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MSc Program (07/09)
Renewable Energy in Eastern and Central Europe

Heat recovery from wastewater of the paper-mill in Augsburg; data acquisition and potential study

A Master Thesis submitted for the degree of
„Master of Science“

supervised by
Mag. (FH) Josef Walch

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Augsburg, September 30th 2009

Affidavit

I, Christian Bratzdrum, hereby declare

- that I am the sole author of the present Master's Thesis, "Heat recovery from wastewater of the paper-mill in Augsburg; data acquisition and potential study" 59 pages, bound, and that I have not used any source or tool other then those referenced or any other illicit aid or tool, and
- that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Augsburg, September 30th 2009 ______________________________

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Relying strongly on internal data from UPM-Kymmene Augsburg and the wastewater treatment plant, I appreciate the interest from both sides and help besides the daily business. The meeting and following tour at the paper-mill with Mr. Meister, Mr. Kienle and Mr. Krodel were essential for the potential analysis. The study profited a lot from the visit at the wastewater treatment plant and discussions with Mr. Stegmayer, manager of the plant.

Special thanks go to my employer Dr. Spiegel (CheMin GmbH) for supporting my passion for renewable technologies and Alke Smeja for her patience and understanding as well as my parents.

Abstract

Large amounts of low-caloric heat are wasted every day in our wastewater. The discharge of large, energy consuming industries such as the UPM-Kymmene paper-mill in Augsburg has an average temperature of 35°C, yet the huge heating potential is inadequately investigated. Data acquisition from UPM and the municipal wastewater treatment plant are essential to evaluate the exact amount of useful heat. The best technical and economically most feasible solutions for the heat recovery from wastewater are discussed. Characteristics of the wastewater from the paper machines favour inexpensive plate heat exchangers to heat freshwater from the borehole for the paper production process. A temperature reduction of the wastewater by 5°C results in an annual heat recovery of 7.9 GWh and 11.6 GWh for the two paper machines. The utilisation of this low-caloric energy source can reduce the overall primary energy demand of the paper-mill by 1%, which equals to annual savings of approximately 200,000 m^3 of gas and respectively 5,000 t of CO_2 immissions. This potential, otherwise wasted in the canalisation can also be used in combination with a heat pump to cover heating and cooling demand. Projects of that type show economic and ecological benefits and Augsburg definitely has excellent potential with minor risks.

List of abbreviations and indices utilised in equations

abbr.	unit	explanation
$\dot{Q}$	W	thermal energy, heat flow
A	m^2	surface area
T	°C	temperature
Δ	-	delta - difference
k	$W/(m^2*K)$	coeff. of heat transmission
λ	W/(m*K)	thermal conductivity
ϑ	K	temperature
s	m	material thickness
r	m	radius
L	m	length
$\dot{M}$	kg/s	mass flow rate
C	W/(s*K)	heat transfer capacity
ρ	kg/m^3	density
$\dot{V}$	m^3/s	volume flow rate
c	J/(kg*K)	specific heat capacity
α	$W/(m^2*K)$	heat transfer coefficient
f	-	fouling factor
V	m^3	volume
X	kg	mass of solids
S	$(m^3*kg)/d$	loss of sludge
Q	m^3/d	flow rate
SA	d	sludge age
μ	d^{-1}	growth rate
SF	-	safety factor
NTU	-	number of transfer units
R	-	ratio of heat transf. capacity
P	-	temp. changes of two flows
NPV	€	net present value
C	€	cash-flow
T	a	time of operation
t	a	time
NII	€	net initial investment
PV	€	present value
k	%	discount rate
PI	€	profitability index
NINV	€	net investment

index	explanation
he	heat exchanger
w	(waste)water
i	inner
o	outer
la	large
sm	small
res	resulting
ab	aeration basin
ex	excess
avg	average
cl	clarifier
tot	total
max	maximum
nit	nitrificants
aer	aerobic
ano	anoxic

Table of contents

List of figures

List of tables

1. Introduction

Waste heat from industrial processes and the municipal sewer are sources for low-caloric energy, which have great potential as sustainable heating alternative. Having a higher energy content than groundwater, which is utilised with surface geothermal heat pumps, this source of heat is more important in densely populated areas. On the one hand the recovery of waste heat reduces the dependency on fossil fuel imports and rising prices; on the other hand it increases the value of the industry and municipal sewer system.

Large paper-mills, such as UPM-Kymmene in Augsburg discharge large quantities of wastewater with an average temperature of 35°C to the canalisation. Heat exchangers of manifold designs can be used to access this heat source. Data acquisition and evaluation of the wastewater characteristics are essential for the energetic utilisation. Annual flow rates and temperatures for both paper machines are very promising, yet interactions with the wastewater treatment plant have to be considered.

Technical solutions for utilisation of the high volumes of warm water from the paper machines are discussed. Less solids and bulky material allow easier handling in comparison to communal wastewater. Heat exchangers for the application on site of the paper-mill are analysed for the most efficient recovery of this low-caloric energy. For the most suitable design, an economic analysis is conducted. Knowing the large heat demand for paper production, the project should not only reduce the primary energy use, but the heat recovery should also be profitable, which is shown by its net present value. Overall, the ecological benefit of using energy which otherwise would be wasted in the canalisation, is obvious.

This feasibility study should show the potential and costs for the heat recovery from the paper-mill's wastewater. Changes in the complicated water recycling system are expensive, for that reason the potential may not be used and would be available in the municipal sewer. Although applications with more than 20 years of experience exist, the utilisation of heat from wastewater is still not very common. With rising oil and gas prices, these alternative heating systems become more and more attractive.

2. Project framework

The city of Augsburg and the bifa environmental institute are currently (since March 2009) working on a project to develop an energy strategy for the economic region. The aim of the project is to provide a concept for the efficient utilisation of low-caloric energy and further use of renewable energy sources. As a basis for this study, it is essential to assess all sources and possible consumers of low-caloric energy. As its utilisation strongly depends on the exact knowledge of available amounts throughout the year, the characteristic data for supply and demand have to be researched. Furthermore, the technical feasibility, legal restrictions and economic value are part of this study, which is financed by the "Bayerischen Staatsministerium für Umwelt und Gesundheit (StMUG)".

Special focus of the project is the low-caloric rejected heat from the waste incineration plant, the gas turbine and the biomass boiler of the communal energy supplier and the refuse derived fuel incineration plant of a chemical industry park. Besides geothermal sources and biogas plants, large amounts of heat are continuously produced from paper production or intermittent from metallurgic processes. All partners from industry and communal authorities closely work together to find the best economical and ecological solution for Augsburg.

Being one of the leading paper companies, UPM-Kymmene is constantly improving its environmental performance. The paper-mill in Augsburg has a production capacity of approximately 500,000 t/year. Since 2000, one of the most modern Light Weight Coated-paper (LWC) production lines called PM3 is in operation. The evaluation of an energetic utilisation of the wastewater from both paper machines in Augsburg is the major task of this master thesis within the framework of the study.

3. Wastewater as a source of heat

3.1. Concept of heat recovery from wastewater

For the reduction of greenhouse gas emissions, the first approach should be an increase in efficiency and utilisation of existing energy sources, such as wastewater. The sewage of households and industry is typically seen worthless, although a thermal utilisation is often possible. Local authorities often know about the possibilities of heat recovery from wastewater, but usually do not see the full potential. A study of the “Deutsche Bundesstiftung Umwelt” (DBU, 2005) estimates a combined heating potential for 2 to 4 million households at several thousand locations in Germany. This would result in a CO_2 reduction of 2 billion tonnes per year.

Together with the sewage water, unused heating energy runs through the canalisation to the wastewater treatment plant. Therefore the heat recovery becomes energetically and economically interesting. In existing projects, a heat exchanger and a heat pump are combined to heat public buildings and/or private houses via local district heating networks. Characteristically, this heat recovery technique is used to supply base load heating, while an additional boiler is started for peak demand (Schmid-Schmieder, 2009). In combination with a combined heat and power (CHP) plant, such a multivalent system works very efficiently and ecologically.

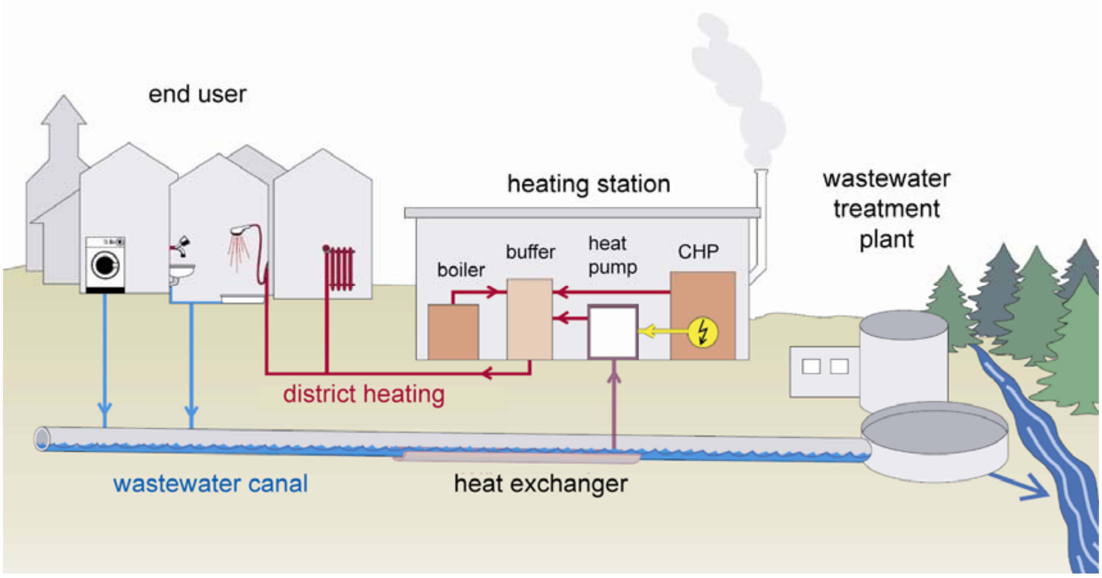


Figure 3-1: Schematic illustration of multivalent heating system with heat recovery from wastewater (EnergieSchweiz, 2005)

The utilisation of a heat pump reduces the demand of primary energy by at least 10 % in comparison to a modern condensing gas boiler and up to 44 % in comparison to oil (DBU, 2005). Heat pump systems based on the utilisation of wastewater can reach very high seasonal performance factors (SPF) up to 4, due to the very constant heat supply in the sewer. A further application for the heat pumps could be the cooling of buildings in summer. In comparison to conventional heating systems, the heat recovery from wastewater reduces CO_2 emissions. Figure 3-2 shows the energy flows of multivalent heating system with a CHP plant, heat pump and heat recovery from wastewater.

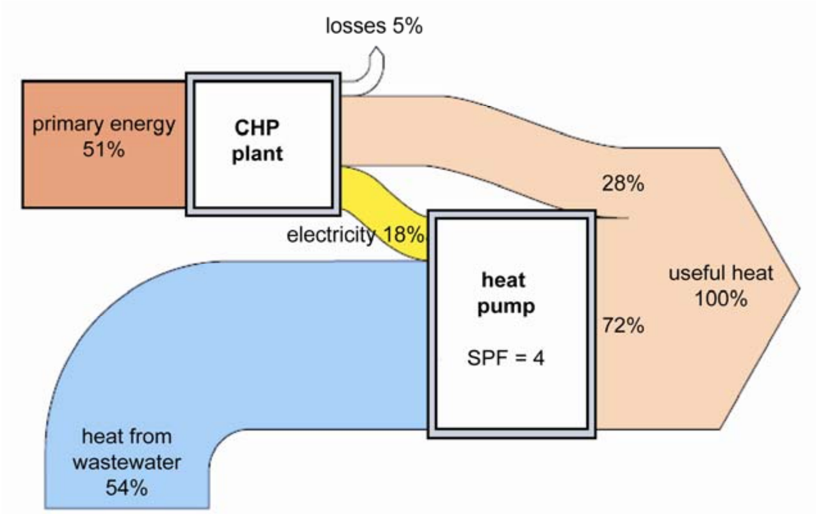


Figure 3-2: Energy flow diagram for multivalent wastewater heating (DBU, 2005)

3.2. Heat exchangers suitable for wastewater application

In a heat exchanger the two flowing media are separated by the exchanger surface, which is the essential connection between the energy in the wastewater and circulating media. Its transfer of thermal energy $\dot{Q}$ [W] is strongly depending on the surface area of the heat exchanger A_{he} [m^2] which is overflown by the wastewater, the mean temperature difference ΔT_w [K], as well as the materials coefficient of heat transmission k [W/(m^2*K)]. The following equation (1) describes the simplified mathematical relations (Bischofsberger and Seyfried, 1984):

$$\dot{Q} = k * A_{he} * \Delta T_w \qquad (1)$$

Normally the size of the wastewater canal is set, therefore the most influencing factor on the heat transfer capacity is the temperature difference. The thermal transfer coefficient is typically known for the used material; stainless steel for example has a k-value of about 15 W/(m^2*K). This means one square meter of stainless steel can transfer 15 W heat between the two media per 1 K of temperature difference.

The inhomogeneity of wastewater requires special constructional designs of the heat exchangers. A strict separation of wastewater and secondary media is essential as well as large diameters and few flow barriers such as bends. It is also very important to guarantee easy cleaning. For that reason, in the operation period of the heat exchanger, the reduction of the thermal transfer by fouling has to be estimated. Layers of inorganic material but also microorganisms can reduce the thermal transfer up to 60 % as shown by investigations of Wanner (2004). For the application in wastewater, large surfaces consisting of stainless steel typically minimise this problem.

The heat recovery from wastewater depends on the given geometry of the canalisation; forms vary from round and egg-shaped to rectangular, basins can also be equipped with a heat exchanger and bypass solutions are common as well. The used material has to fulfil all requirements of a normal sewer canal such as hydraulic properties, little susceptibility for fouling, but also for maintenance such as accessibility and high-pressure resistance for cleaning. Three different methods apply for the heat recovery from the wastewater depending on the given situation. The heat exchanger 1) is placed supplementary in the canal, 2) is integrated in canal modules or 3) is placed externally.

3.2.1. Supplementary refitting of heat exchanger

Most applications of wastewater utilisation require a refitting of existing canals. Those heat exchangers consist of several modules, which can be expanded to the necessary capacity and typically fit all forms. The heat exchanger is made from stainless steel hollow-plates or capillary tube mats. An example for a round shaped system is shown in Figure 3-3. The inlay forms of the major companies have slightly different designs. Depending on the application and the shape of the canal, various methods of refitting are practical (see Figure 3-4).

