Cf. Steffan, C. (2010), p. 14.
[65] Cf. Reichmann, B. (2011), p. 34.

extending the production hall can also increase the useful life. A flexible and expandable building offers the opportunity for later conversion, restructuring and expansion. This is particularly useful for industrial buildings, as the requirements often change due to the significantly shorter utilization times of a production plant. [66]

A further resource efficiency potential in terms of space arises with regard to the mostly **large roof surface areas of industrial buildings**. The use of this surface area depends on the shape and orientation of the roof. With most roof types it is possible to use the surface area for energy generation, i.e. for photovoltaics or solar thermal energy. The flat roof has the most potential here. On the one hand, green roofs store rainwater, which can evaporate with a time delay. On the other hand, greening promotes biological diversity. Depending on the type of green roof and construction, the green roof can be combined with a photovoltaic or solar thermal system or with a recreation room for the employees. Higher investment costs for green roofs are a cause for concern. However, these can be eliminated with the versatile advantages of a successful roof greening. Green roofs regulate the climate, absorb sound and pollutants and thus improve the quality of the rooms. In addition, the storage of rainwater (Chapter 3.3) can save waste water charges [67]in many municipalities. [68]

A major factor in surface area consumption in the manufacturing industry is the **sealing of outdoor surface areas** by the required infrastructure, which is created by parking spaces and delivery traffic. In general, efficient planning of outdoor surface areas can reduce sealing and make efficient use of the surface areas. Since different requirements apply to stationary and flowing traffic, they should be considered separately. The infrastructure for flowing traffic can in turn be divided into delivery and passenger traffic. The increased burdens and requirements for delivery traffic leave little scope for many efficiency measures. In advance, it is possible to seal as little space as possible through intelligent surface area planning. In operation, the potential lies in the reduction of delivery traffic by merging orders or deliveries and

[66] Cf. Assmann beraten und planen AG (2008), p. 36.

[67] The waste water charges are regulated differently depending on the municipality.

[68] Cf. Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (2015), p. 59.

deliveries and thus achieving a more efficient utilization of delivery traffic. Another positive effect resulting from the reduction in traffic volume is the reduction in road wear.

Passenger traffic can also be reduced by better connections to **public transport and cycle paths**. [69] Parking spaces or parking facilities provided for stationary traffic as well as pedestrian paths have the potential to unseal these surface areas, i.e. replace the closed asphalt or concrete roads with a surface that can seep away (e.g. grass pavers and gravel joint paving). One advantage of unsealing is the reduced discharge of rainwater, which leads to a reduction in the precipitation water charge. It also contributes to flood protection and groundwater recharge. [70]

3.5 Industry 4.0

"Industry 4.0" describes the intelligent networking of people, machinery, products and logistics as well as virtual product development with the goal of more efficient and flexible production. Digital transformation measures lead, among other things, to an increase in resource productivity, e.g. by reducing downtimes. The effects of digital transformation on resource efficiency cannot yet be quantified in general terms. In addition to the resource conservations through industry 4.0, the resources consumed in the production of information and communication technology (ICT) components, such as sensors and control systems, must also be taken into account. To date, there are no quantitative studies on this subject. Since the realisation of industry 4.0 is so far mostly at an initial stage, there is an opportunity to integrate the optimisation of resource flows from the outset. In the study "Resource efficiency through industry 4.0 - Potentials for SMEs in the manufacturing sector" of VDI ZRE, the influence of industry 4.0 on resource efficiency was examined. [71]

The first step towards digital transformation is the networking of sensors and actuators. This enables processes and consumption to be monitored and

[69] Cf. von Hauff, M. and Wolf, V. (2009).

[70] Cf. Fachvereinigung Betriebs- und Regenwassernutzung e.V. (fbr) (2009).

[71] More information on the study can be found at: http://www.ressource-deutschland.de/fileadmin/Redaktion/Bilder/Newsroom/Studie_Resource_efficiency_through_industry_4.0.pdf.

operating data to be linked to machinery data, enabling errors and irregularities to be detected better and faster. With advanced digitisation, the collection of data will be further expanded. The systems then no longer only collect data, but also analyse it and, if necessary, derive measures. The fully automated control of machinery through data acquisition and analysis then corresponds to a fully implemented industry 4.0. The practical applications implemented in the businesses surveyed in the above-mentioned study primarily resulted in savings in the areas of waste quantity, error rate, storage space, material and power consumption as well as transport. The businesses in the case study reported savings of up to 25 % in energy and materials. [72]

3.6 Examples of "zero-emission enterprises"

The following examples show various resource efficiency measures in the enterprises. In order to achieve "zero emissions" in the industrial estate, the individual local enterprises should implement the internal potentials for increasing efficiency.

3.6.1 design.s Workshop (joinery)

The business design.s was founded in 1989 by master carpenter Richard Stanzel. Since then, the carpenter's workshop has been designing and manufacturing individual wooden furniture. In 2010 the enterprise was able to move to its new "zero emission manufacturing building" in Pulling. [73]

The architecturally high-quality new building combines not only design qualities but also ecology and economy (Figure 7). Already during the planning phase, attention was paid to a compact building form that is adapted to the required dimensions of the uses. The large workshop area on the north façade can be used flexibly thanks to its open and column-free layout. All other enclosed rooms, such as warehouses or staff rooms, are located on the south façade. The outer shell of the workshop is designed as a timber frame construction with core insulation. The components in contact with the ground are also continuously insulated. The north façade consists of recycled and

[72] Cf. VDI Zentrum Ressourceneffizienz GmbH (2017), p. 9.
[73] Cf. designs (2017).

translucent polycarbone elements, which ensure a high daylight yield in the workshop and have good insulating properties.[74] The remaining windows are triple-glazed. The structural shading (folding shutter) prevents the rooms from overheating in summer. Due to the versatile structural measures, both the heating requirement and the power consumption for the lighting could be kept low.

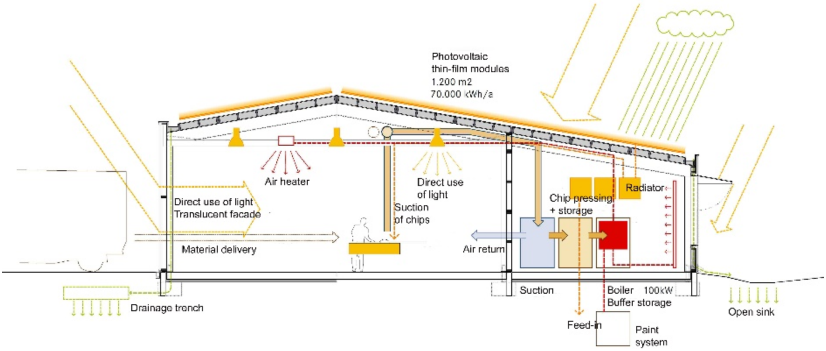

Figure 7: Technical concept of the wood workshop (Source: Deppisch Architekten)

The photovoltaic modules (1,200 m^2) embedded in the roof surface generate 70,000 kWh of electricity per year and can thus not only cover the entire consumption of the carpenter's workshop, but can also feed electricity into the public grid. The heat requirement of the carpenter's workshop is 100 % obtained from renewable energy. The pressed wood and wood shavings from the joinery and wood chips serve as energy sources.[75]

The rainwater on the property seeps away via a drain and a seepage trough, so that the enterprise does not have to discharge rainwater into the sewer.[76]

Overall, the construction costs for the new zero emission factory building were no higher than those for a comparable production hall.[77]

74 Cf. Deppisch Architekten GmbH (2017).
75 Cf. Association of German Architects BDA Münster-Münsterland (2017).
76 Cf. Association of German Architects BDA Bavarian State Association (2017).
77 Cf. Association of German Architects BDA Münster-Münsterland (2017).