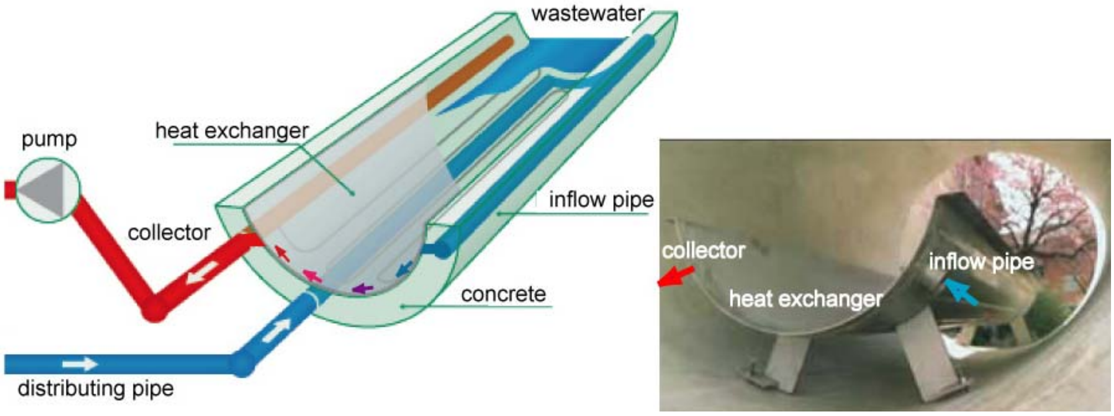


Figure 3-3: Example of heat exchanger module for refitting in existing canals (RABTHERM, 2009; Foto from: Rometsch, 2004)

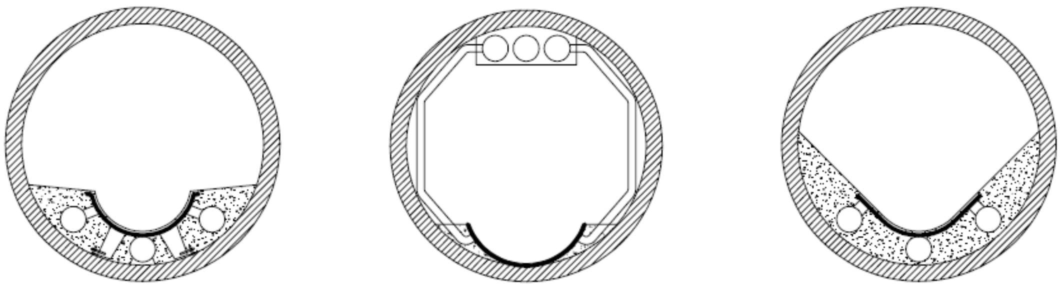


Figure 3-4: Heat exchanger designs for refitting in existing canals (Wallstein, 2009)

3.2.2. Heat exchanger integrated in canal walls

In the case of a new construction or refurbishment of canals suitable for heat recovery, the heat exchangers are integrated into the canal walls. This can either be at the bottom of the canal with longitudinal distribution and collector tubes (Figure 3-5) or coiled tubing (Figure 3-6). The advantage of this solution is the accurate integration of the heat exchanger in the canal modules. This assures high quality surfaces with a long lifetime expectation. Though, a major and very costly disadvantage is the problem of bypassing an existing wastewater flow around the construction site for the new sewer.

Figure 3-5: Integrated RABTHERM heat exchanger modules (Wallstein, 2009)

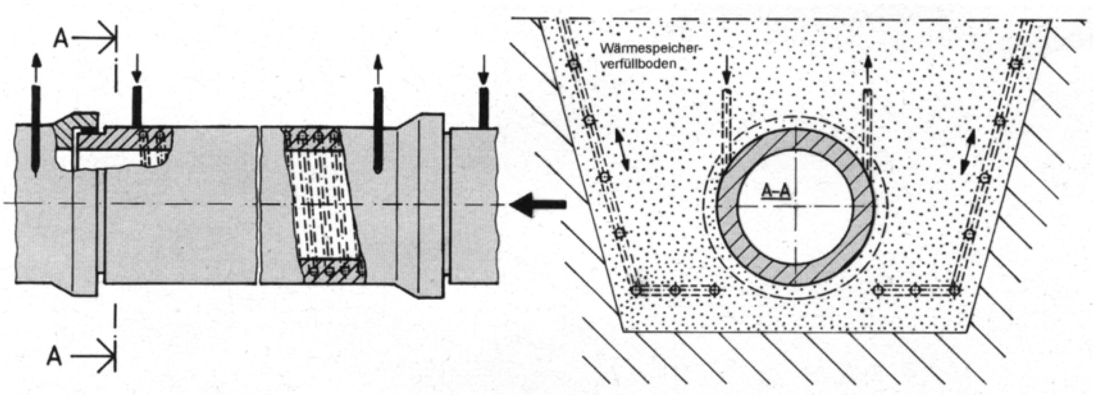


Figure 3-6: Coiled tubing heat exchanger module (DWA, 2008)

3.2.3. External heat exchanger

A further possibility for the heat recovery is to bypass the wastewater in an external heat exchanger. The advantage of this solution is the possibility to adjust the layout and the flow rate. For long-term, failure-free performance a water strainer should be installed to keep coarse fractions from plugging up the heat exchanger. For such a bypass installation, double tube or plate heat exchangers are common. Double tube heat exchangers have the higher possible diameters and less flow barriers compared to the plate heat exchangers. They are more robust and less susceptible to fouling but less efficient. On the other hand, the plate heat exchangers have better efficiency due to larger surface areas but are more problematic with fouling. The wastewater characteristics from the paper machines in Augsburg allow both types.

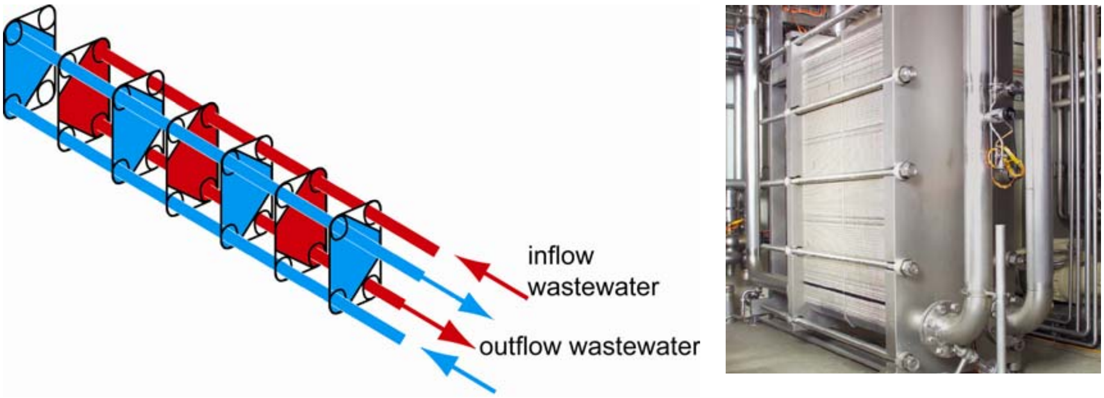


Figure 3-7: Single pass counter flow plate heat exchanger (Own diagram; Foto from: GEA TDS, 2009)

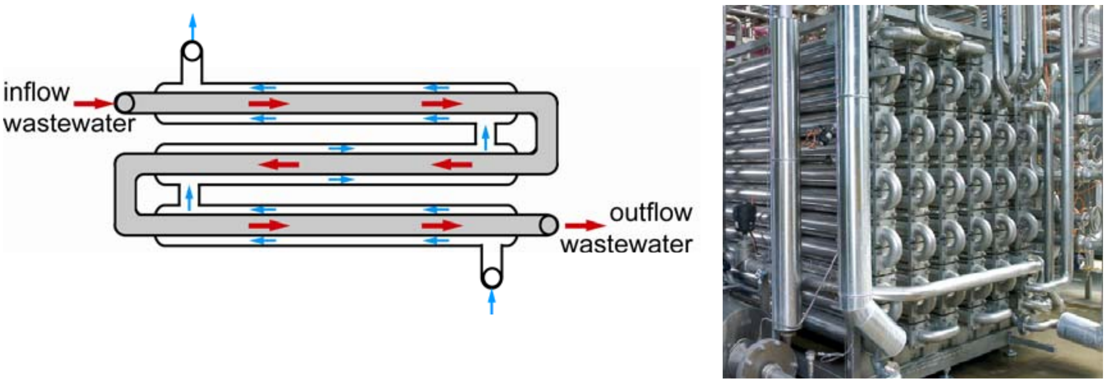


Figure 3-8: Double tube counter flow heat exchanger (Own diagram; Foto from: GEA TDS, 2009)

Spiral layout heat exchangers and hollow plate systems are applicable in sewage basins or bypass installations, but not discussed any further.

3.3. Fundamentals of heat transfer

For all heat exchangers, Fourier's law is applicable. The heat flow $\dot{Q}$ [W] through a material with the area A [m^2] is dependent on its thermal conductivity λ [W/(m*K)] and temperature difference ϑ.

$$\dot{Q} = -\lambda * A * \frac{d\vartheta}{dx} \qquad (2)$$

The differential equation of Fourier's law is given by the above equation (2) and illustrated in Figure 3-9.

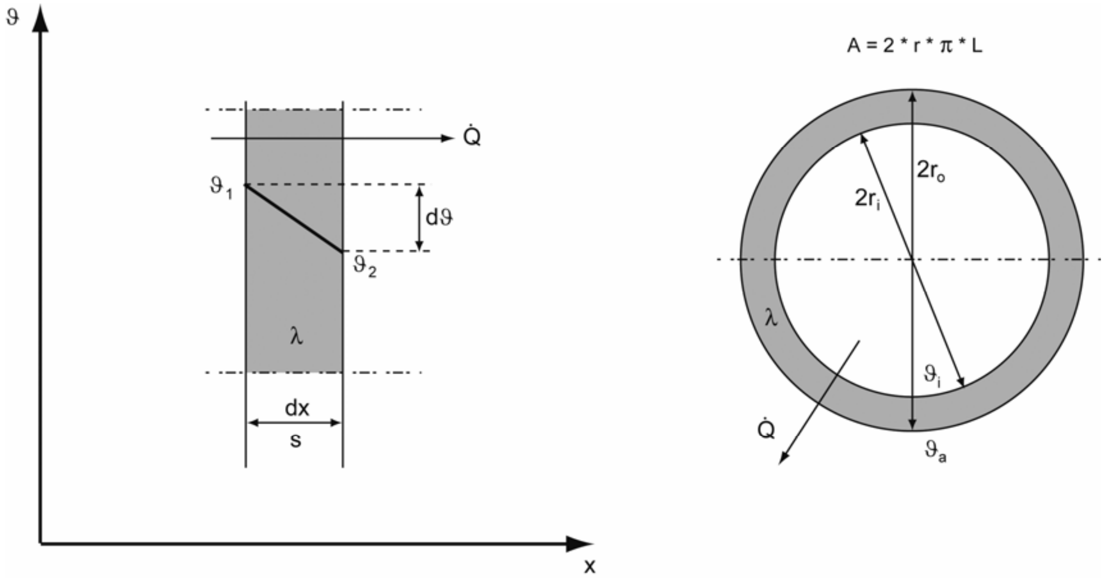


Figure 3-9: Fourier's law for heat transfer in flat and cylindrical body (Wagner, 2005)

The derivation of the differential equation (2) for a flat body from one material and constant thickness s [m] and area results in equation (3):

$$\dot{Q} = \frac{\lambda}{s} * A * (\vartheta_1 - \vartheta_2) \qquad (3)$$

For the application of Fourier's law to heat exchangers in cylindrical form, it is important to know the inner and outer diameters 2r [m] and the length L [m] of the used tubes or the canal section.

$$\dot{Q} = \frac{2 * \pi * L * (\vartheta_1 - \vartheta_2)}{\frac{1}{\lambda} * \ln \frac{r_o}{r_i}} \qquad (4)$$

Equations (3) and (4) are valid for the calculation of the heat flow $\dot{Q}$ between two fluids in a stationary system with constant temperatures on both sides of the heat exchanger surface. In reality, the fluid temperatures change while flowing through the recuperator.

The temperature difference ΔT_w [K] between the wastewater flow ($\dot{M}_1$) and the heat exchanger medium ($\dot{M}_2$) in equation (1) is the mean value of their temperature differences on the inflow and outflow. For parallel flow as well as for counter flow of the heat exchanging medium, the mean temperature difference can be obtained from the derivation of the heat transfer capacity with respect to the area. For further detail refer to Wagner (2005), pages 37ff.. A temperature sequence for parallel and counter flow with respect to the heat exchanger area is shown in Figure 3-10. To avoid negative numbers, the temperature differences at the inflow and outflow are changed to large $\Delta\vartheta_{la}$ and small $\Delta\vartheta_{sm}$. Due to the two different flows through the heat exchanger, the mean temperature difference ΔT_w [K] is calculated with the following equation (5):

$$\Delta \mathbf{T_w} = \frac{\Delta\vartheta_{la} - \Delta\vartheta_{sm})}{\ln\frac{\Delta\vartheta_{la}}{\Delta\vartheta_{sm}}} \qquad \textbf{(5)}$$

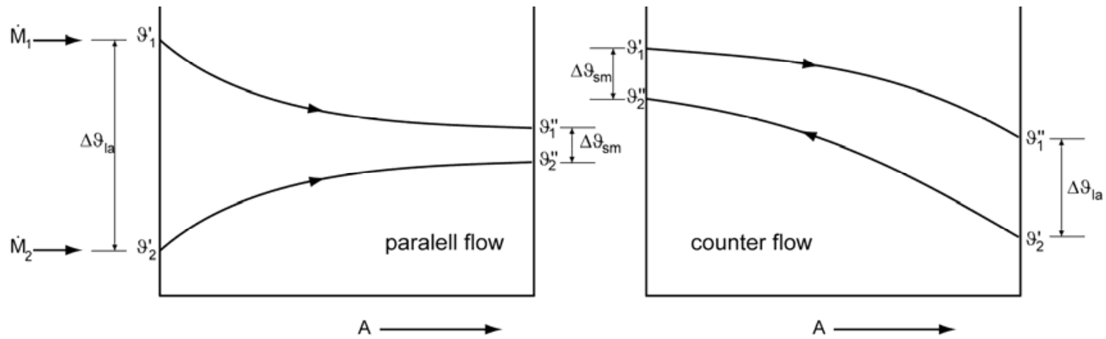


Figure 3-10: Temperature difference sequences with respect to heat exchanger area (Wagner, 2005)

The major advantage of counter flow recuperators is the possibility to warm up the cold fluid to a higher temperature ϑ''_2 than the warmer fluid at the outflow ϑ''_1, see right diagram in Figure 3-10. An example of the following fluid temperatures visualises this: ϑ'_1 = 65°C, ϑ''_1 = 50°C, ϑ'_2 = 15°C, ϑ''_2 = 45°C. For parallel flow the large and small temperature differences are $\Delta\vartheta_{la}$ = 50°C and $\Delta\vartheta_{sm}$ = 5°C, with formula (5) the resulting temperature difference is ΔT_w = 19.5°C. For counter flow $\Delta\vartheta_{la}$ = 25°C and $\Delta\vartheta_{sm}$ = 20°C, the resulting ΔT_w = 22.4°C is slightly higher.

3.4. Basic principles for the evaluation of exploitable heat

The available thermal energy $\dot{Q}$ [W] of the wastewater is proportional to its heat transfer capacity C_w [W/(s*K)] and the mean temperature difference of the wastewater ΔT_w [K] from cooling.

$$\dot{\mathbf{Q}} = \mathbf{C_w} * \Delta \mathbf{T_w} \quad \textbf{(6)}$$

The heat transfer capacity C_w [W/(s*K)] of the wastewater can be calculated by the following equation (6), from the specific heat capacity of water c_w [J/(kg*K)] and its mass flow $\dot{M}_w$ [kg/s] or from its density ρ_w [kg/m^3] and volumetric flow $\dot{V}_w$ [m^3/s] (Bischofsberger and Seyfried, 1984).

$$\mathbf{C_w} = \mathbf{c_w} * \dot{\mathbf{M}}_\mathbf{w} = \mathbf{c_w} * \rho_\mathbf{w} * \dot{\mathbf{V}}_\mathbf{w} \quad \textbf{(7)}$$

As the limiting factor for heat recovery is typically regulated by the local authorities, the question is how much heat can be gained from cooling of the water in a certain limit. The combination of equations (6) and (7) shows the resulting heat transfer capacity in a canal with known flow rates in the following (Wanner, 2004):

$$\dot{\mathbf{Q}} = \mathbf{c_w} * \rho_\mathbf{w} * \dot{\mathbf{V}}_\mathbf{w} * \Delta \mathbf{T_w} \quad \textbf{(8)}$$

The specific heat capacity of water c_w at 25°C is 4,19 kJ/(kg*K), its density ρ_w is 1000 kg/m^3. For example, in a canal with a volumetric flow $\dot{V}_m$ = 150 l/s (540 m^3/h) and a cooling of the water ΔT_w = 1 K, the heat exchanger should be designed for 630 kW heat transfer.

For the estimation of temperatures in a particular section of the canalisation, the temperature levels of the different inflowing streams with different volumetric flows combine to the resulting temperature $T_{w,res}$. Therefore the influence of single streams is often compensated by inflow of other streams with higher flow rates.

$$\mathbf{T_{w,res}} = \frac{\sum_i (\dot{\mathbf{V}}_{\mathbf{w,i}} \mathbf{T_{w,i}})}{\sum_i \dot{\mathbf{V}}_{\mathbf{w,i}}} \quad \textbf{(9)}$$

As typically canals are not always completely filled with water and normally not insulated, the temperature balance in the canal is partly influenced by three factors; heat transfer to air, evaporation and heat transfer through canal walls (Bischofsberger and Seyfried, 1984). Temperature losses caused by one of these factors can be ignored for an industrial wastewater utilisation, as the heat is typically extracted close to the source. For a rough estimation of useable heat in wastewater from industrial processes (cooling-water or process-water) Figure 3-11 can be used as a reference, if flow rates and temperatures are known and outflow temperatures are not regulated (e.g. by legislation or capacity of wastewater treatment plant). The basic assumption of this diagram is the utilisation of the recovered heat for heating buildings. Therefore reheating of the media from the heat exchanger is necessary at wastewater temperatures below 75°C. At temperatures lower than 40°C, a heat pump would be required.

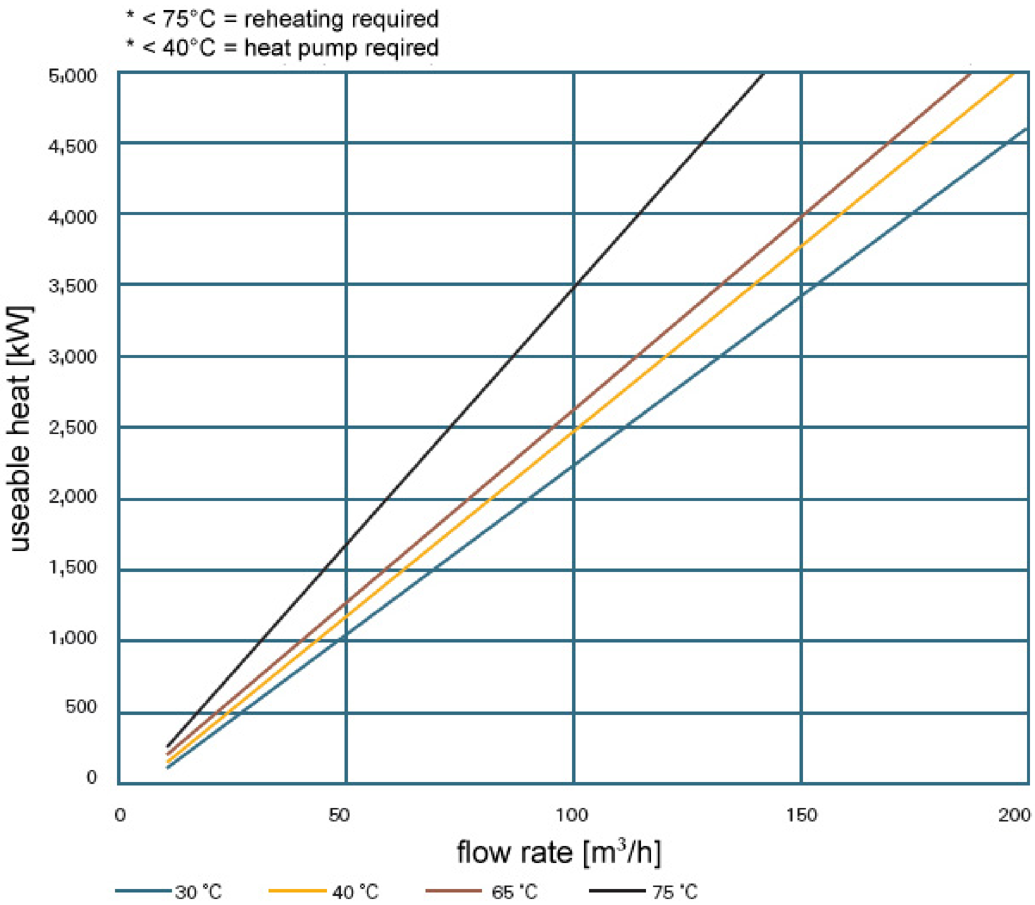


Figure 3-11: Reference diagram for the estimation of usable heat from industrial wastewater (LfU, 2008)

Using a simple example from the above diagram, from wastewater with a temperature of 40°C and a flow rate of 100 m^3/h (~28 l/s) approximately 2,500 kW heat can be recovered. Input of the numbers in equation (8) results in a temperature difference ΔT_w of about 21.5 K. The water at the heat exchanger outflow would then have a temperature of 19.5 K.

3.5. Influence of fouling on heat exchanger surfaces

High contents of organic matter in municipal wastewater lead to fouling in the canal system. Heat exchangers installed in such an environment can suffer dramatic losses in the efficiency due to the low thermal conductivity λ [W/(m*K)] and heat transfer coefficients α [W/(m^2*K)] of these materials. The parameters having an effect on fouling were investigated and measured by Wanner (2004). The reciprocal fouling factor f is a measure for the thermal resistivity of the fouling. The correlations of fouling and heat exchanger efficiency are shown in Figure 3-12.

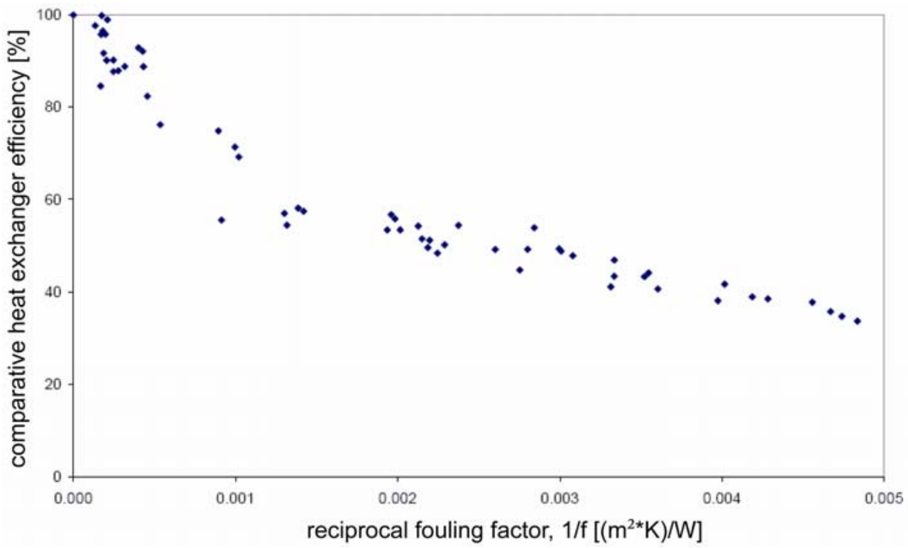


Figure 3-12: Reciprocal fouling factor vs. heat exchanger efficiency (Wanner, 2004)

Several different coatings and finishing methods were applied to the heat exchanger surface, as well as obstacles mounted on the surface to reduce the effect of fouling. Yet, the best results were obtained with regular cleaning (Wanner, 2009). Figure 3-13 shows the heat exchanger surface after flushing with higher hydraulic pressure.

Figure 3-13: Fouling on heat exchanger surface before and after flushing, image size 18 mm x 24 mm (Wanner, 2004)

Most existing heating systems require cleaning of the heat exchanger surfaces. Depending on the layout, various methods are applied with different significance (see Figure 3-14). The most common methods applied for all types are mechanical cleaning and flushing with clean water. The canal-integrated heat exchangers are typically cleaned with high pressure flushing as applied to the normal canal system. For the bypass solutions with tubular and plate heat exchangers, chemical flushing is very common.

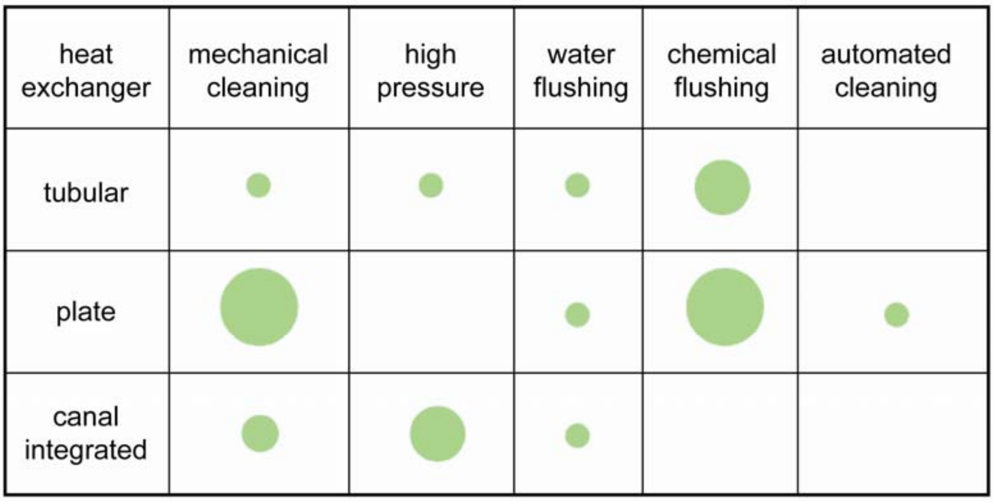


Figure 3-14: Significance of various cleaning methods for different heat exchanger types (Wanner, 2009)

Mechanical cleaning of the plates is very common and efficient, but very time consuming. Canal-integrated heat exchangers are often brushed and swept, if access is very good, otherwise industrial high pressure flushing devices are used. Water flushing – initiated by staff or spontaneously by heavy precipitation – are often applied with minor result. For the tubular and plate heat exchangers, the chemical flushing is very effective as long as they are not plugged up. After disconnection, the cleaning fluids are pumped through the tubes or plates and, a few hours later, reconnected.

3.6. Legal aspects for wastewater utilisation in Germany

On June 6th 2008, the German Bundestag (federal parliament) passed a law to subsidise renewable energies for heating, the so-called Erneuerbare-Energien-Wärmegesetz (EEWärmeG). The law requires that 14 % of the heat demand in Germany is covered by economically reasonable renewable solutions by 2020 for the sake of our climate. Further ideas are the preservation of fossil resources, the reduction of dependency on energy imports and the stimulation of development in new technologies (BMU, 2008). The law is binding for all buildings with more than 50 m^2 total area built after 01.01.2009. Table 3-1 shows the minimum ratios of renewable energies in the total heat balance of those buildings.

The EEWärmeG (§2) defines heat recovery from air and water as renewable, with the exception of waste heat (air or water) from technical processes. This makes the heat recovery from drinking water renewable in contrary to the utilisation of heat from wastewater. Although, if compensatory measures (§7) can cover at least 50 % of the heat demand of a building, the utilisation of waste heat fulfils the requirements of the law! Appendix IV of the EEWärmeG expects the use of a heat pump or any state of the art utilisation of the waste heat to meet §7 as a compensatory measure. It is important that the used heat pumps have a SPF of 4, which is determined on basis of their energy demand and heat production.

Table 3-1: Minimum ratios of renewable energy in the total heat demand of buildings imposed in §3 EEWärmeG

Source		Ratio	Requirements
Solar (thermal)	➔	15 %	Minimum-area of collectors
Biomass (gaseous)	➔	30 %	Combined heat and energy
Biomass (liquid)	➔	50 %	Best available technique of boiler
Biomass (solid)	➔	50 %	Boiler after 1. BimSchV
Geothermal	➔	50 %	Heat pump fulfils technical minimum
Environmental heat	➔	50 %	Heat pump fulfils technical minimum
Recovery of waste heat	➔	50 %	§7 and technical minimum of heat pump

The wastewater from a paper-mill has to meet the requirements of the European Council Directive 96/61/EC of September 24th 1996 on the Integrated Pollution Prevention and Control (IPPC) to avoid and reduce pollution with the best available technique. This directive is also incorporated in the German Abwasserverordnung (AbwV). Approximately three quarters of German paper-mills operate their own biological wastewater treatment plant (as best available technique) to fulfil the requirements of Appendix 28 of the AbwV.

Table 3-2: Binding legal requirements for wastewater from paper-mills before discharge (AbwV, 2004)

Qualified sample or 2 hour composite sample	mg/l	kg/t
Filtered solids	50	
5-day biochemical oxygen demand BOD_5	25	
Total nitrogen (ammonia, nitrite, nitrate, etc.) N_{tot}	10	
Phosphate P	2	
Chemical oxygen demand COD		3

As the wastewater from the UPM paper-mill in Augsburg is treated externally, the requirements for the wastewater have to be fulfilled by the communal wastewater treatment plant. Appendix 28 also regulates the amount of Adsorbable Organic Halogens (AOX) from paper-mills before discharging into the canalisation. This indicator is set at 10 g/t in Germany, with exceptions to certain paper types not produced in Augsburg (AbwV, 2004).

As the wastewater treatment plants with biological nitrogen elimination are very dependent on constant temperatures, lower wastewater temperatures can have a negative impact on the biological cleaning efficiency. Therefore, the influence of heat recovery on the temperature levels in the treatment plant has to be determined by equation (9) first.

The wastewater treatment plants with outflow temperatures of 12°C and higher have to obey limiting values specified in the AbwV (2004). A plant with the size of Augsburg's, has its limits for ammonia set at 10 mg/l and total nitrogen at 13 mg/l. Instead of the temperature level, this regulation may also be valid from May 1st to October 31st only. If the total reduction of nitrogen is at least 70 %, even higher levels of up to 25 mg/l total nitrogen receive a water quality consent for discharge. For lower temperatures in winter, the limiting values are typically set by the consent authority. The influence of lower temperatures due to heat recovery is considered in chapter 5 with special focus on the nitrogen elimination.

4. Potential for the paper-mill in Augsburg

4.1. Wastewater from pulp and paper industry

In the year 2008, approximately 100 companies produced 22,848,000 t of paper almost half of it was exported. Table 4-1 shows the production capacity of the German paper-mills in the last year. The paper manufacturing industry uses mainly woody fibres and therefore renewable, biodegradable raw materials.

Table 4-1: Paper production in Germany 2008 (VDP, 2008)

	in 1,000 t
Graphic paper	10,585
Packaging material	9,356
Hygiene paper	1,405
Special papers	1,502
Total	22,848

Water plays the most important role in paper production for the suspension and transport of the fibres. In the pulp stock chest, the different types of fibres and additives are mixed. After passing the sorting machine, this mix goes to the flowbox. A large amount of water is necessary to form a first layer of fibres on the paper screen and is the essential media for the formation of hydrogen bridges. The water consumption varies from 250 m^3 to 1.000 m^3 per tonne depending on the paper sort. The majority of the water can be reused as illustrated in Figure 4-1. After dewatering on the moving screen, the water content of the raw paper at the end of the press section is about 45% to 60%. Further steam drying reduces the water content to less then 10% (DWA, 2007), about 1,5 m^3 of water evaporate from one tonne of paper in the dryer section (Möbius, 2006). Wastewater from the paper production process is generated from the inflow of freshwater to assure the water quality of the circulating flows and is also necessary in small quantities at various steps of the production.