3.6.2 Müller Production GmbH

Alois Müller Produktions GmbH has been producing components for energy, building services and plant engineering in the Allgäu region for over 40 years. Thanks to an innovative building services engineering system, the businesses was able to build a production and training hall that covers almost all of its energy requirements for the building and production using renewable energies on site. The business focuses entirely on solar energy and environmental heat. A 2,800 m² photovoltaic system with an output of 350 MWh forms the heart of the supply for the production hall. [78]

The solar power is used to heat, cool and light the building. To keep heat losses to a minimum, the outer shell consists of sandwich panels with integrated insulation. The two electrically driven heat pumps work with the water from the two suction wells and transfer the heat to two buffer tanks. Not only the heat from the heat pumps is fed into these, but also the waste heat from the machinery cooling system and the compressors. The heat is transferred from the buffer storage tank via underfloor heating in the production hall and via ceiling heating in the offices. The excess heat is fed into an innovative concrete core storage system. The energy storage system is a 600 m² large and 0.5 m thick concrete surface, which stores the heat energy by a concrete core activation. [79] Building and machinery are cooled by the groundwater from the suction wells. Energy-efficient daylight-controlled lighting has also kept power consumption low for lighting.

In production, the electricity requirement is also covered by the photovoltaic system and has been significantly reduced by more efficient machinery and the switch from cooling machinery to natural cooling. In addition, energy-intensive processes such as nitrogen production, water desalination and compressed air production take place when there is an excess of electricity. In this way, the surplus electricity can be used to replenish the respective stocks.

Solar power is also used to supply electric machines such as forklifts, construction machinery, lifting platforms and electric cars. Any excess electricity is fed into the public grid. The system functions through an integrated

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[78] Cf. Bundesverband Wärmepumpe (BWP) e.V. (2017).

[79] Cf. LEW Innovation Award (2015).

energy management system to which almost 100 measuring sensors and the control technology are connected. The energy flows are displayed via so-called dashboards and serve as control. By networking all processes, energy flows and loads can be precisely controlled. With this integrated energy concept, the enterprise saves 770,000 kWh of electricity and 350 t of CO_2 per year. [80]

3.6.3 oeding print GmbH

The company oeding print GmbH was founded in 1797 and specialises in high-quality industrial and advertising printed matter. In 2014, the enterprise opened its first "zero-emission printing plant" ("zero-emission building").

On the road to zero emissions, the enterprise focused on energy efficiency, energy recycling (waste heat recovery) and energy generation. The building shell of the new printing plant was highly insulated, so that the insulation value is 50 % below the requirements of the then valid Energy saving regulation (EnEV 2009). [81] Goods are delivered through thermal airlocks to reduce heat loss through air exchange. Presence- and daylight-controlled LED lighting also made it possible to achieve high conservations in the power consumption of the building.

The building's electricity requirements are covered by a photovoltaic system and its own combined heat and power unit with combined heat, power and cooling. Excess electricity is used in production or fed into the public grid. This means that 30 % of the electricity required for production can be covered by electricity generated in-house. [82] If additional electricity is required for production, only certified green electricity is purchased.

Heat and hot water are also produced regeneratively. A large part of the demand is generated by the block-type thermal power station and additionally

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[80] Cf. LEW Innovation Award (2015).
[81] Cf. Allianz für die Region GmbH (2015).
[82] Cf. oeding print GmbH (2017).

by heat recovery from the production processes and compressed air generation. The waste heat is stored in high and low temperature storage tanks and can be used for heating, hot water preparation and cooling by an adsorption chiller if required. [83]

[83] Cf. Allianz für die Region GmbH (2015).

4 NETWORKING WITHIN THE INDUSTRIAL ESTATE

By networking the enterprises among each other, there is an opportunity to further increase resource efficiency in the individual enterprises in addition to measures for resource efficiency. Since industrial estates are very different, the following section shows various strategies and approaches that can be applied to and adapted to the respective industrial estate.

4.1 Energy

Safe energy generation is essential in an industrial estate. Once the measures in the individual businesses with regard to increasing energy efficiency and the use of renewable energies have been implemented, there is still potential within the industrial estate.

4.1.1 Energy analysis in an industrial estate

The basis for a joint energy concept within an industrial estate is an analysis of consumption and potential. For this purpose, data on energy demand, energy infrastructure and potential are collected and entered in a suitable map of the area. Energy requirements include power consumption and heating/cooling requirements. In addition, information on the existing energy infrastructure, such as existing heating networks, combined heat and power plants, solar parks, private energy production plants, etc., should be identified. In the final step, the potential for renewable energies and industrial waste heat can be analysed. Energy quantities, possible surface areas and climatic conditions are taken into account. This poses challenges, as enterprises usually do not know their respective consumption or do not want to disclose the data for competitive reasons. It is an advantage if the enterprises belong to different industries. A solution for this can be a neutral neighbourhood manager, who takes over the task of data collection.

4.1.2 Exchange of energy

If a business has a surplus of energy that cannot be used sensibly in the enterprise itself, it can either transfer it to the public grid (e.g. electricity) or to another enterprise that can use this energy (e.g. waste heat). In both cases, the enterprise benefits and additional resources are saved.

There are possibilities to use waste heat, which cannot be avoided or used in the enterprise itself, inter-enterprise or to feed it into a **district heating network**. One advantage of feeding into an existing heating network is that these usually have central heat storage facilities and can thus compensate for fluctuations. The waste heat can usually be fed into the flow or return flow, whereby the temperature requirements change. The district heating network requires temperatures between 80 and 140 °C in the flow pipe and temperatures approx. 30 to 40 °C below the flow pipe temperature in the return pipe. In a local heating network, the temperatures are lower (flow: 70 to 90 °C, return: 50 to 55 °C).

For an **inter-enterprise waste heat utilisation** between individual enterprises, detailed information on the energy quantity, the temporal course and the stability of the waste heat is required. In Thuringia, an international project has created a waste heat register in which the quality and quantity of the waste heat source has been made visible.[84] A waste heat atlas is also already available in other federal states. In the further analysis it must be checked whether the properties and the load profile of the waste heat source match those of the heat consumer. The following framework conditions should be reviewed as a first estimation for a sensible waste heat utilisation:[85]

- The temperature required by the customer is approx. 20 °C below that of the supplier.
- The ratio of heat to distance is at least 2 MWh_{th} per meter (length of pipe) and year (impact on costs and energy loss).

Enterprises are often reluctant to enter into such interenterprise relationships because they shy away from the risk of dependency. If, however, an enterprise can demonstrate good operational stability and the customer plans a replacement supply, this risk can be significantly reduced.

84 Cf. Thüringer Energie- und GreenTech-Agentur GmbH (ThEGA) (no date).
85 Cf. McKenna, R.; Fichtner, W. (2011), p. 122 f.

4.1.3 Power supply

Three types of energy are usually used in an industrial estate: Electricity, heat and cold. Most of the conservations and efficiency gains take place within the enterprises themselves (Chapter 3.1). Part of the renewable energy can also often be generated directly by the enterprise. Nevertheless, most of them still need energy from the public grids.

Within an industrial estate, however, there is still further resource efficiency potential with regard to energy supply:

- Exchange of surplus energy, such as waste heat (Chapter 4.1.2),
- Planning of an energy supply concept for the entire industrial estate. The generation of renewable energies on common areas or the installation of a combined heat and power unit (CHP) for the common energy supply can usually significantly reduce CO_2 emissions.

Power supply

Community steps to reduce CO_2 emissions include, on the one hand, identifying further measures to increase energy efficiency in the industrial estate (e.g. street lighting) and, on the other hand, jointly selecting an environmentally friendly electricity provider. Electricity from renewable energy sources is often somewhat more price-intensive, but a higher purchase of electricity by several enterprises may allow more favourable conditions to be negotiated and the higher costs to be compensated. [86]

Heating and cooling supply for the industrial estate

For a conversion to renewable energies and waste heat utilisation, a **low-temperature heating network** is an option, as the temperature level is lower (up to approx. 70 °C) than in district heating networks and thus renewable energies can be integrated more efficiently. Further advantages are that grid losses are reduced due to the lower temperature difference to the environment (ground) and the connected parties can feed energy more easily. It is also possible to combine such a low-temperature heating network

[86] Cf. Müller-Christ, G. (2009), p. 31 f.

with intermediate storage tanks, such as a seasonal storage tank. In this way, the renewable energy produced can be used more efficiently, as more flexible coverage of supply and demand is possible. In Germany there are only a few realisations. In other countries, such as Denmark, low-temperature heat networks are more widespread. [87]

4.2 Material

During production, not only unused energy is generated, but also residual materials that can no longer be used in the enterprise itself. These residues can be reused by another enterprise or enterprises within an industrial estate can combine disposal if the properties of the residual materials are compatible.

4.2.1 Cross-business material flow cooperation

Due to the different types and qualities of material residual materials, it is often more difficult to find a way to reuse or recycle them in a neighbouring enterprise. In order to enable a material exchange, the material flows, in particular the output, must be analysed at the beginning. With the help of a material and material flow analysis according to VDI 2689 "Leitfaden zu Materialflussuntersuchungen" the quantity of the output can be recorded. [88] In addition, data on the quality of the residual materials should be recorded. The more precise the data on quantity and quality, the easier it is to find a buyer for the residual materials. The material flows should be as stable and available in sufficient quantities as possible, especially from the customer's point of view. [89]

The composition of the enterprises in the industrial estate also plays a role. The following main **enterprise relationships** can be distinguished: [90]

[87] Cf. Schneller, A.; Frank, L. und Töpfer, K. (2017), p. 8 f.

[88] VDI ZRE's short analysis "Resource efficiency in the value chain" explains VDI Directive 2689 in more detail.

[89] Cf. by Gleich, A.; Gößling-Reisemann, (2008), p. 145

[90] Cf. Liesegang, D. G.; Sterr, Th. (2003), p. 279.

The highest potential for a material flow cooperation is given in a supplier-customer relationship, since the businesses are already in contact and different input/output flows exist. With identical input/output flows, as is usually the case with enterprises in the same sector, the potential is low. However, it is possible to implement a common waste management system (Chapter 4.2.2). In the case of enterprises outside the industry, the input/output flows are different, but the enterprises are usually not in contact.

Table 1: Influence of the enterprise relationship on the potential of material flow cooperation

Enterprise relationship	Input/output streams	Teamwork	Potential
Supplier-customer relationship	Various	Information exchange in place	High
Enterprises in the same industry	Equal	Potential competitors	Low
Enterprises from outside the industry	Various	Usually no contact present	Remedy

In addition to the types and relationships of the enterprises, the **distance between the enterprises** also has an influence on possible enterprise cooperation. From an economic point of view, shorter distances are positive, as the infrastructure required for this is usually cheaper. This also depends on the type of infrastructure, such as pipelines or transport routes. Distance also plays a role in the life cycle evaluation, as the environmental impact of transport exceeds the conservations from reusing a material at a certain distance.

The industrial estate shows exactly the advantage of the spatial proximity between the enterprises. The realisation of a working group or a network within the industrial estate can promote the communication required for cooperation and the building of trust. Depending on the mix of the industrial estate, it may be helpful to expand the search for a cooperation partner regionally in order to increase the chances of material cooperation.

An example of the recycling of residual materials is the use of blast furnace slag from the steel industry in the production of cement. Not only is a by-product of high quality recycled, but it also replaces cement clinker. [91]

4.2.2 Waste management infrastructure

If residues remain as waste after the efficiency and cooperation measures, a joint residual materials disposal system offers further resource efficiency potential. For this it is necessary to know the quantity and quality of your waste. Among other things, the previous separation of waste, the emptying cycle, the amount of non-hazardous and hazardous waste, the quantity and type of pollutants play a role. These points can be covered by a waste balance sheet or a waste management concept. In addition, the waste management concept provides a framework for planning measures for waste avoidance and recycling and for estimating the future type and quantity of waste. The information on the waste can be used to evaluate the waste streams of the industrial estate and to find possibilities for joint disposal. Exploiting these synergies can reduce disposal costs [92]. In addition, the higher quantity may make a high-quality recycling route economically worthwhile[93] e.g. recycling old pallets in an inter-enterprise network.[94]

4.2.3 Further resource efficiency potential

Further possibilities for cooperation with regard to material within the industrial estate are the formation of purchasing syndicates and the establishment of exchange or loan systems.

- **Purchasing syndicates:** Combining purchases has the advantage that a larger quantity often leads to a discount and can reduce delivery traffic. The challenge here is to find a product that several enterprises need in roughly the same cycle. Examples are printer paper or other office supplies.

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[91] **Cf. Schneider, M., Meng, B. (2002), pp. 10 - 14.**
[92] **Cf. von Hauff, M.; Little A. (2014), p. 90.**
[93] **Cf. Liesegang, D. G.; Sterr, Th. (2003), p. 282.**
[94] **The recycling network in Chapter 4.5.5serves as an example.**

- **Exchange systems/ Rental systems:** Efficient use occurs when a machine, tool or product is working at maximum capacity. Therefore, the utilisation of capital-intensive machinery particular should be considered. If there is another enterprise within the industrial estate that also needs this machine, a rental system or tool pooling [95] can increase utilisation and save costs. The realisation of such a system results in additional administrative effort, which pays off depending on the cost of the object. [96] Not only machinery, but also rooms or cars can be shared. An example from agriculture are so-called machinery rings, in which farms join together to jointly use agricultural and forestry machinery and labour, but also knowledge. [97]

4.3 Water

Costs can be saved by saving fresh water and reducing the amount of waste water. In the following, various joint opportunities for enterprises to increase water efficiency are outlined.

4.3.1 Rainwater

With regard to rainwater, most of the resource efficiency potential lies with the individual enterprises. For the industrial estate itself, it is possible to return the rainwater to the natural water cycle through **joint retention and infiltration areas.** The advantage for enterprises is that they save on waste water charges. In general, the intelligent use of rainwater can also have a positive effect on the microclimate in an industrial estate: The risk of flooding and heat generation are linked to this. [98] However, the realisation of the measures must take account of various starting conditions, such as the degree of pollution or the nature of the soil. Developing a water management concept for an industrial estate helps to maintain an overview.