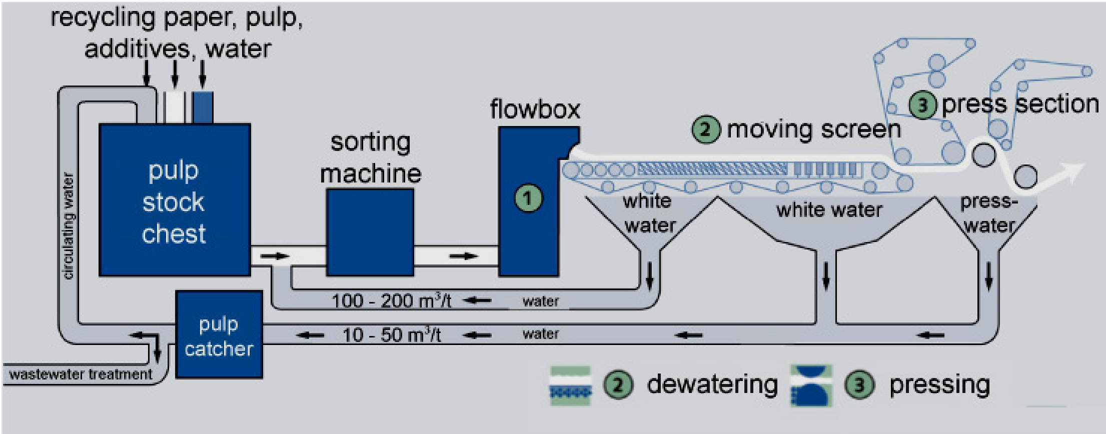


Figure 4-1: Schematic scheme of water flows in a paper-mill (VDP, 2009)

The sum of freshwater consumption is refered to as the specific water consumption of the paper machine. Considering the evaporation in the dryer section, the wastewater from a modern paper machine is about 10 m^3/t – 15 m^3/t for most sorts. UPM-Kymmene reduced the average wastewater volumes for all paper-mills almost by half from 20 m^3/t in the year 1999 to only 12m^3/t in the last year (see Figure 4-2).The paper-mill in Augsburg produces at a constantly low wastewater level for the last decade.

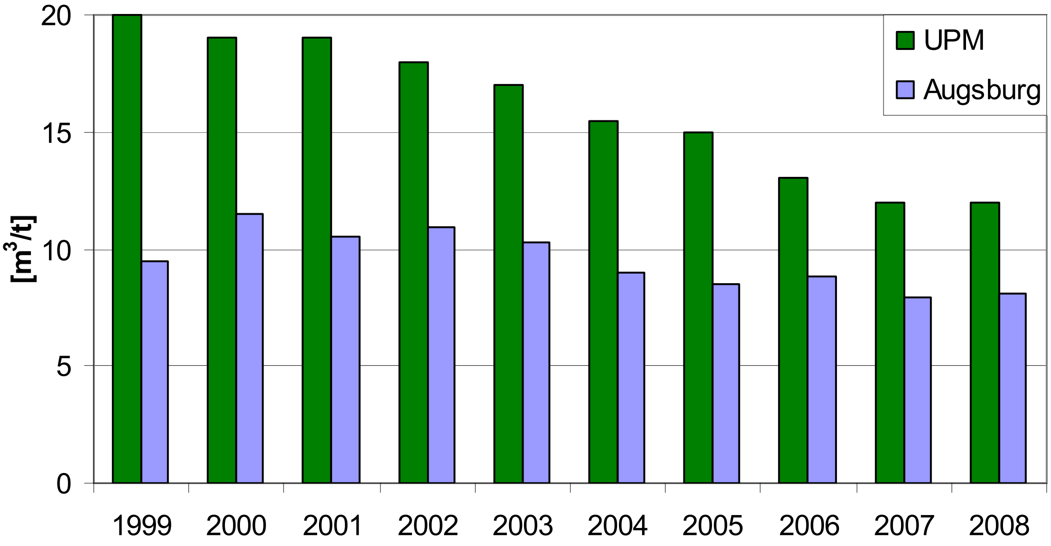


Figure 4-2: Average process wastewater volumes for UPM-Kymmene paper-mills compared to Augsburg in the last decade (UPM, 2009b; UPM, 2009c)

The wastewater form paper-mills in Germany have to meet the requirements of the AbwV before discharge. Biological treatment is the best available technique, as little inorganic substances are used in paper production. Approximately three quarters of the wastewater from German paper-mills is directly discharged after biological treatment on site, 18 % of it is treated externally in communal wastewater treatment plants (DWA, 2007). For the discharge into the canalisation, the wastewater may not harm the subsurface installations and the treatment plant or its personnel. Settleable solids from the paper production (if not removed on site) can also have positive effects on the thickening behaviour in the active sludge process (Möbius, 2006). Commonly, the paper-mills are expected to fulfil the general obligation duty of solids separation, reduction of sulphate concentration, neutralisation and reduced temperatures (>35°C). Often cooling-towers or heat exchangers are used to reduce the wastewater temperatures without utilisation of this low-caloric energy.

4.2. Characteristics and flow rates of the paper-mill in Augsburg

The average paper production from two paper machines in Augsburg is about 500,000 t. Two machines are situated in Augsburg, the modern PM3 in the northern part and PM2 in the southern part respectively.

The steam for the paper production is provided by natural gas burners in several low-pressure condensing boilers and one high-pressure boiler, which also generates electricity. In the last year, 101 GWh of a total 615 GWh electricity demand was generated on site, which is more than 15% of the mill's electricity demand (UPM, 2009c). The process heat demand is four to five times as much as the electricity demand. The boilers emitted about 142,000 tonnes of CO_2 last year. In comparison to 2007 with 323 kg CO_2 per tonne of paper, only 311 kg CO_2 were emitted per tonne of paper production (UPM, 2008; UPM, 2009c).

Figure 4-3: Overview of UPM in Augsburg (UPM, 2009a)

In total, the two paper machines have a freshwater demand of about 4.6 million m^3 per year, the majority of the water is internally recycled (UPM, 2009d). The process water is pumped from the borehole fountain on site. Due to losses from steam drying to the environment, the total wastewater amount averages at about 3.9 million m^3 per year. The larger PM3 in the north generates ~60% of the total wastewater sum, the remaining ~40% are from PM2 (UPM, 2009d).

The wastewater is discharged to the communal sewer for cleaning in the municipal wastewater treatment plant. Table 4-2 shows the emissions of the UPM paper-mill in Augsburg.

Table 4-2: Emissions in wastewater from paper-mill in Augsburg 2008 (UPM, 2009c)

3,679,200 m^3 total	t/a	mg/l
Filtered solids		* 80 / 200
5-day biochemical oxygen demand BOD_5	5,200	1,413
Total nitrogen (ammonia, nitrite, nitrate, etc.) N_{tot}	56	15
Phosphate P	20	5
Chemical oxygen demand COD	10,000	2,718
AOX	1.35	0.37

* PM3 / PM2 respectively

The discharge temperature of the paper-mill into the municipal sewer has an upper temperature limit of 42°C. Short term peaks in the case of torn paper are difficult to avoid, but generally the limit has to be obeyed. Safety problems can occur as the canalisation normally is not constructed for high temperatures. Annual mean values for both paper machines are always lower than the 42°C limit (Figure 4-4).

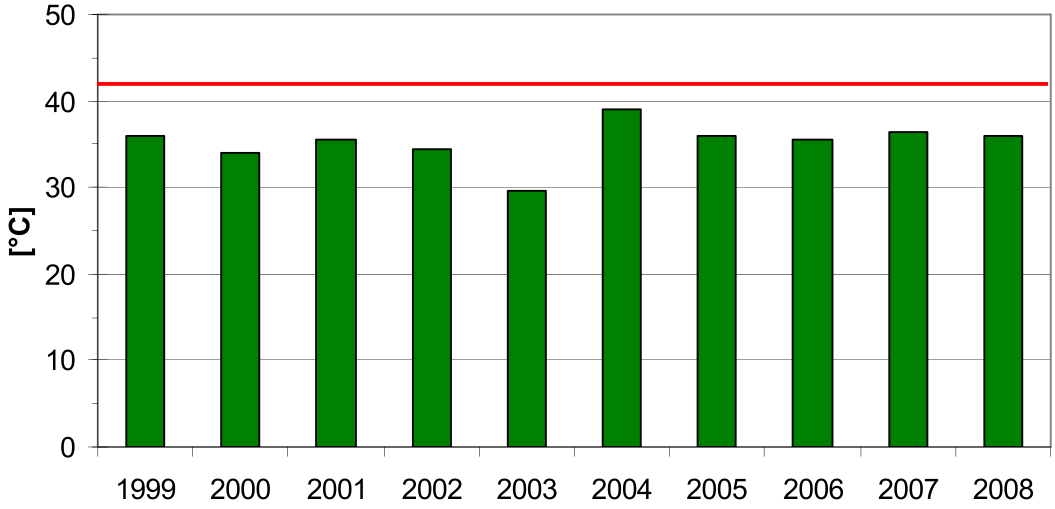


Figure 4-4: Average wastewater temperatures for the paper-mill in Augsburg in the last decade (UPM, 2009c)

All water flows in the paper-mill are pumped in a system with approximately 3 bar. The water can be diverted to heat exchangers running with river waters as cooling media. These heat exchangers are operated to cool down the water to the limiting discharge temperature of 42°C when necessary. Each year, approximately 10 million m³ of water from the river are used to cool down the wastewater (UPM, 2009d).

4.2.1. Paper machine PM3 in the northern area

The newer and larger paper machine PM3 has very good internal water recycling, which results in low wastewater temperatures. The mean temperature is approximately 35°C with seasonal variations, around 33°C in winter and 36-37°C in summer (UPM, 2009d). The volumes range from 200 m^3/h to peaks of 500 m^3/h, the average is about 250 m^3/h as seen in Figure 4-5. The large fluctuations in temperatures and volumes are due to different stages or torn paper in the production process.

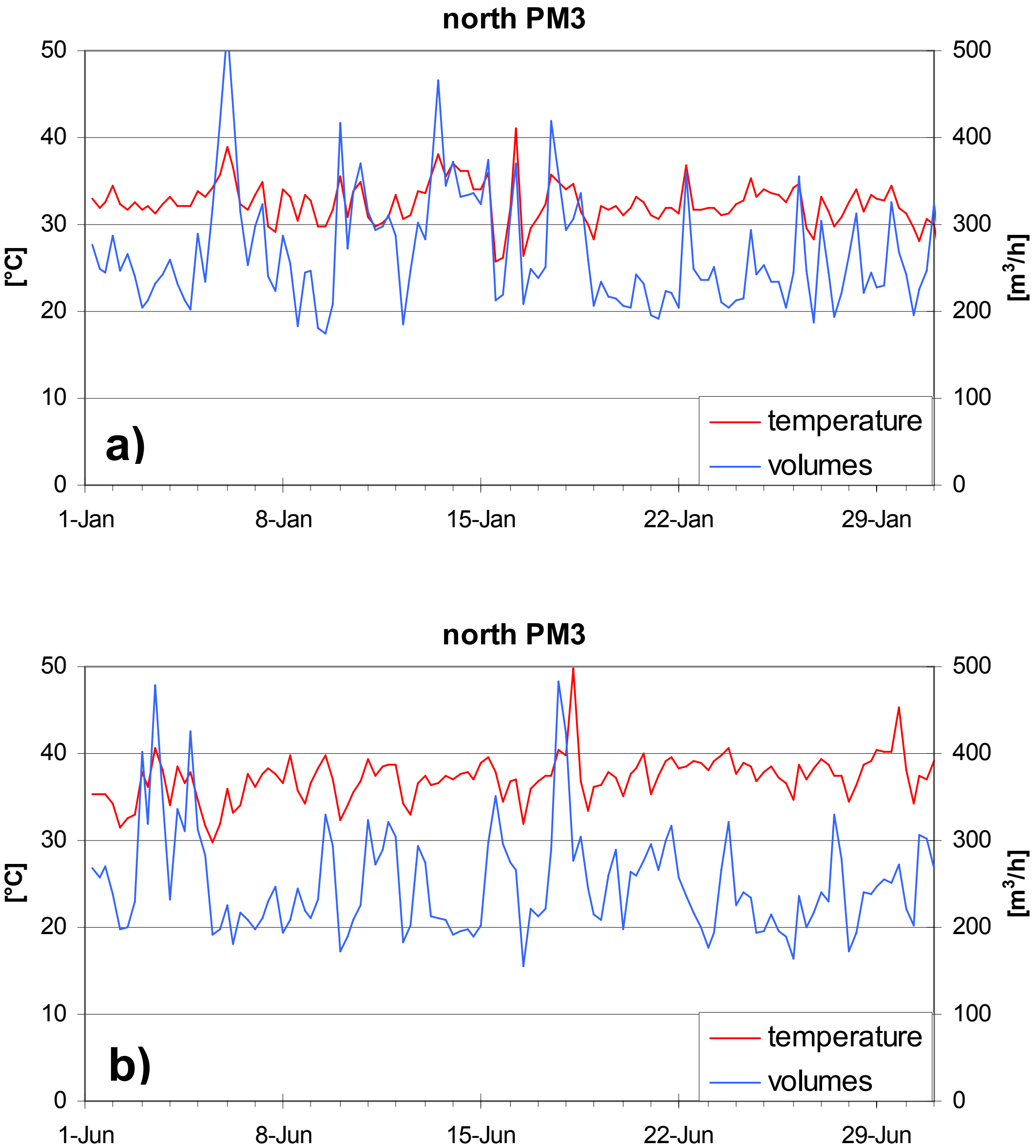
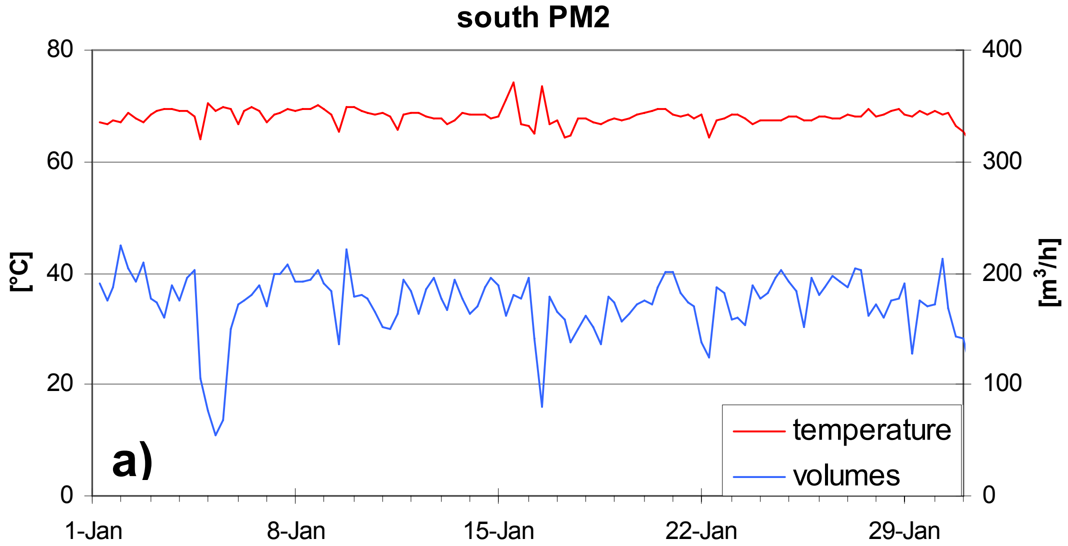


Figure 4-5: Average wastewater temperatures and volumes from PM3 for a) January and b) June (UPM, 2009d)

4.2.2. Paper machine PM2 in the southern area

The smaller paper machine in the southern part of UPM-Kymmene in Augsburg has a higher wastewater temperature of approximately 70°C at the outflow. River cooling is used to reduce the wastewater temperature to 35-38°C in winter, and just below the limit of 42°C in summer, the yearly average is 38°C for PM2 (UPM, 2009d). The wastewater volumes show less fluctuation in comparison to PM3 with average flow rates of 170 m^3/h as shown in Figure 4-6.



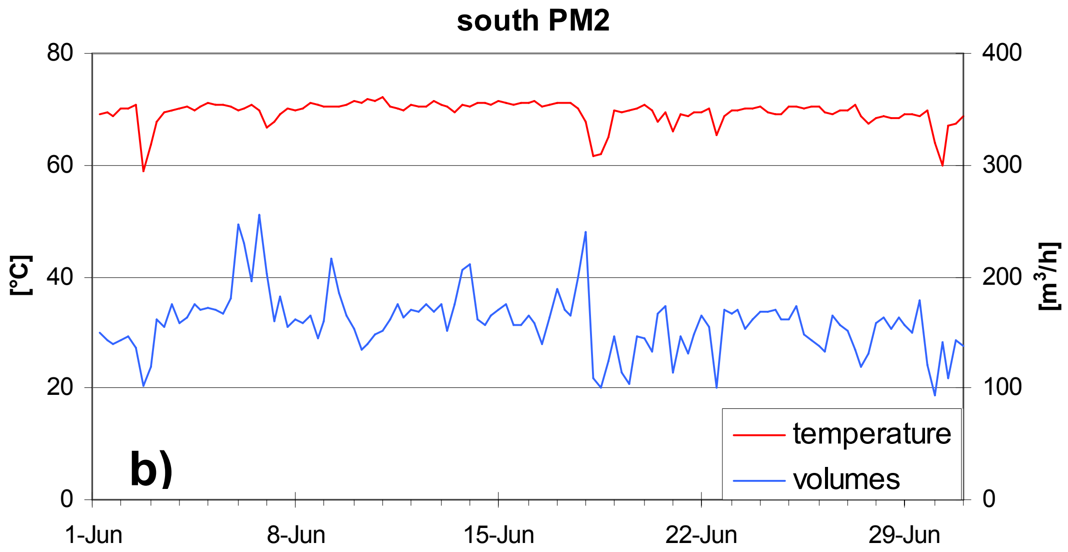


Figure 4-6: Average wastewater temperatures and volumes from PM2 for a) January and b) June (UPM, 2009d)

4.3. Evaluation of exploitable heat

Typically the production of paper in Germany requires 4.17 kWh/kg to 5.28 kWh/kg of heat (LfU, 2008), which sums up to approximately 2,085 GWh to 2,640 GWh heat demand per year for the paper-mill in Augsburg.

The large volumes of low-caloric heat in the wastewater from paper production suggest its recovery for low temperature applications and heating. Equation (8) applied to the volume flows of 170 m^3/h and 250 m^3/h with c_w = 4,19 kJ/(g*K) and density ρ_w = 1000 kg/m^3 gives the amount of heat recovered by a heat exchanger. The cooling of the wastewater by only 5 K with a heat exchanger for preheating of freshwater can save 7.9 GWh or 11.6 GWh of primary energy (see Figure 4-7). Although 19.5 GWh primary energy savings from the combined utilisation of both wastewater streams with a cooling of 5 K seems small in comparison to the total heat demand of the mill, the amount of saved primary energy is quite large.

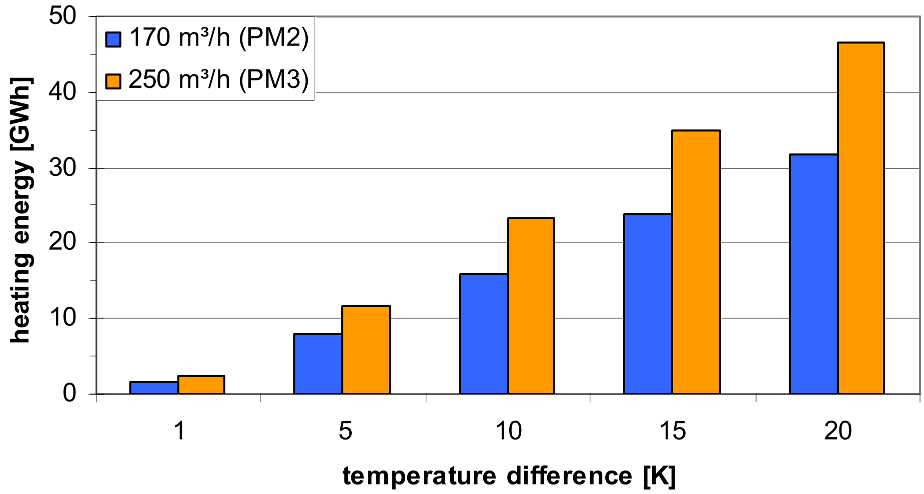


Figure 4-7: Maximum possible heat recovery from wastewater utilisation of the two paper machines per year (own calculations)

The process heat in Augsburg is produced by condensing boilers with natural gas as fuel. Those boilers can reach efficiencies of 85% - 95%, therefore the fuel demand for the generation of 1 GWh heating energy as shown in Figure 4-8 is 5% - 15% higher in reality. This calculation considers slightly varying values of the higher heating value for the fuel types with the error bars. When the low-caloric energy from the heat recovery can be reused for preheating of freshwater for the process, 1 GWh of heat from wastewater can save 100,000 m^3 of natural gas or for example 200 t of biomass.

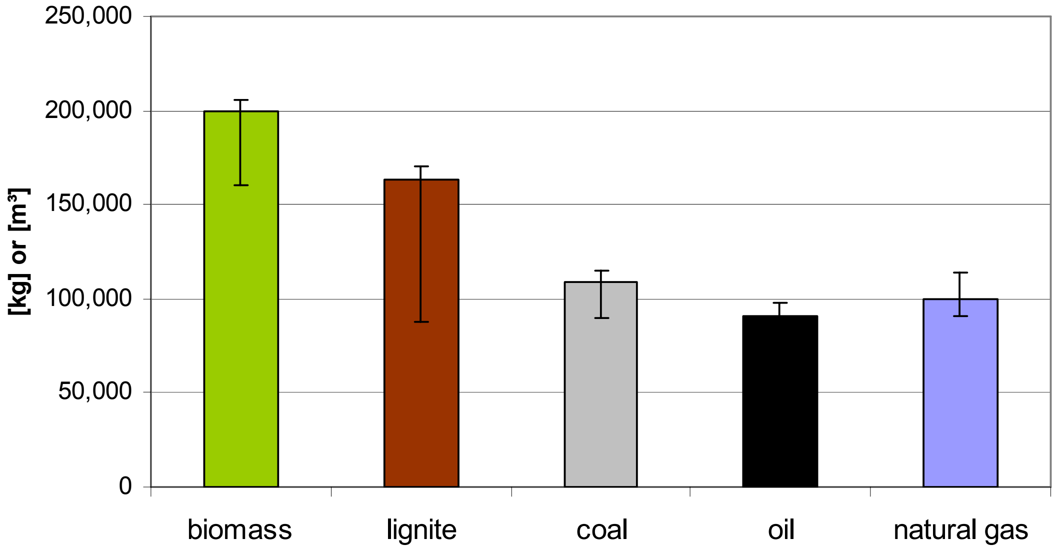


Figure 4-8: Amount of fuel necessary to release 1 GWh of heat energy (calculations based on higher heating values from different sources)

Assuming average wastewater flows of 250m^3/h at 35°C from PM3 and 170m^3/h at 70°C from PM2 for heat recovery, a large source of low-caloric energy can be taped. As most important and feasible application is the direct preheating of freshwater from the borehole, (which averages about 15°C) in a heat exchanger. Due to losses from steam drying, the inflow in the paper machines is approximately 20% higher then the outflow. But still, this is the perfect application for heat recovery with large potential and direct improvement of the machines' efficiencies. Further use for low temperature wastewater could be in combination with a heat pump for combined heating in winter and cooling in summer.

When large volumes of industrial wastewater from one producer are treated in a municipal plant, interactions and undesirable consequences can emerge for the cleaning efficiency when inflow temperatures (or volumes) are dramatically lowered. This is discussed in the following chapter 5.

5. Interactions with the wastewater treatment plant

5.1. The biological cleaning process

After mechanical cleaning, the wastewater treatment plant in Augsburg undergoes biological nitrogen elimination. The activated sludge process is used to oxidise nitrogeneous and carbonaceous matter in the wastewater, which are transformed to volatile gases such as N_2 and CO_2 by bacteria. Nitrification and denitrification are the two important processes in the biological wastewater treatment, also taking place every day as part of the nitrogen cycle in soil. The transformation of ammonia in the wastewater is performed by aerobic, chemotrophic-autotroph bacteria, the nitrificants. They gain energy from chemical reactions and synthesise all necessary organic compounds from CO_2. The nitrification process can be described in two major steps, both being exothermic (Fuchs, 2006):

$$\mathbf{NH_3 + 1\tfrac{1}{2}\,O_2 \rightarrow NO_2^- + H^+ + H_2O} \qquad \mathbf{(10)}$$

$$\mathbf{NO_2^- + \tfrac{1}{2}\,O_2 \rightarrow NO_3^-} \qquad \mathbf{(11)}$$

Equation (10) shows the transformation of ammonia to nitrite by nitrite-bacteria, equation (11) is the product of nitrate-bacteria. The combination of the two reactions in equation (12) shows the simplified process in the nitrification basin which is permanently oxygenated with air.

$$\mathbf{NH_3 + 2\,O_2 \rightarrow NO_3^- + H^+ + H_2O} \qquad \mathbf{(12)}$$

As a further step in the biological wastewater treatment, denitrification takes place in anoxic basins. Due to the lack of oxygen, heterotrophic bacteria are forced to use the oxygen from the nitrate and organic matter in the water to produce the energy they need to life. As by-products gaseous N_2 and CO_2 are formed and can escape to the atmosphere as shown in the following equation (Stadt Augsburg, 2006).

$$\mathbf{4\,NO_3^- + 4\,H^+ + 5\,C \rightarrow 2\,N_2 + 2\,H_2O + 5\,CO_2} \qquad \mathbf{(13)}$$

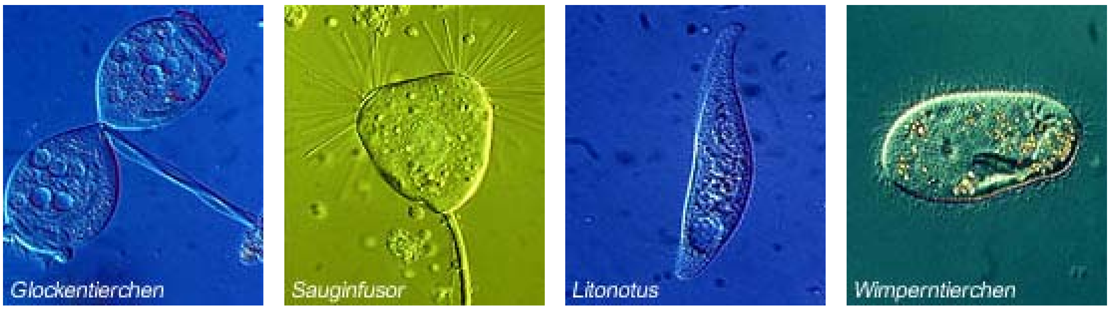


Figure 5-1: Nitrificants and denitrification bacteria (Stadt Augsburg, 2009a)

Using upstream denitrification in Augsburg, the first anoxic basins receive large amounts of organic matter from the inflow and NO_3^- from recirculation of water from the nitrification basins. The specialised bacteria in the denitrification basin feed on C and nitrate, which is supplied from the downstream nitrification basins. The degassing of nitrogen can take place after equation (13) as illustrated in Figure 5-2. In the downstream nitrification basin the bacteria reduce ammonia to NO_3^- after equation (12). The wastewater treatment plant in Augsburg has two activated sludge basins with a volume of 23,400 m^3 and 40,000 m^3.

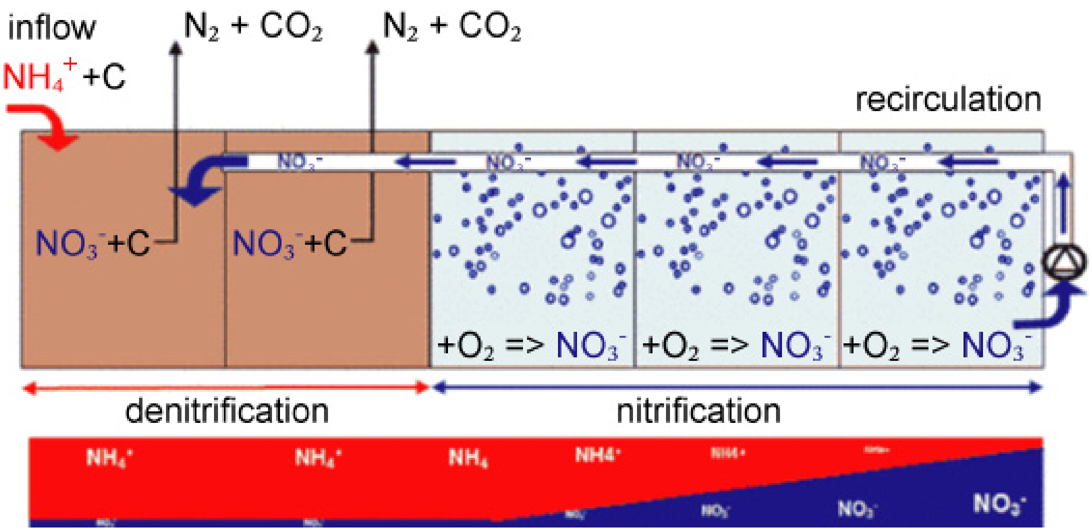


Figure 5-2: Biological nitrogen elimination by activated sludge process with upstream denitrification (Stadt Augsburg, 2009a)

5.2. Influence on the biological nitrogen elimination

Heat recovery from wastewater can significantly lower the inflow-temperature of wastewater treatment plants. The biological process of nitrogen elimination is very sensitive on temperature changes. The link between nitrogen removal and temperature is shown in the model of Koch et al. (2001). All relevant processes in the activated sludge basins, such as hydrolysis, endogenous respiration, nitrification and denitrification are considered in this model.

In this context, the age of the sludge is the most important factor for the dimensioning of the activated sludge basins in wastewater treatment plants. The following contributions are based on the work of Wanner (2004). The whole mass of solids in the aeration basin ($V*X_{ab}$) divided by the daily loss of excess sludge (S_{ex}) and the overflow in the clarifier ($Q_{avg}*X_{cl}$) indicates the total sludge age (SA_{tot}).

$$SA_{tot} = V*X_{ab} / (S_{ex} + Q_{avg}* X_{cl}) \quad (14)$$

The average growth rate of the bacteria (μ_{avg}) is directly correlated with the inverse of the average sludge age (SA_{avg}).

$$\mu_{avg} \approx 1/SA_{avg} \quad (15)$$

With this understanding of sludge age and bacteria growth, it is obvious that the species with maximum growth-rate (μ_{max}) dominantly colonise the active sludge.

$$\mu_{max} \approx 1/SA \quad (16)$$

The nitrification in the aeration basin is directly related to the growth rate of nitrificants. For the security of nitrogen elimination in the wastewater treatment plant, it is important to consider unpredictable situations which lower the amount of nitrificants in the basins. This can either be the inflow of chemicals inhibiting the growth of the bacteria, temporarily high sludge production or low settling of the active sludge, as well as high peak loads diluting the nitrificants. All plants operate with a safety factor of nitrificats (SF_{nit}), which correlates to the growth-rates as shown in the following equation (17).

$$SF_{nit} = \mu_{nit,max} / \mu_{nit,avg} \quad (17)$$

With input of equation (15) for the aerobic growth of bacteria in equation (17), the safety factor can be related to the aerobic sludge age (SA_{aer}):

$$SF_{nit} = \mu_{nit,max} * SA_{aer,avg} \quad (18)$$

The safety factor secures the compliance of the limiting factors for water discharge from the plant in 80 % of the operating load conditions. The aeration basins of most wastewater treatment plants are dimensioned for an inflow temperature of at least 10°C. The following equations show the link between bacteria growth and sludge age.

$$\mu_{nit,max}(T) = \mu_{nit,max}(10°C)\ e^{0,11(T-10°C)} \qquad \text{with: } \mu_{nit,max}(10°C) = 0,2\ d^{-1} \quad (19)$$

By using equations (18) and (19) to reach a suggested safety factor of 1.8 at temperatures of 11°C, the average, aerobic sludge age has to be approximately 8 days. A temperature of 10.5°C results in a sludge age of 8.5 days with the same safety factor.