In addition, enterprises can enter into a **cooperation regarding rainwater**. A lot of rainwater accumulates on the large roof areas of industrial buildings.

[95] More information on the subject of "tool pooling" can be found in the VDI ZRE short analysis "Resource Efficiency in the Value Chain".

[96] Cf. rust, N. (2009).

[97] Cf. Maschinenring Deutschland GmbH (2017).

[98] Cf. City of Frankfurt am Main (2014), p. 45.

The amount of rainwater collected varies from enterprise to enterprise. A water-intensive enterprise could therefore purchase rainwater from an enterprise with low demand but high production (e.g. a logistics enterprise) and thus save drinking water. For the other enterprise, the costs of discharging rainwater into the sewer system are reduced. With the inter-enterprise rainwater utilisation, however, logistics and quality monitoring must also be organised and various legal questions must be answered. [99]

4.3.2 Waste water

After the process water has been used, it must normally be treated before it can be discharged into the public sewer or river in accordance with the regulations. Enterprises should therefore aim for a closed water cycle within the enterprise. If this does not succeed, there are further possibilities to increase water efficiency:

- **Waste heat utilisation:** Water is often used as a source of energy (heat/cold). For example, residual heat from an enterprise's waste water (Chapter 4.1.2) or waste heat from the sewerage system can be used. The required temperature can be reached with the aid of a heat pump. [100] An example is a furniture store in Berlin-Lichtenberg that uses the heat from the sewer system. [101]

- **Cascading use:** An inter-enterprise cascading use of water is suitable if the process water can no longer be used internally. A suitable buyer must be found in the industrial estate. Quality (pollution, toxicity, temperature, etc.) and quantity (quantity and regularity of the accumulation) are decisive for a potential customer. In the example of the Kalundborg industrial estate (Chapter 4.5.2), one enterprise can use the closed circuit cooling water of the other enterprise to produce steam from the already pre-tempered water. This saves both water and energy.

[99] Cf. Boots, R. (2017), p. 126.

[100] Cf. Urbansky, F. (2016).

[101] More information is available at: http://www.abwasserbilanz.de/wp-content/uploads/101213_schitkowsky.pdf

- **Common water treatment plant:** The treatment of waste water is usually carried out in the individual enterprises, as the type of preparation depends on the type of pollution. Since the composition of the enterprises in an industrial estate is often very mixed and therefore the waste water is also different, it becomes difficult to install a common water treatment plant. The waste water from the office and catering sectors is of equal value and can therefore be processed in a joint waste water treatment or recycling plant. [102] A joint waste water treatment plant can save material, energy and costs.

4.4 Surface area

The space efficiency in the industrial estate can be increased with various measures and strategies. The responsibility lies with the individual enterprises (Chapter 3.4). Much has already been laid down in the development plan, but there are still resource efficiency potentials that can be implemented jointly or through cooperation.

4.4.1 Use of space

One way to increase space efficiency in the industrial estate is to center uses. Many rooms are often not fully utilised, such as seminar rooms. These could be shared. Apart from the shared use of various facilities (canteen, central car park, kindergarten, truck scale, etc.), roof surface areas (including central facilities) or other unused surface areas (shared) could be equipped with photovoltaic systems. [103]

The sealed surface areas in the industrial estate could be checked. It may be possible to unseal some of these surface areas, e.g. visitor parking spaces. Unsealing surface areas saves costs (waste water charges) and contributes to local flood protection in the event of heavy rainfall and to improving the microclimate (see also Chapter 3.4).

[102] Cf. Drees & Sommer Advanced Building Technologies GmbH (2014), p. 25.
[103] Cf. Chamber of Industry and Commerce Northern Black Forest (2015), p. 13.

Existing residual and brownfield sites offer the possibility of compacting or revitalising them. Thus, unused surface areas can also be designed as common recreational surface areas. Extensive care can also contribute to biodiversity. The greening of traffic control elements (e.g. roundabouts) or edge strips is also a contribution to the sustainability of an industrial estate.

The surface area management can take over a central person of the industrial estate management, who records the surface areas and their uses. On this basis, an area concept can be created.

4.4.2 Infrastructure areas

The infrastructure areas occupy an important part of the industrial estate. On the one hand the employees have to come to the enterprises, on the other hand producing enterprises generate a high load traffic. In cooperation between enterprises, measures can often be found to reduce the volume of traffic, especially for passenger transport. The expansion of local public transport and of cycle paths, sidewalks or exchange platforms for commuter communities can make a positive contribution to this. For more or new surface area consumption for bicycle and pedestrian paths, land consumption must be taken into account. An intelligent traffic concept that is also fit for the future should therefore be developed in consultation with local enterprises, but also taking into account the wishes of those affected (commuters). Further ideas would be the installation of car sharing points and the extension of charging stations for electric vehicles. [104]

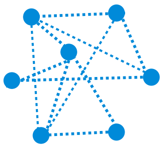
Efficiency can also be increased in the case of heavy goods vehicles. When planning an industrial estate, a good motorway connection can be taken into account, which relieves the roads around the industrial estate. Combining orders and collections can reduce traffic. The switch from heavy goods vehicles to electric or hybrid vehicles may offer a possible alternative in the near future. In most cases, however, the measures relating to freight transport are still associated with greater effort and investment.

[104] Cf. SME initiative on energy system transformation and climate protection (2016).

4.5 Realisation and examples

4.5.1 Realisation

In order to increase resource efficiency, e.g. through industrial symbioses, similar principles are usually used.



Networks promote trust: A basis of trust and openness is a prerequisite for the successful exchange of information and data between enterprises. It is often difficult to disclose data on material flows and emerging energies for competitive reasons.[105] A network with regular meetings for getting to know each other, for exchange and for further training can promote the necessary trust. The formulation of a common objective can further strengthen the network (see example 4.5.3).

Inventory analysis: The inventory analysis includes all information and data on an industrial estate. This includes data on the surface area, the infrastructure, the enterprises as well as data on energy and material requirements. The information on the individual material flows and available energies is essential to identify possible cooperation[106] (see examples 4.5.3, 4.5.4, 4.5.5).

Potential analysis: Potentials are analysed from the preceding stocktaking. This can reveal possibilities for resource efficiency in the individual enterprises and for industrial symbioses. The distance between the cooperation partners and the existing infrastructures play an important role here (see examples 4.5.3, 4.5.4, 4.5.5).

[105] Cf. Johnson, I. et al. (2015), p. 17.
[106] Cf. Gleich, A.; Gößling-Reisemann, (2008), p. 146.

Catalogue of measures: A catalogue of measures can be developed on the basis of the potential analysis. The resulting investment requirements and the technical expenditure of the individual measures must be ecologically and economically sensible (see examples 4.5.3, 4.5.4, 4.5.5).

“Low hanging fruits”: First of all, measures should be implemented with little effort but relatively high conservations in order to promote a positive mood and motivation (see example 4.5.4).

Climate manager: In the case of smaller enterprises, the time and personnel costs that arise as a result of the coordination and coordination effort involved in a merger of enterprises are a particular challenge.[107] A climate manager (or area manager) as an external person can support the enterprises in this.

The following examples illustrate the wide range of approaches and measures.