Nitrogen elimination basins are divided into the aerobic nitrification and anaerobic denitrification volume. These volumes have to be equilibrium for optimum operation. A lower temperature in the basins at consistent volume and total sludge age can either result in a lower denitrification or in a lower safety factor. Figure 5-3 gives a better understanding of this complex correlation.

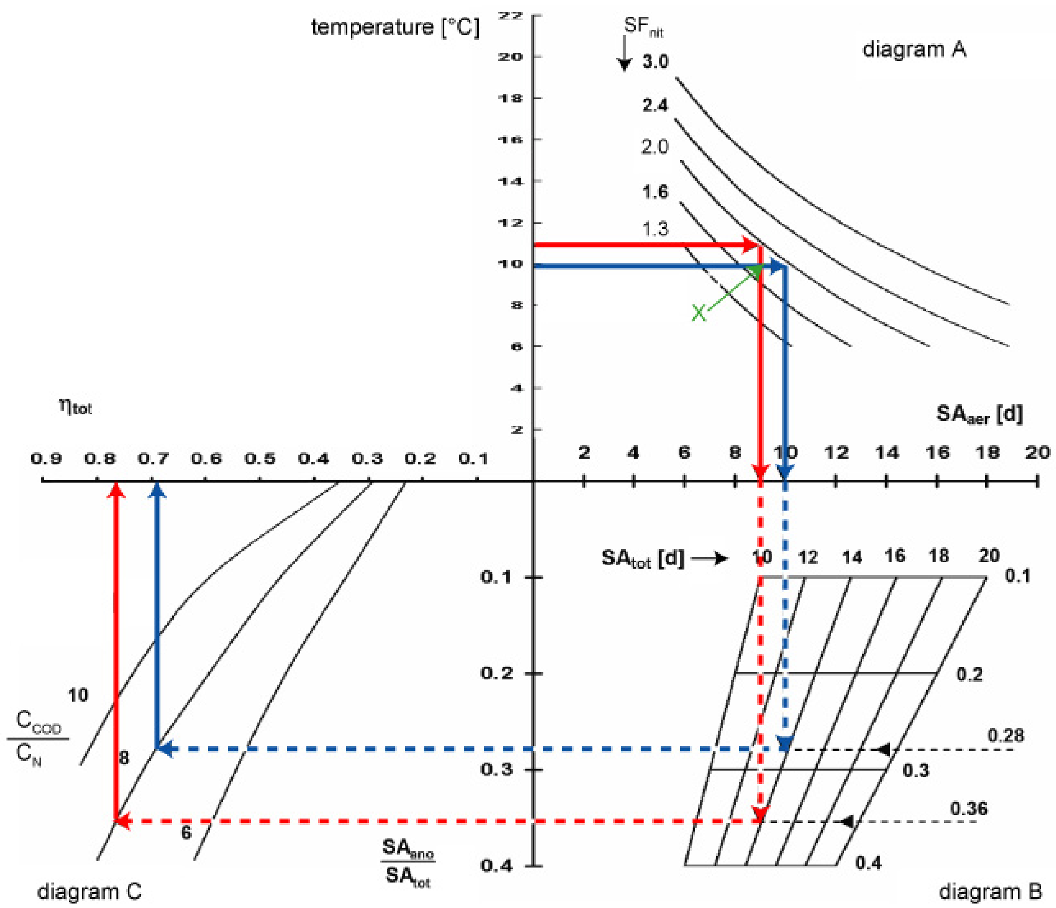


Figure 5-3: Effects of lower temperature on the nitrogen elimination efficiency of a wastewater treatment plant (Wanner, 2004)

Diagram A in Figure 5-3 illustrates the effect of lower temperatures on the aerobic sludge age. At a temperature level of 11°C (red line) and 10°C (blue line), using equations (18) and (19) the aerobic sludge age (SA_{aer}) is 9 days or 10 days respectively, for a constant safety factor of 2.0. An aerobic sludge age of 9 days can be also achieved, if the safety factor is lowered to 1.8; follow the horizontal blue line to point X and down the red line. In this case, the total sludge age (SA_{tot}) is set invariably at 14 days, as shown in diagram B. For the temperature of 11°C with a aerobic sludge age of 9 days, the remaining anoxic sludge age (SA_{ano}) is 5 days, resulting in a ratio of 0.36 of SA_{ano}/SA_{tot} , for 10°C this ratio is 0.28. The ratio of total chemical oxygen demand (C_{COD}) and nitrogen (C_N) in the inflow determines the efficiency of the biological nitrogen elimination. In diagram C, this ratio is set to 8.2 for an average city. As a conclusion derived from these diagrams in Figure 5-3 the dramatic effect of a temperature reduction from 11°C to 10°C in the inflow becomes obvious: The total nitrogen efficiency η_{tot} at constant volume and safety factor is reduced from 77 % to 69 %.

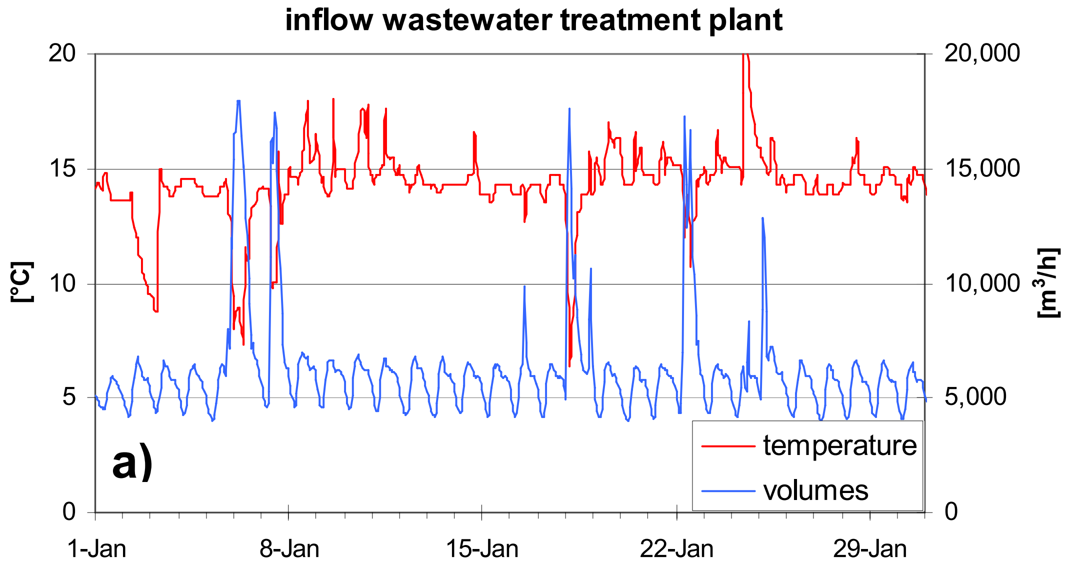
5.3. Consequences for the treatment plant in Augsburg

The wastewater treatment plant in Augsburg is located at the northern rim of the city on the river Lech. The maximum capacity is planned for a total number of 800,000 inhabitants and population equivalents (PT), currently the inflow is about 375,000 PT from inhabitants 375,000 PT from industry (Stadt Augsburg, 2009b).

Figure 5-4: Aerial view of wastewater treatment plant in Augsburg (Stadt Augsburg, 2006)

Wastewater from villages up to 20 km southward flows into the plant due to the constant gradient along the river featuring good hydraulic conditions. The distance from the UPM-Kymmene paper-mill to the wastewater treatment plant is less than 5 km. The discharge is situated close to one of the three main collectors. Although the paper-mill itself discharges large volumes at higher temperatures than average inflows, the influence of many other steams with lower temperature levels is dominant according to equation (9). This becomes obvious in the diagrams in Figure 5-5. The volume flows clearly show the daily fluctuations; extraordinary peaks arise from precipitation. While temperatures stay relatively constant in dry weather conditions, the influence on water temperatures from rain or melting snow is especially large in winter. The temperature levels show daily variations during peak consumption but little changes during dry weather conditions. As mentioned by Bischhofsberger and Seyfried (1984) the heat transfer through canal walls plays an important role due to the “buffer-capacity” of the surrounding soil. This can be seen in the relatively constant temperature curves in Figure 5-5. Taking into account, that large volumes from other streams flow into the wastewater treatment plant, a lower discharge temperature of UPM-Kymmene due to further heat recovery would only have a small or no effect. Temperature levels at the inflow of the biological cleaning basins would only sink by parts of a tenth.

Therefore the influence of the paper-mills discharge temperature on the cleaning efficiency of the wastewater treatment plant in Augsburg can be neglected!



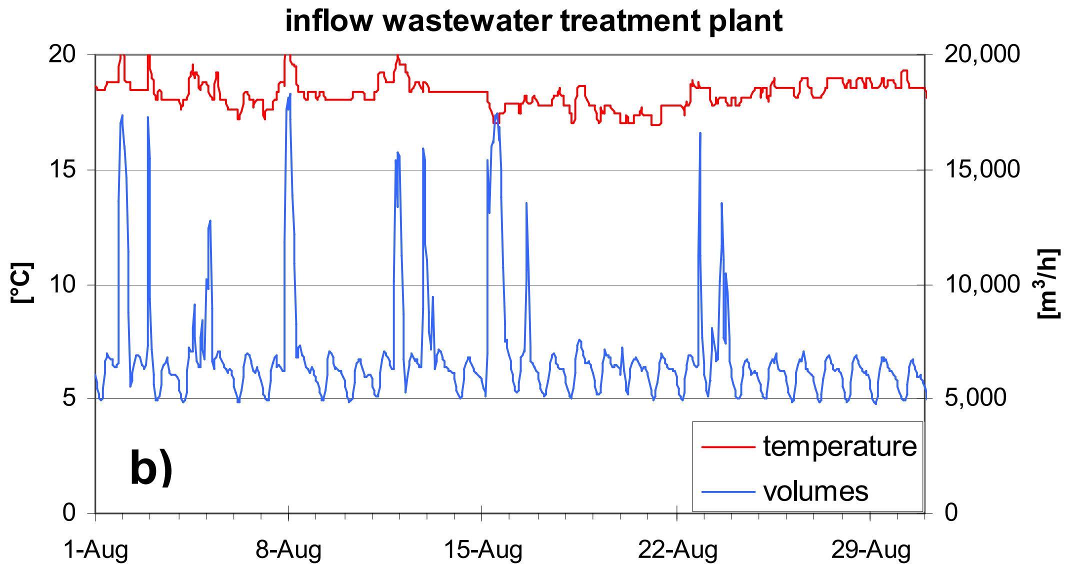


Figure 5-5: Average inflow temperatures and volumes for a) January and b) August (Stadt Augsburg, 2009b)

On the other hand, the high amount of organic matter from the wastewater of the paper-mill has a positive influence on the nitrogen elimination. The load of chemical oxygen demand (COD) and 5-day biochemical oxygen demand (BOD_5) is very high as shown in Table 4-2. The high content of organic carbon supports the heterotrophic bacteria in the denitrification basins with additional C supply necessary for the ongoing conversion of nitrogen to gaseous N_2 and CO_2 after equation (13). Table 5-1 shows the emission load in the wastewater before and after treatment. A plant of this size typically has problems with the nitrogen elimination due to lack of organic material. The treatment of the paper production wastewater has a big advantage in this case. The total cleaning efficiencies (η_{tot}) are very high.

Table 5-1: Emission data for the wastewater treatment plant in Augsburg (Stadt Augsburg, 2009a)

54,570,310 m^3 total	Inflow [t/a]	Outflow [t/a]	η_{tot} ratio
Chemical oxygen demand COD	27,719	2,576	90.7
5-day biochemical oxygen demand BOD_5	13,808	189	98.6
Total nitrogen (ammonia, nitrite, nitrate, etc.) N_{tot}	1,726	234	86.4
Phosphate P	256	18	93.2

A comparison of the organic material load in the paper-mill wastewater with the total inflowing load shows, that the share of UPM on the total chemical oxygen demand (COD) and 5-day biochemical oxygen demand (BOD_5) is at least 35%. Figure 5-6 shows that almost no nitrogen originates from paper production. This situation results in the very high nitrogen elimination of 86.4 in the Augsburg's treatment plant.

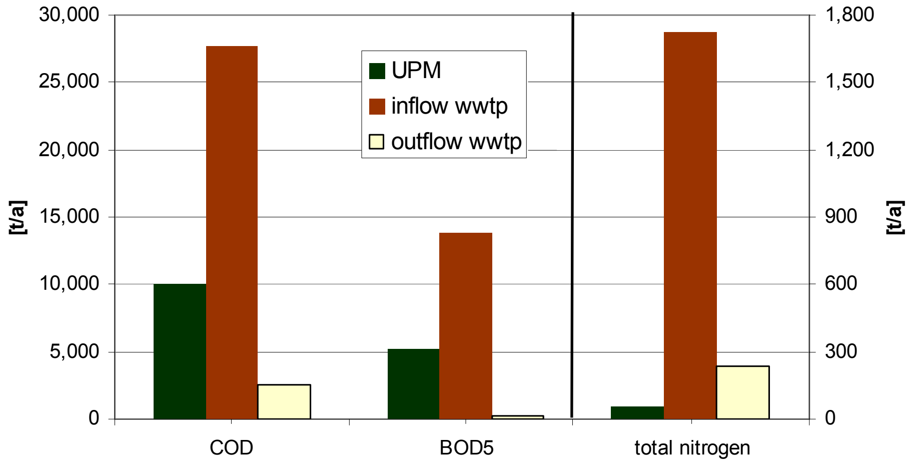


Figure 5-6: Annual organic load and N share of UPM-Kymmene discharge in the wastewater treatment plant (wwtp) in Augsburg (Stadt Augsburg, 2009a; UPM, 2009c)

6. Best technical solution

6.1. Realisation methodology

All water flows in the UPM-Kymmene paper-mill in Augsburg are transported in pressure pipes at 3 bar (UPM, 2009d), which is common in most paper-mills. Heat exchangers in canals are therefore no option on site. The characteristics of the wastewater allow most heat exchanger designs. A principal methodology for the best technical realisation of heat recovery with a heat exchanger is shown in the following scheme:

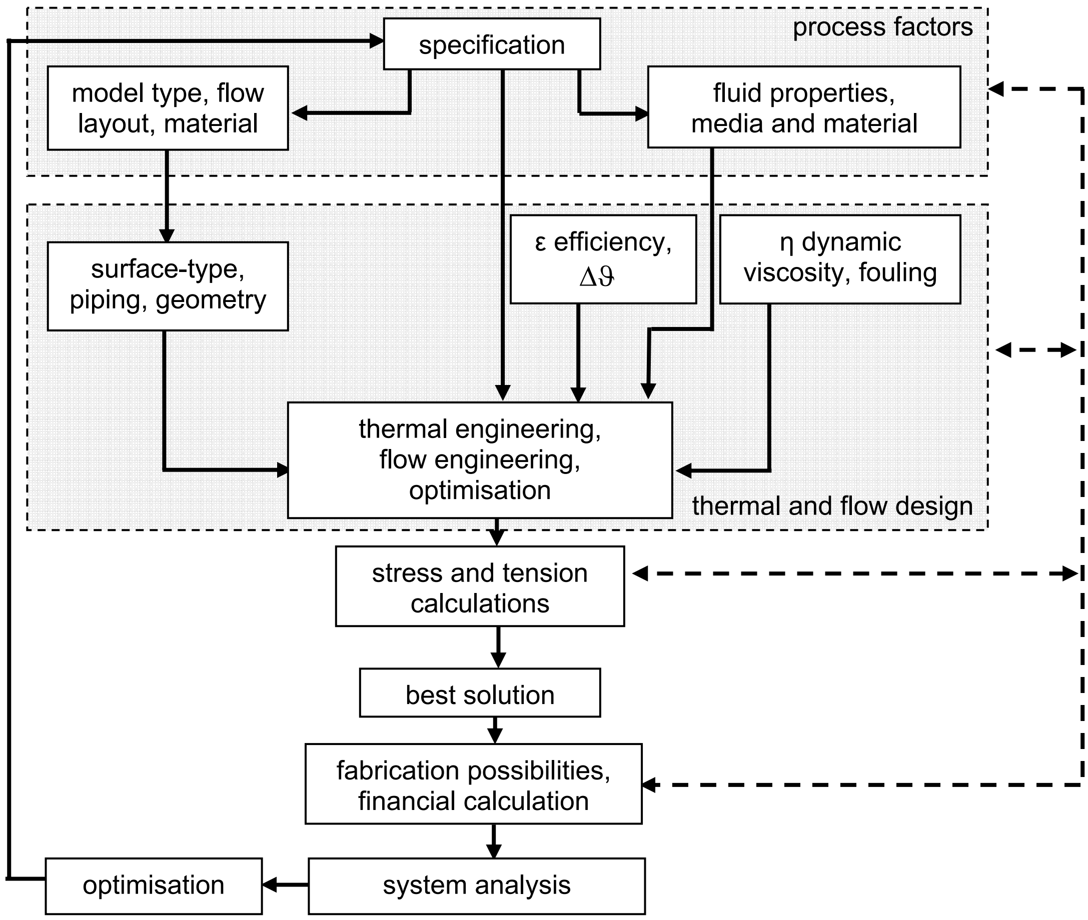


Figure 6-1: Principal realisation methodology for a heat exchanger (Wagner, 2005)

Considering the given process factors, it is essential to achieve a good efficiency and flow design to make the system work well and profitably. For the application at the UPM-Kymmene paper-mill in Augsburg, double tube and plate heat exchangers with counter flow are most suitable. As the wastewater has no harmful and aggressive properties, no special materials and pipes are necessary. Corrosion has not been a problem on site, and fouling has minor impact on the process lines so far. In the following chapter, layout calculations to achieve high efficiencies with a double tube and plate heat exchanger for this application are shown.

6.2. Heat exchanger layout

Thermal designs of heat exchangers for stationary systems are based on the equations to be found in Chapter 3. The thermal energy $\dot{Q}$ [W] which is transferred from the wastewater to the cooling medium is expressed by the simple equation (1) depending on the heat exchangers thermal transfer coefficient k and surface area A_{he}, but is also dependent on mass flow rates $\dot{M}$ of the wastewater as shown in equations (6) and (7). The heat flow in a heat exchanger can be described with the following schematic figure and equation (20) as a combination of the above mentioned equations.

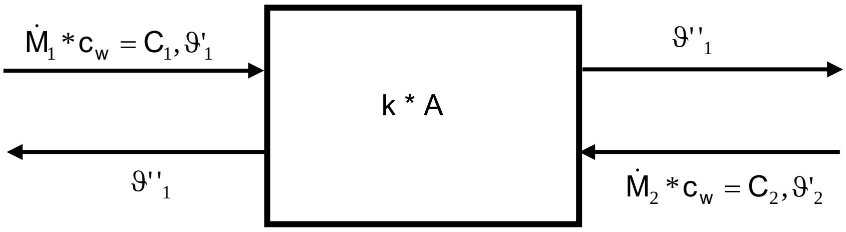


Figure 6-2: Schematic illustration of heat transfer in heat exchangers (own diagram)

$$\dot{\mathbf{Q}} = \mathbf{k} * \mathbf{A} * \Delta \mathbf{T_w} = \mathbf{C}_1 * (\vartheta'_1 - \vartheta''_2) = \mathbf{C}_2 * (\vartheta''_2 - \vartheta'_2) \qquad \textbf{(20)}$$

From equation (20) a number of dimensionless parameters can be derived. Most important is the number of transfer units (NTU) for the two flows,

$$\mathbf{NTU}_1 = \frac{\mathbf{k} * \mathbf{A}}{\mathbf{C}_1} \quad \textbf{and} \quad \mathbf{NTU}_2 = \frac{\mathbf{k} * \mathbf{A}}{\mathbf{C}_2} \qquad \textbf{(21)}$$

furthermore the ratios of heat transfer capacities R

$$\mathbf{R}_1 = \frac{\mathbf{C}_1}{\mathbf{C}_2} \quad \textbf{and} \quad \mathbf{R}_2 = \frac{\mathbf{C}_2}{\mathbf{C}_1} = \frac{1}{\mathbf{R}_1} \qquad \textbf{(22)}$$

and the temperature changes P of the two flows (VDI, 2006).

$$\mathbf{P}_1 = \frac{\vartheta'_1 - \vartheta''_1}{\vartheta'_1 - \vartheta'_2} \quad \textbf{and} \quad \mathbf{P}_2 = \frac{\vartheta''_2 - \vartheta'_2}{\vartheta'_1 - \vartheta'_2} \qquad \textbf{(23)}$$

A concept for the calculation of existing heat exchangers is explained in chapter Ca of the VDI-Wärmeatlas (2006). A large variety of equations for different models and flow layouts can be found for the dimensionless parameter P_1 as a function of NTU_1 and R_1. Only in rare cases NTU_1 can be determined by solving these equations.

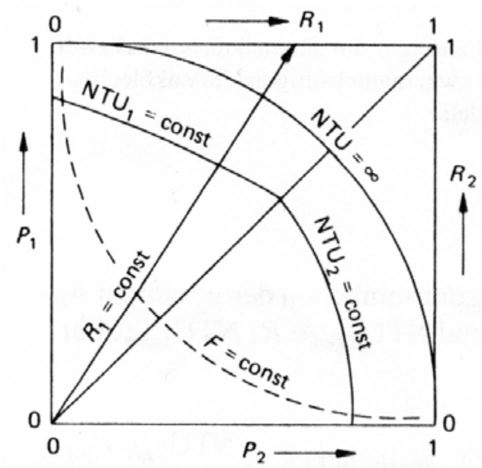


Figure 6-3: Schematic diagram for heat exchanger calculation (VDI, 2006)

Layout calculations often have to be solved with iteration. For symmetrical flows, the index 1 can be replaced by 2. Based on these equations, diagrams for different layouts can be plotted. The coordinate axes of the schematic diagram in Figure 6-3 represent the temperature changes P_1 and P_2, while the two remaining sides represent the heat transfer capacities R_1 and R_2. Two types of curves are shown in the diagram the full lines show the NTU for the specific P values, the dotted line stands for the correction factor F. After plotting the P values in the diagram, their intersection gives the NTU for the specific heat exchanger. The correction factor should reduce the effects of the logarithmic temperature difference, which is neglected for the following considerations. For flow layouts with $NTU_1 = NTU_2$, both curves meet at the bisecting diagonal line in the diagram. The following chapters discuss two types of heat exchangers suitable for the application with wastewater from the paper machines.

6.2.1. Double tube heat exchanger

Double tube heat exchangers consist of an inner tube which is fixed “swimming” in the outer tube. This method of flexible layout is important to compensate longitudinal expansions due to temperature differences between the inner and outer tube. Variations in the diameters of the tubes allow flows of highly viscous media, even with large pieces or fibres; the most important advantage. Typically the inner tube has only few bends and barriers to guarantee free flow. The tube connections of larger double tube heat exchangers are designed with flanges for easy access, maintenance and modular expansions. They are often found in the food processing and dairy industry with lumpy and viscous media flows.

Fast estimations of the numbers of transfer units of existing heat exchangers with known media temperatures are possible with the help of equation (23) and Figure 6-4. For a possible application with $\vartheta'_1 = 40°C$, $\vartheta''_1 = 30°C$, $\vartheta'_2 = 15°C$, $\vartheta''_2 = 25°C$, the dimensionless parameters P_1 and P_2 are both 0.4. For symmetrical flow with $R_1 = R_2$, the number of transfer units for this heat exchangers should be around 0.67 as indicated by the cross in the diagram.

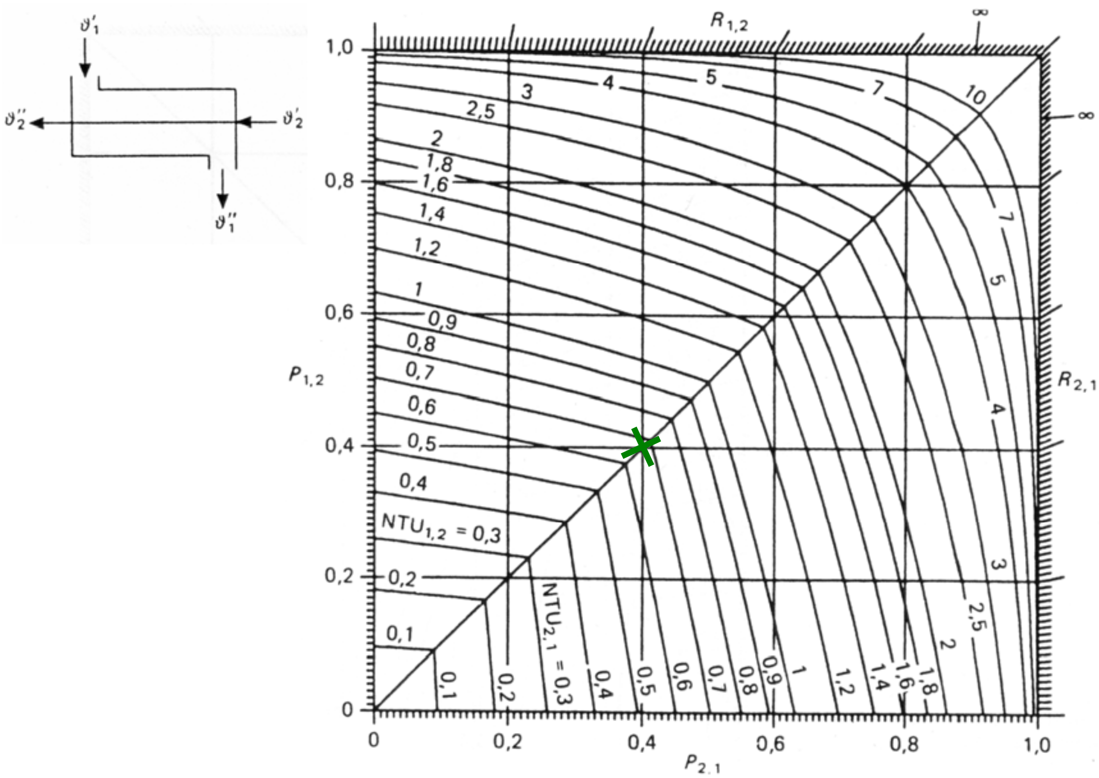


Figure 6-4: NTU diagram for heat exchangers with counter flow (VDI, 2006)

As mentioned before, the layout calculations for heat exchangers are not trivial. For simple counter flow designs, the layout calculations are based on the equations from table 4 page Ca7 in the VDI-Wärmeatlas (2006). These diagrams give a first idea about the possible temperature transfers. For the calculation an Excel spreadsheet is used, the specific heat capacity of water c_w is set to 4,190 J/(kgK) and density ρ_w is 1000 kg/m^3. For the two examples the realistic flow rates for the paper machines are used; wastewater from PM2 at 170 m^3/h and freshwater at 200m^3/h, for PM3 the wastewater flow is 250 m^3/h and freshwater feed-in is 300m^3/h. For heat exchangers with the thermal coefficient of 1000 W/(m^{2}K), the exchanger surface is plotted against the temperature transfer in Figure 6-5, without considering the flow directions as shown in Figure 3-10.

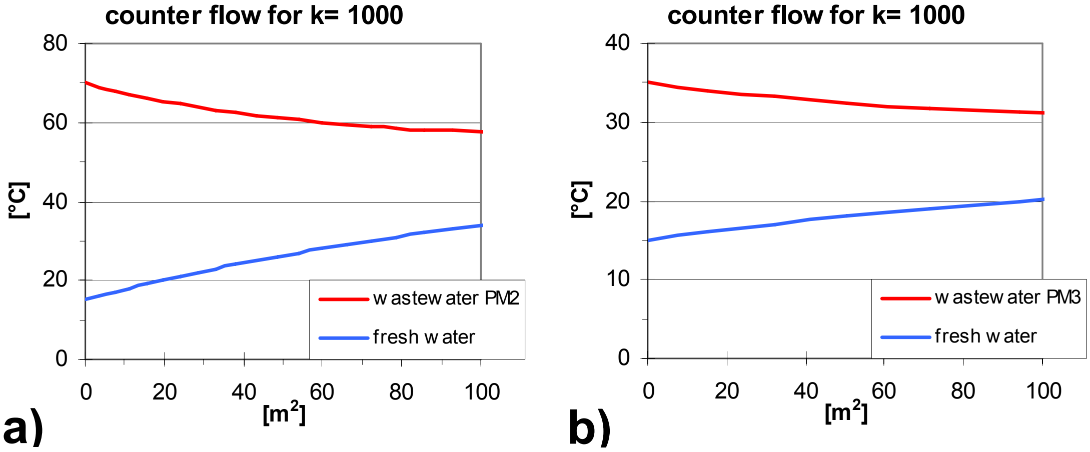


Figure 6-5: Layout calculations for counter flow designs at two temperature levels a) for PM2 and b) for PM3 (own calculations)

6.2.2. Plate heat exchanger

Large surfaces make plate heat exchangers a very powerful device for heat transfer applications. Compact designs reduce space demand but also allow easy expansion. Different types of plate surfaces allow the application with liquid but also viscous fluids. Additionally, the embossing of the plates enhances the thermal efficiency, lowers the loss of pressure or raises the differential pressure resistance. Free-flow plates as shown in Figure 6-6 are designed with a gap width of up to 12 mm for media with maximum 10% particles of up to 10 mm in size. The GEA free-flow plates are produced at a length of 2,772 mm and width of 985 mm for max. 1,900 m^3/h flow rate.

Figure 6-6: Embossing of GEA free flow plate (GEA TDS, 2009)

Plate heat exchangers are found in the beverage (juice and brewery) and food processing industry as well as pulp and paper industry. For sustaining a high efficiency, the plates require frequent cleaning which is time consuming.

The numbers of transfer units of plate heat exchangers with known media temperatures can be estimated with equation (23) and Figure 6-7. An application with $\vartheta'_1 = 70°C$, $\vartheta''_1 = 60°C$, $\vartheta'_2 = 15°C$, $\vartheta''_2 = 30°C$ results in the dimensionless parameters $P_1 = 0.18$ and $P_2 = 0.27$. Plotting these parameters for a plate heat exchanger with single passage of flow 1 and double passages for flow 2 in Figure 6-7, the number of transfer units for this heat exchanger should be around 0.37 as indicated by the cross in the diagram. This layout with parallel flow of the warmer medium and serial flow of the cooling medium is state of the art for plate heat exchangers.