4.5.2 Industrial estate Kalundborg, Denmark

The Kalundborg industrial estate in Denmark is regarded as a pioneer of industrial symbiosis. It includes enterprises from the chemical, petrochemical, agrochemical and pharmaceutical industries as well as the electricity and building materials industries.[108] As early as the 1980s, the first investigations into cooperation between the individual enterprises began. Within approx. 15 years, numerous material cycles between the enterprises were created. The term "industrial symbiosis" was coined by this first functioning enterprise network.

The exchange of materials and energy in the Kalundborg industrial estate was not only planned for environmental reasons, but has also developed for

[107] Cf. Drießen, H. (2015).
[108] Cf. Schön, M. et al. (2003), p. 12.

economic reasons and has been further expanded over decades. The aim of the individual enterprises was to avoid the very high disposal costs in Denmark and to make an additional profit by transferring their surplus material and energy. This has enabled them to significantly increase their competitiveness. The prerequisites for the successful development of the symbioses were economic efficiency, mutual trust among the enterprise partners, a lack of fear of competition and short spatial distances. Some symbioses are briefly described here.

At the centre of the network is the largest Danish coal-fired power plant, Asnass. The steam generated there is used to operate turbines to generate electricity. When leaving the last turbine of the coal-fired power plant, the steam still has a temperature of 350 °C. This is where one of the first cooperation between enterprises began. In a newly installed heat network, the steam supplies heat to residential buildings and enterprises, including the refinery and a fish farm. In biotech enterprises, steam is used for fermentation processes in insulin and enzyme production.

In the future, the energy supply is to be switched from coal to biogas and biomass. New cooperation are planned with the changeover. The system of symbioses exists despite changes and project shutdowns, as the partners and symbioses are constantly evolving.

In addition to energy, the coal-fired power plant also produces other residual materials that can be used by other enterprises in the network. Flue gas desulphurisation produces REA gypsum, which is further processed in the gypsum plasterboard factory and replaces natural gypsum. The fly ash finds its way to a cement manufacturer. Even the biomass from the process water of the biotech enterprises can be reused. It is used to produce biogas or mixed with lime and processed into a high-quality fertilizer that is sold to farmers.

The natural resource groundwater could also be conserved through the use of surface water and cascading use. The waterworks processes the surface water of the lake and delivers it to the enterprises that use it to cool their production. In the refinery, the cooling water is conducted in a closed pipe system and is therefore not contaminated. It is passed on to the power plant where it is used to generate steam. In addition to the use of surface water, rainwater is also collected in a water reservoir and used in the power plant (Figure 8).[109]

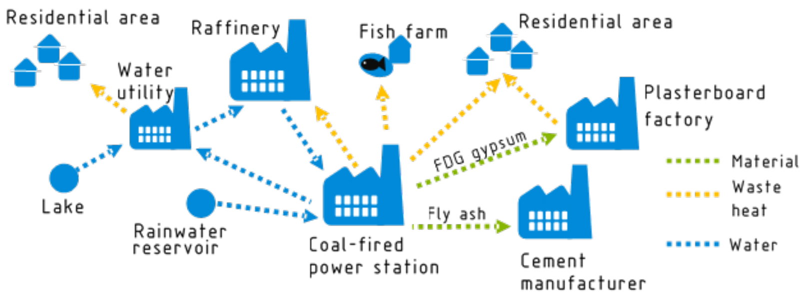


Figure 8: Industrial symbiosis of the Kalundborg Industrial Park[110]

Kalundborg can save approx. 3 million m^3 of water, 150,000 tonnes of natural gypsum[111] and 240,000 tonnes of CO_2[112] annually through the many measures of industrial symbiosis. The enterprises spent a total of approx. US$ 60 million on the expansion of the new materials infrastructure. Annual revenue is estimated to be approx. US$ 10 million and the average payback period is five years.[113]

4.5.3 "NEMo", industrial estate Motzener Str., Berlin

The 112.5 ha industrial and industrial estate on Motzener Straße in the south of Berlin has set itself a major goal: zero CO_2-Emissions by 2050. 5,000 people are employed in 200 enterprises at the site. Half of these enterprises, i.e. 80 % of all employees in the industrial estate, work in the manufacturing sector. The focus is on metal processing, mechanical engineering and plastics processing. In 2005 the location initiative Enterprise Netzwerk Motzener Straße was founded, which in 2016 created the ambitious climate protection

[109] Cf. Kalundborg Symbiosis (2016).
[110] Cf. Kalundborg Symbiosis (2016).
[111] Kalundborg Symbiosis (2016).
[112] Deffke, U. (2009).
[113] Cf. Schön, M. et al. (2003), p. 13.

sub-concept for the project "NEMo" (Zero Emission Motzener Straße). A total of 60 enterprises with almost 2,500 employees participate in the project. [114] The aim is to reduce CO_2-Emissions by 40 % by 2030.

In order to achieve this milestone, a climate protection sub-concept for ten to 15 years was first drawn up. The starting point was an inventory and a CO_2 balance based on it. Potential analyses were carried out for selected fields of action and a catalogue of measures was drawn up.

The corporate network's strategy is to raise awareness of resource efficiency issues through events and publications and to bring different enterprises together to exchange experiences. Every month, enterprise meetings are held at which neighbouring enterprises can introduce themselves, get to know each other and, if necessary, enter into cooperation agreements with other enterprises. The exchange of information on current resource efficiency measures is also always on the agenda. Through these meetings, many of the site's enterprises were motivated and supported to implement measures to increase resource efficiency.

In the context of the CO_2 balance it was determined that approximately 2/3 of the emissions in the Motzener Straße industrial estate are attributable to the generation of heat and mechanical energy. The measures therefore concentrate on these areas of application. Examples of implemented measures are: hydraulic balancing of heating systems and energy-efficient building renovations in order to save energy for the generation of space heating. The enterprise also plans to optimise processes, use heat recovery systems, improve machinery maintenance and switch to electric motors in production. [115] A number of enterprises have already switched to LED lighting. Five enterprises offer e-charging stations, some for their employees, and have supplemented their vehicle fleets with e-cars. In addition, photovoltaic systems are installed in the industrial estate, which together cover a surface area of over 12,000 m^2. A dozen enterprises have undergone a comprehensive resource check and determined that in individual cases up to 88 % CO_2

[114] Cf Business network Motzener Straße e.V. (2017).
[115] Cf Business network Motzener Straße e.V. (2016).

could be saved – at economically justifiable costs. The enterprises have already started to switch to green electricity and various projects are planned to use landfill gas and heat from waste water in the future. Incentives are to be created for the employees to reach the industrial area by public transport instead of by private car (regional train station, "mobility hubs").

In order to make the use of water resources more efficient, bio-waste water treatment plants are to be constructed to clarify grey water and rainwater drainage systems. Measures to improve the infiltration of rainwater have already been implemented. An enterprise in the network has constructed a new infiltration trough to which 25 % (almost 4,000 m^2) of the sealed surface area has already been connected. This not only makes ecological sense (protection of the groundwater level), but also leads to an annual conservation of € 12,000, as the rainwater discharge fees for this surface area are no longer applicable. [116]

A 400 m long hedge was planted to date, which saves 4,000 kg of CO_2 per year. [117] In addition, almost ten years ago, a day nursery close to the enterprise with 80 places in the meantime was set up as a result of cooperation within the network. [118]

The NEMo project has been honoured as an "Awarded Landmark 2016" in the national innovation competition "Germany - Land of Ideas".

4.5.4 Industrial estate Ludwig-Erhard-Allee, Bielefeld

In the east of Bielefeld is the Ludwig-Erhard-Allee industrial estate, one of the largest commercial areas in Bielefeld. The area covers about 116 hectares and employs about 2,300 people in over 50 enterprises, including manufacturing (36 % of employees), services and logistics. [119]

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[116] Cf Business network Motzener Straße e.V. (2018a).

[117] Cf Business network Motzener Straße e.V. (2018b).

[118] Cf Business network Motzener Straße e.V. (2018c).

[119] Cf. Zero Emission GmbH (2015).

The objectives are to reduce CO_2 emissions by 40% by 2020 and to achieve CO_2 neutrality by 2050. In 2016, a climate protection sub-concept was developed in six steps (inventory – potential analysis - catalogue of measures – public relations concept – controlling concept).

The potential analysis for the industrial estate showed that the majority of emissions are generated by space heating, hot water (25 %) and mechanical energy (23 %) as well as lighting (20 %). A high technical and economic potential for the use of solar energy via photovoltaic and solar thermal systems was revealed. However, only roof areas are to be used for this purpose. The potential for the use of wind energy was classified as mediocre. [120]

Concrete measures to increase energy efficiency are, for example, the introduction of smart metering (intelligent electricity meters), energy-efficient building refurbishment, heating balancing or the optimisation of compressed air systems. In a vote on possible measures, the introduction of LED lighting, the use of photovoltaic systems and biogas CHP plants were considered favourites.

Other planned measures included the expansion of public transport and joint stations for electric bicycles in order to exploit synergies in the industrial estate.

4.5.5 Pfaffengrund recycling network, Heidelberg

The Pfaffengrund industrial estate covers a surface area of approx. 93 ha and is one of the largest closed industrial estates in Heidelberg. Approximately 45 enterprises with a total of 7,500 employees are located at the site. [121]

As early as 1996, a project was initiated with the aim of establishing an inter-enterprise recycling network in the Pfaffengrund industrial estate in Heidelberg. The model was the Kalundborg industrial estate. Initially, individual discussions were held with the enterprises and the internal waste management was analysed. Waste data was recorded in the individual plants, with

[120] **Cf. Zero Emission GmbH (2016), p. 132.**

[121] **Cf. Drees & Sommer Advanced Building Technologies GmbH (2014), p. 15.**

the type, quantity and disposal price components of the waste streams being recorded separately. In this way, weak points within the enterprise could be identified and the first internal optimisations and cost conservations could already be achieved. [122]

Then the inter-enterprise level was considered. This resulted in a data pool on the waste quantities and qualities recorded. On this basis the following cooperation partnerships could develop: [123]

- One corrugated board producer accepted certain quantities of waste paper from other enterprises.
- A fluorescent advertising manufacturer agreed to collect fluorescent tube waste from other enterprises and to dispose of it with its own, as certain disposal routes only become economically viable when a critical amount of material is involved.
- A ring traffic system was developed for the processing and further use of wooden pallets.
- One enterprise was able to incorporate the polyethylene waste of a neighbouring enterprise into its own production process after internal preparation.

Many of the cooperation still exist today and a working group "Material Flow Management" has been established. The recycling network led not only to a reduction in transport kilometres and disposal costs, but also to a general reduction in disposal volumes. [124]

[122] Cf. Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (2014), pp. 55 ff.

[123] Cf. Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (2014).

[124] Cf. Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (2014), p. 57.

4.5.6 Cross-enterprise use of process waste heat

The Singen-based enterprise Georg Fischer Automobilguss GmbH produces 200,000 tonnes of castings per year for the automotive industry. [125] Iron is produced in a hot-blast cupola furnace. Only one third of the waste heat generated can be used for internal purposes. In 2008, the enterprise therefore decided to replace its old recuperator with one that was up to 20 % more efficient (up to 14 MW can be used in addition) and to build a 400 m long piping system to supply the neighbouring Nestlé Maggi plant. [126] Excess waste heat is decoupled and used by the food manufacturer year-round to generate steam for a fee. This has enabled the Nestlé Group to reduce its consumption of natural gas for steam generation by two thirds and its CO_2 emissions by 11,000 tonnes per year. The steam is used for the sterilization of food as well as for drying processes and other thermal processes. The hot thermal oil (energy carrier) is fed from the recuperator of Georg Fischer Automobilguss GmbH via the piping system to Maggi's boiler house and into a safety heat exchanger. A total of up to 50,000 MWh of energy are to be saved. [127]

If the waste heat delivery by Georg Fischer Automobilguss GmbH fails, Maggi can immediately fuel the steam boiler located in its enterprise with crude oil. This ensures a secure supply in the enterprise.

The pilot project is also economically interesting for the two enterprises. Maggi pays a contractually fixed price per megawatt delivered, which is lower than the price of the natural gas it previously purchased and also guarantees price stability. Georg Fischer Automobilguss GmbH also expects the project to pay for itself quickly, as they can sell the unused waste product, waste heat, to their neighbours. In addition, the Federal Ministry for the Environment funded the pilot project within the framework of the Environmental Innovation Programme with € 700,000. [128]

[125] Cf Georg Fischer Ltd (2009), p. 3.

[126] Cf Bettinger, F. and Kenzler, M. (2009), p. 6.

[127] Cf. Ministry of the Environment, Climate and Energy Baden-Württemberg (2014), p. 25.

[128] Cf. Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (2008).

5 NETWORKING WITH RESIDENTIAL AREAS

The separation of commercial and residential areas is dissolving more and more. The cities grow and enclose the industrial estates often located on the outskirts of the city. In addition, production in the city will become more attractive as the connection to the potential employer is a decision-making factor and customer proximity will become more important for the enterprises. Production in urban areas with its opportunities and challenges is becoming more and more the subject of discussion and is the subject of various research projects [129]. In the following, the conflict potentials and the relationships between industrial estates and adjacent residential areas with regard to resource efficiency potentials will be examined in more detail. Most of the potential lies in the surface area of energy and space. Water and material resources have little potential for synergies and are therefore not considered.

5.1 Conflict potentials

There are various conflict potentials in industrial estates near residential areas. Noise emissions from industrial estates, increased traffic volumes and climate-damaging emissions are the main points of discussion. If the industrial estate has been further developed after the previous resource efficiency measures, it has greatly reduced its emissions. Nevertheless, further noise abatement measures should be examined, as should a traffic concept that relieves the residential areas. Among other things, these conflict potentials can be reduced by the following measures:

- minimisation of pollutant emissions through modern filter technology,
- air cleaning by greening street elements and buildings,
- reduction of noise emissions through structural measures and low-noise production processes,

[129] Cf. Institute for Work and Technology of the Westphalian University of Applied Sciences Gelsenkirchen (2017), p. 11.

- minimisation of the traffic volume by an efficient connection to the public transport and goods transport network and
- reduction of the traffic load in residential areas through a short connection to main traffic axes (e.g. motorways).

Due to the growth of cities, more and more industrial estates are being surrounded by residential buildings. As a result, the industrial estates can hardly expand any further in terms of space. A solution for enterprises can be vertical production or a floor factory. In a vertical production, production steps or units are arranged spatially one above the other. This means that less surface area is built over and required.[130]

The traditional Austrian enterprise Manner switched its production to vertical production (Figure 9). This enabled the enterprise not only to expand its location in the city of Vienna (30 % increase in space), but also to increase its energy efficiency through the internal use of waste heat.[131]

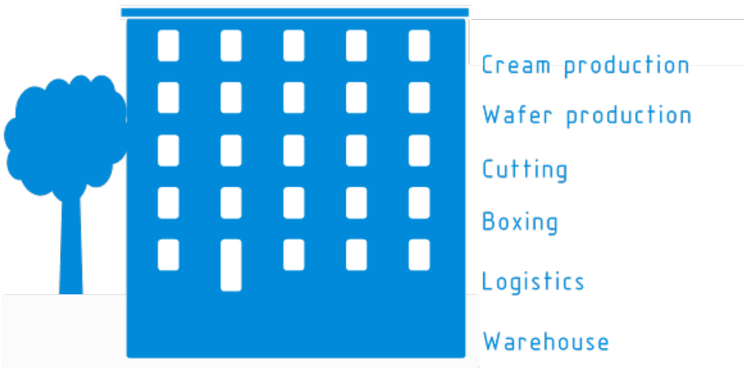

Figure 9: Exemplary vertical production of a confectionery manufacturer

[130] Cf. Neckhaim Consulting GmbH (2018).
[131] Cf. Josef Manner & Comp. AG (2015), p. 2.

5.2 Energy

Industrial estates not only use a lot of energy but also emit it, mostly in the form of waste heat from heat-intensive production steps such as kilns or cross-sectional technologies. If this waste heat can neither be avoided nor used in the enterprise itself, it is possible to make this energy available to external customers. These do not necessarily have to be located within the industrial estate, as described in Chapter 4.1.2. Nearby residential areas can also use the waste heat. The individual parts of the technical solution (e.g. heat pumps) for the realisation of a heat network between enterprises and residential buildings are known. It is possible to plan the network as a long-distance, local and low-energy grid depending on the temperature range [132] of the waste heat.

Opportunities for all parties involved in a heat network:

- different expansion stages of the heat sinks, [133]
- use of waste heat considered emission-free, [134]
- image gain for the enterprise and increase of sustainability in the enterprise and
- establishment of a relationship between the enterprise and the residential area: positive atmosphere, higher acceptance for the local enterprises.

Special features of a heating network with industrial waste heat:

- high organizational expenditure by different involved parties: Enterprises, public authorities, heat consumers, contracting partners,
- long payback periods: Planning for the long term,

[132] Further details on the temperature ranges are given in chapters 4.1.2, 4.1.3.
[133] Cf. Kühn, A. (2017), p. 16.
[134] Cf. Fraunhofer Institute for Environmental, Safety and Energy Technology (1998), p. 20.

- a required minimum number of heat consumers or a heat quantity (for consumers, the changeover/connection must be profitable),

- legal peculiarities must be clarified (e.g. an assurance of waste heat for x years),

- high initial investment, depending on the transport distance and

- protection by a conventional replacement heat generator.

Due to the increased organisational effort and legal challenges, only a few projects have been implemented to date (Chapter 5.4). The new subsidy programmes for waste heat utilisation or for pilot projects "Heat Networks 4.0" (low-temperature heat networks) provide financial support for enterprises and municipal enterprises in implementing them.

5.3 Surface area

Most industrial estates stand for asphalted roads, large industrial buildings and unattractive open spaces. After work, the industrial estates are emptied and avoided. Due to the many sealed surface areas and the small proportion of green and water surface areas, heat islands are created which have a negative impact on the urban climate. By integrating the industrial estate into the surrounding area, both its attractiveness and the urban climate can be improved.

- **Green networking**: When greening an industrial estate, the surroundings should be taken into account so that "green corridors" can be created that link the industrial estate with its surroundings. In addition, the wind direction can be taken into account in order to reduce the warming of the industrial estate. In an existing industrial estate, existing green areas can be upgraded by planting trees and hedges.

- **Social venues:** By creating public meeting points, such as cafés or fitness centres, the attractiveness of the industrial estate is increased not only for the employees but also for the residents. In addition, public offers provide for a revival of the industrial estate after working hours.

- **Path guidance:** Attractive footpaths and cycle paths allow the industrial estate to open up to residents and thus become an active part of the city.

The integration of the industrial estate into the urban fabric enlivens the industrial estate and increases the quality of living. It improves the quality of local recreation for employees and residents, which contributes to making the location even more attractive. The revitalisation of the industrial estate also increases the feeling of security. Further advantages are the resulting efficient land use in the area, even outside working hours, and the improvement of the urban climate (greening). The measures should already be taken into account in the planning of an industrial estate. For existing industrial estates, a concept can be developed in cooperation with the public authorities. [135]

5.4 Examples

5.4.1 Local heat supply through industrial waste heat

In cooperation with Waffelfabrik Meyer zu Venne GmbH & Co KG, Venner Energie eG, the citizen energy cooperative founded by the municipality and the citizens, has realised a local heating supply through industrial waste heat and can thus save more than 1,100 t CO_2 annually.

The production processes in the wafer factory generate approx. 10 million kWh of waste heat annually. Before the realisation of the "waste heat project", this was given away unused to the environment. As part of a climate protection concept of the district of Osnabrück, the idea of a local heat supply through industrial waste heat was born. Thanks to good cooperation between politics, administration and the population in the municipality of Ostercappeln and the Meyer zu Venne enterprise, the local heating supply with 154 adjoining properties could be realised.

The waste heat heats the heat transfer medium water to approx. 90 °C, transports it to the houses by means of a local heating network and transfers it via house stations. Fluctuations in demand and supply are compensated by

[135] Cf. Wissenschaftsladen Bonn e.V. (2017), pp. 15 f.

a buffer tank with a volume of 1,000 m^3. Two additional boilers are installed for the supply at peak loads.

The costs for the construction of the local heating network, the buffer storage, the two peak load boilers and the 154 house stations amounted to approx. € 3.94 million. Approximately € 1 million of this was used as KfW financing. A further € 2.7 million was financed through loans, the remaining costs being borne by the cooperative. The investments will have paid for themselves in about ten years. [136]

5.4.2 Industrial waste heat in Hamburg

In cooperation with enercity Contracting Nord GmbH, the copper group Aurubis AG intends to supply part of the waste heat generated by the enterprise to Hafencity Ost.

The copper group Aurubis AG produces copper cathodes and various copper products from them. During production, waste heat is generated which can be decoupled by three strands in the plant. About 160 million kWh per year can be produced from one string. The enterprise uses part of the industrial waste heat itself and can therefore dispense with the use of natural gas for steam generation. This enables the copper producer to save around 10,000 tonnes of CO_2 per year in its own operations. Another part of the waste heat (70 million kWh) is decoupled and delivered to the plant boundary. Enercity organises the securing and onward transport of the heat to the respective areas of use. Due to the decoupled heat quantity, Hafencity Ost would be supplied almost exclusively with waste heat from Aurubis.

Hafencity Ost can save around 4,500 tonnes of CO_2 per year in its final phase (target is 2029). [137] The German Energy Agency (dena) has described the project for the agreed district heating supply as a "lighthouse for energy-efficient waste heat utilisation". [138]

[136] Cf. German Institute of Urban Affairs (2016).
[137] Cf. Deutsche Energie-Agentur GmbH (dena) (no date).
[138] Cf. Deutsche Energie-Agentur GmbH (dena) (2017b).

5.4.3 Low-temperature network Meitingen

The market community of Meitingen, the SGL Group and the Showa Denko Carbon Division are planning to implement a low-temperature network to supply a nearby new housing estate.

The products of the two enterprises must be cooled after the high-temperature processes (up to 3,000 °C). The cooling water, which heats up to 30 °C, is fed into the local heating network. Every hour, 40 m^3 of cooling water flows into the grid and can thus supply 125 residential units in the nearby development area with heat.[139] With the help of heat pumps in the houses, the waste heat can be raised to the required level. A daily storage tank is to serve as a buffer, enabling energy-flexible operation. This means that electricity supplied from renewable energies can be used efficiently. The cooled water flows back to the enterprises so that it can be used again for cooling. This creates a closed circuit.

1.5 million kWh of energy per year can be covered by the enterprise' waste heat. In comparison, this would require 150,000 litres of heating oil. The Bavarian Förderverein Kumas – Kompetenzzentrum Umwelt e.V. awarded the project the title of Lead Project 2017.[140]

[139] Cf. VMM Wirtschaftsverlag GmbH & Co KG (2017).
[140] Cf. KUMAS - Kompetenzzentrum Umwelt e. V. (2017)

6 CONCLUSION

The present brief analysis shows resource efficiency potentials in industrial estates. Their special feature is the local accumulation of enterprises. In addition, the issue of "zero-emission industrial estates" is increasingly coming to the fore, as industrial estates are often surrounded by growing cities.

Most resource efficiency potentials lie within the enterprise itself. Once these have been exhausted, there is further potential for networking within the industrial estate or with adjacent residential areas.

Figure 10 provides an overview of the opportunities and challenges of the three areas under consideration.

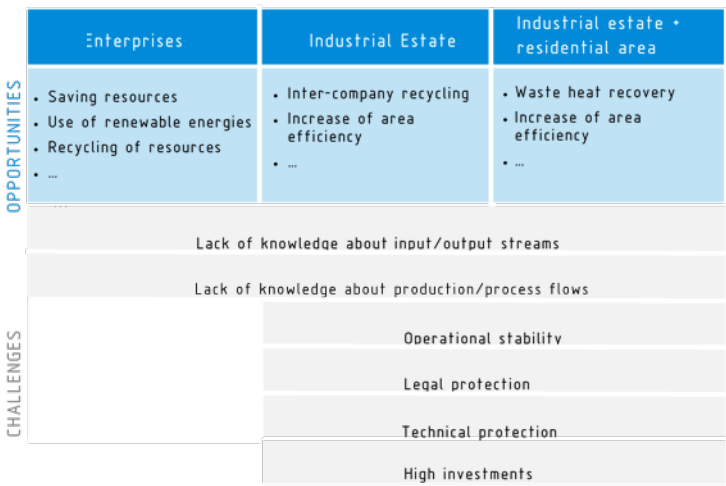

Figure 10: Overview of opportunities and challenges

Chances

Enterprises, industrial estates and networking with adjacent residential areas hold great potential for resource efficiency. Both internal and external resources can be reused and a closed cycle can be created. In the industrial estate, the main inter-business measure is the potential of waste heat. This can also be taken from surrounding residential areas. Materials can also continue to be used beyond the enterprise, although it is much more difficult to find a suitable customer than for waste heat. The shared use of facilities such as canteens or seminar rooms makes it possible to use surface area more efficiently. Many of the efficiency measures implemented in industrial estates and in the networking of residential areas are still "lighthouse projects" that demonstrate the potential of networking.

Challenges

In order to increase resource efficiency and network with other enterprises within an industrial estate or with surrounding residential areas, the input and output flows as well as the production and process flows in the enterprise itself must be known. However, this is often not the case. Cooperation between enterprises can only develop on the basis of secure data. To this end, enterprises must also acquire knowledge of the rough resource flows of neighbouring enterprises. They often hardly know anything about each other.

The individual enterprises should be able to guarantee their operational stability in order to reduce the risk for a cooperation partner. They should have continuous and stable production without significant downtime and should also be economically stable. This is because a failure in an inter-enterprise cooperation involves a considerable risk for the customer.

In order to reduce this risk, the cooperation partners should take out legal insurance. In a contract, the purchase of a resource should be specified for a specific period of time. Furthermore, agreements should be made in the event of supply failures in an enterprise.

In addition to legal protection, enterprises should also protect themselves technically with a "Plan B" for each project in order to be able to react immediately in the event of sudden changes or breakdowns. In an industrial symbiosis, all partners should consult each other regularly and develop or adapt these further in the face of foreseeable changes.

In addition, inter-enterprise networking with its additional security system can initially involve high investment costs.

Notes on realisation

This brief analysis shows various drivers that facilitate the realisation of resource efficiency measures in industrial estates (Figure 11).

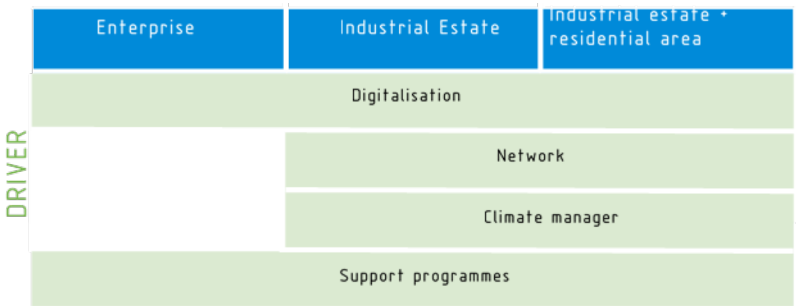

Figure 11: Drivers during realisation

One driver can be seen in the increasing digitalization, which offers many possibilities for better recording of resource flows in the enterprise and networking of data flows between enterprises. New technologies such as block chains, which promise a secure exchange of information and transactions (e.g. smart contracts, peer-to-peer networks), can also be useful.

For enterprises in industrial estates, merging into a corporate network is an important step towards building the necessary mutual trust and profiting from shared experience and knowledge. There, measures can be planned and prepared together. By bundling the knowledge of the individual enterprises and central control by one or more "network managers", enterprises can often share costs and effort. The establishment of an enterprise network with regular meetings can be meaningful for it.

An external climate manager can be useful to support the project. He can take over parts of the organization and relieve the enterprises of time. As a neutral contact person, it is usually easier for him to collect enterprise data. The prerequisite for this is an additional confidentiality agreement.

Support programmes that provide enterprises with financial support may prove helpful in implementing resource efficiency measures in industrial estates. In the current funding period until December 2019, the Federal Environment Ministry is funding climate protection sub-concepts in industrial estates. Following the preparation of such a climate protection sub-concept, the employment of a climate protection manager in the industrial estate and the realisation of various measures will also be promoted. [141]

Outlook

In the future, networking will play a major role, on the one hand through digitisation, and on the other through the convergence of areas with different uses. The resulting symbioses offer a high potential to save resources and should therefore be used.

[141] **More information is available at www.klimaschutz.de/kommunalrichtlinie**

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Im Auftrag des:
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für Umwelt, Naturschutz
und nukleare Sicherheit

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