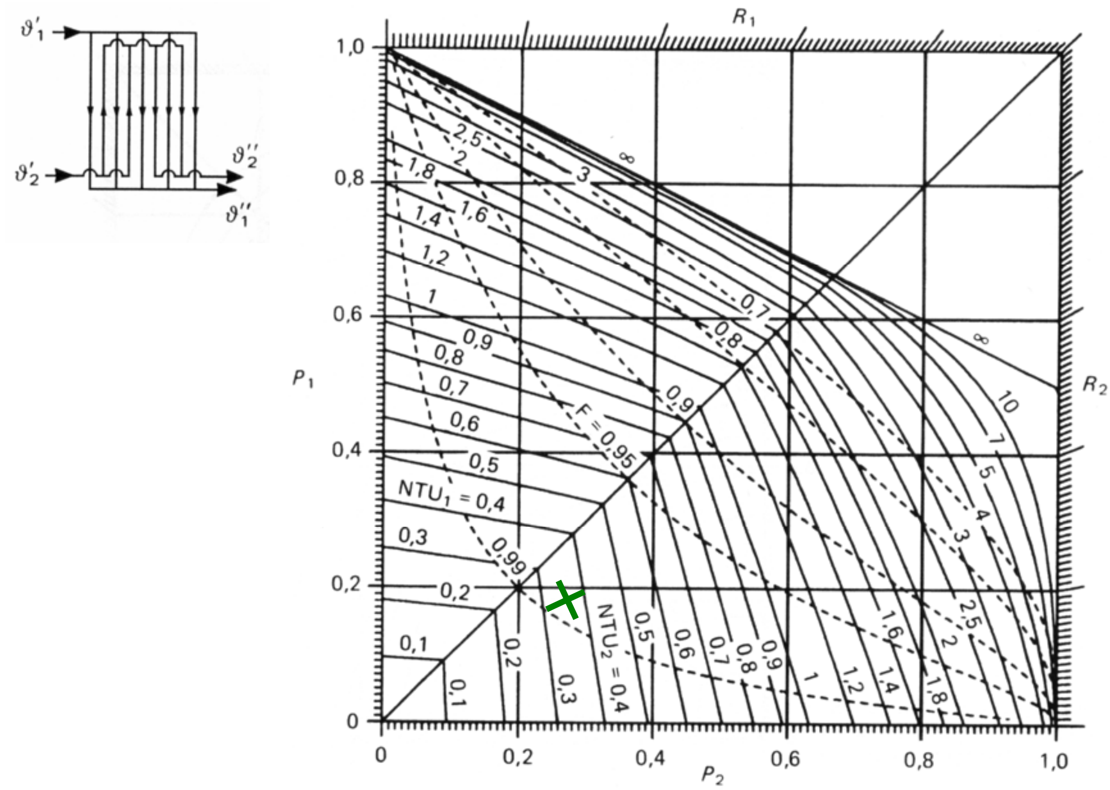
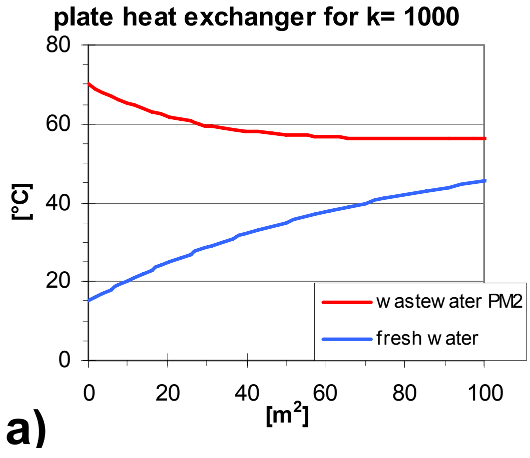


Figure 6-7: NTU diagram for plate heat exchanger with single passage of flow 1 and double passages for flow 2 (VDI, 2006)

The following layout calculations diagrams (Figure 6-8) are based on the equations from table 7 page Ca11 in the VDI-Wärmeatlas (2006). These diagrams use the same basic parameters in the excel calculation as before for the counter flow example. For the two paper machines a plate heat exchanger single passage of flow 1 and double passages for flow 2 and a thermal coefficient of 1000 W/(m^{2}K), the exchanger surface is plotted against the temperature transfer in Figure 6-8.



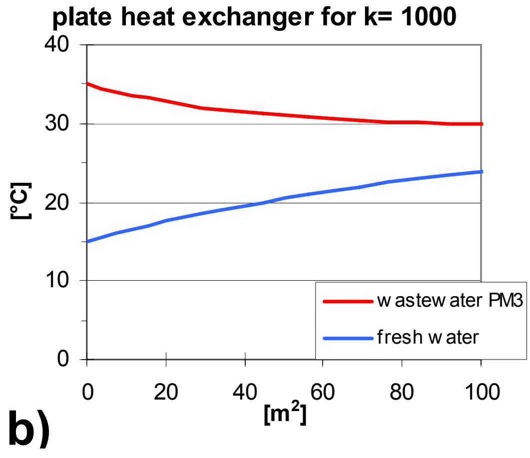


Figure 6-8: Layout calculations for plate heat exchanger with single passage of flow 1 and double passages for flow at two temperature levels a) for PM2 and b) for PM3 (own calculations)

6.3. Technical comparison

The tubular heat exchangers allow a wide range of applications as the diameters of the tubes are variable. This is a major advantage for wastewater heat recovery as this media is more viscous and with large pieces or fibres. Although this type of recuperator is typically used for high pressure and temperature applications, the particular properties of wastewater often require higher diameters, the upper limit is around 2,000 mm for this layout (Balzer, 2009). In contrary, the plate heat exchangers with compact design are limited to diameters of less then 15 mm. In the case of wastewater from paper machines with 80 mg to 200 mg of solids per litre with small diameters, the higher thermal coefficient of the latter is more favourable.

Table 6-1: Thermal coefficients of heat exchangers (VDI, 2006)

k-Value	[W/m^2*K]
Double tube heat exchanger	300 – 1,400
Plate heat exchanger	1,000 – 4,000

For the efficiency of tubular heat exchangers it is important to find the perfect ratio of tube diameter, thickness and length, but also to prevail fouling and clogging problems. The lower cleaning demand and easier maintenance is favourable for the double tube layout, although the spatial demand is higher.

7. Economic analysis of the project

7.1. Incentive programs for waste heat in Germany

Germany will provide about 500 million € per year for the period from 2009 to 2012 to subsidise renewable energies for heating. This funding is also stated in §13 of the EEWärmeG. The majority of this money will be redistributed by the Bundesamt für Wirtschaft und Ausfuhrkontrolle (BAFA) and the KfW bank via the market incentive program, the so-called MAP. Within this program the BAFA provides funding for solar collectors, biomass incineration and high efficient heat pumps, which supply heat from renewables considering the requirements of the EEWärmeG. Prerequisit for funding of a project which utilises heat from wastewater is the combination with an electric heat pump for combined hot water supply and heating. Funding for efficient heat pumps is dependent on the SPF which varies for the used media and age of the building (Table 7-1). For the determination of the SPF, the used electricity and produced heat have to be metered.

Table 7-1: Federal incentives for water/water heat pumps (BAFA, 2009)

	Existing buildings	New – building application before 01.01.2009	New – building application after 31.12.2008
Basic funding	20 €/m^2	10 €/m^2	7.50 €/m^2
SPF ≥ 3. (existing)	max. 3.000 € p.u.	max. 2.000 € p.u.	max. 3.000 € p.u.
SPF ≥ 4. (new)	max. 15% net-inv.	max. 10% net-inv.	max. 7.5% net-inv.
Innovation funding	30 €/m^2	15 €/m^2	
SPF ≥ 4.5 (existing)	max. 4.500 € p.u.	max. 3.000 € p.u.	
SPF ≥ 4.7 (new)	max. 22.5% net-inv.	max. 15% net-inv.	

p.u.: per accommodation unit
net-inv.: net-investment costs for heat pump (planning, material, connection)

Additionally to the funding by the MAP, several projects of waste-heat recovery are funded by the "BMU Klimaschutzinitiative". A large project for a cement mill utilises the hot flue gas from the rotary furnace in a newly designed recovery boiler to produce electricity. Waste heat recovery from a refinery is planned in Karlsruhe to feed the district heating network and process heat from metal casting in a foundry will be used for steam processes in a neighbouring food factory.

The heating in the UPM paper-mill is already a part of an internal water recycling system. Therefore the preheating of the 15°C cold process water by recovery of low-caloric heat with a heat exchanger is a promising application. This energy would replace natural gas and increase the efficiency of the paper machines. The installation of a heat pump is not considered for preheating of the process water in the paper-mill due to high investment costs and available heat from the gas boilers.

7.2. Investment costs

After the specification of all technically relevant parameters and the discussion of advantages and disadvantages for the heat recovery from the wastewater of the paper machines, two companies were asked to submit an offer. The heat exchanger layouts are planned with 35°C wastewater temperature cooled to 30°C and heating of 15°C freshwater to 20°C for the flow parameters of PM2 and PM3, respectively. GEA Ecoflex GmbH provided full layout calculations and offers for plate heat exchangers, whereas Wilhelm Deller GmbH & Co. KG only provided approximate numbers for double tube heat exchangers.

The high costs of double tube heat exchangers, which are generally more than 10 times higher in comparison to plate heat exchangers, are due to a higher amount of material and manpower (Balzer, 2009). For that reason, a double tube heat exchanger in an industrial application of low-caloric heat recovery can never be economically feasible and is not considered in the following.

The very detailed layout calculation and the offered prices for plate heat exchangers suitable for the application with wastewater from a paper machine can be found in appendix A (Kaimer, 2009). The calculations use a standard layout with a single passage for flow 1 and double passages for flow 2 as discussed in chapter 6.2.2. The best suitable layout of the GEA products is the FA 184 B-6 free flow plate with 12 mm and 6 mm width for the two media (Kaimer, 2009) as shown below.

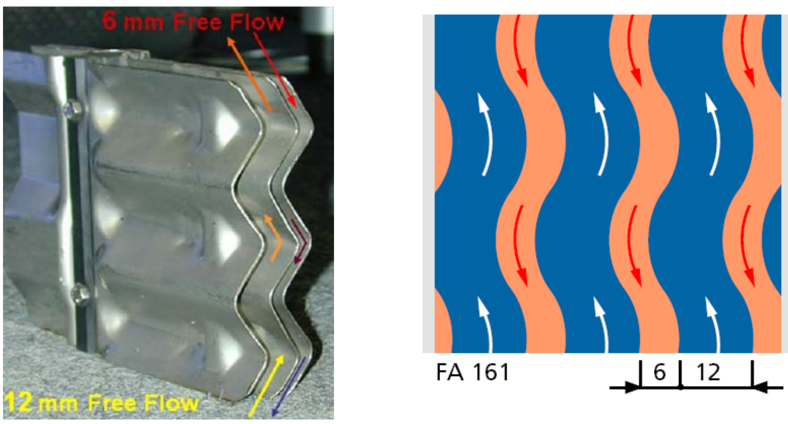


Figure 7-1: Cross section of GEA Ecoflex free flow plates (Kaimer, 2009)

The offer considers 100% backup to compensate maintenance and cleaning for continuous preheating of the process water. The redundant heat exchanger minimises the risk of failure downtime and losses requiring alternative preheating devices.

The calculated area is totally consistent with the calculations from the excel spreadsheet based on VDI-Wärmeatlas (2006) and includes 10% extra area for losses due to fouling (further details can be found in appendix A).

Table 7-2: Offer for plate heat exchangers, inflow temperature 35°C (Kaimer, 2009)

Model: GEA Ecoflex FA 184 B-6		PM2	PM3
Exchanger surface area	m^2	24.8	37.6
k-value	$W/(m^2*K)$	2,599	2,514
Heat capacity	kW	978.2	1,438.5
Number of plates		34	50
Price (1 pcs.)	€	7,800	9,500
Total price	€	15,600	19,000

Piping for the connection of the heat exchangers has to be installed, existing piping eventually redesigned. The costs for each paper machine amount to approximately 5,000 € for material and manpower (UPM, 2009d). The above heat exchanger layout for PM2 is also suitable for 70°C (Kaimer, 2009).

7.3. Heat demand and production costs for useful heat

Low-caloric energy can be used directly to heat cold freshwater from the borehole for further applications at higher temperature levels. The preheating with the heat content of process- and wastewater is very common in modern paper machines, yet there is still some possibility to improve the efficiency. If installed as first level heating device, the heat exchangers recover about 7.9 GWh (PM2) or 11.6 GWh (PM3) of heating energy by cooling the wastewater from 35°C to 30°C and heating the freshwater from 15°C to 20°C. In the case of the older PM2 in Augsburg, where the 70°C wastewater is not utilised yet, and cooled down by river water to reach the discharge temperature, a large potential is still unused. The preheating of process water to 30°C from wastewater would compensate for up to 23.7 GWh of heating energy.

The paper production of the UPM-Kymmene paper-mill in Augsburg strongly depends on the gas price, as this fossil fuel is the only energy source for the steam production on site. As a result, the constant rise of gas price during the last years (see Figure 7-2) directly increases the production costs for paper.

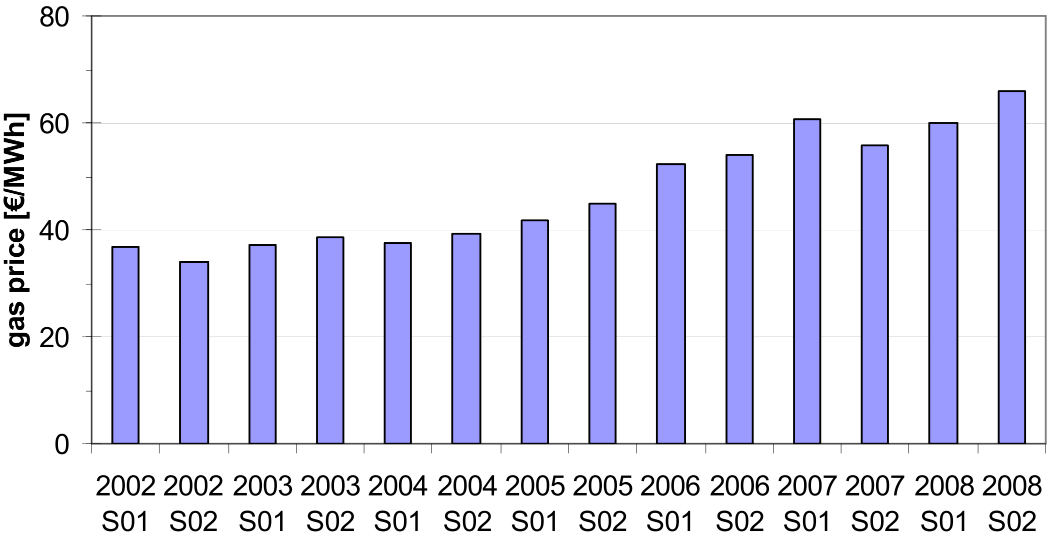


Figure 7-2: Semestral gas price changes since 2002 for industry (EUROSTAT, 2009)

The changes in gas prices from about 36.90 € per MWh in 2002 to 66.10 € per MWh at the end of 2008 equates to a price rise of 180% within 6 years.

7.4. Financial analysis

Heat recovery from wastewater typically entails higher investments than conventional heating systems, but can reduce operation costs by lowering the fossil fuel demand.

The high heating potential may pretend large savings, but all initial and running costs have to be taken into consideration. For the evaluation of the heat recovery with plate heat exchangers from the 35°C wastewater of the UPM-Kymmene paper-mill, the net present value (NPV) method is used. All future cash flows and the time value of the money are considered with NPV calculations. Being a very common method for the evaluation of long term projects, it measures the discounted cash flows (C_N) for the time of operation (T) compared to the net initial investment (NII).

Table 7-3: Basic principle of NPV (Aussenegger, 2008)

Time	t = 0	t = 1	t = 2	…..	t = T
Net cash flows	– NII	C_1	C_2	…..	C_N

The NPV results from the subtraction of the NII from the present value (PV) of the project with a certain discount rate (k) as shown in equation (24).

$$\mathbf{NPV = -NII + PV = -NII + C_1*(1+k)^{-1} + C_2*(1+k)^{-2} + \ldots + C_N*(1+k)^{-1T}} \quad (24)$$

If the NPV is used to determine whether the project is an acceptable investment, the NPV of the project should be higher than 0, otherwise it should be rejected. This also means for two competing alternatives, the one yielding a higher NPV should be realised.

For heat recovery from wastewater, it is important to know, if the project can be profitable in comparison to other alternatives. Only projects which increase the amount of value created per unit of investment with consideration of all possible costs are realised. The profitability index (PI) measures the NPV per net investments (NINV) and serves as decision criteria when several projects have a positive NPV but only limited resources are available (Aussenegger, 2008). The projects with higher PI are favourable; projects with negative PI due to negative NPV are strictly rejected. Often a minimum PI has to be reached in short time.

$$\mathbf{PI = \frac{NPV}{NINV}} \quad (25)$$

The following feasibility calculations are based on the offer from GEA for the free flow heat exchangers FA 184 B-6 with 100% backup, piping and labour costs of 5,000 € and 19% value added tax (VAT).

7.4.1. Feasibility for PM2

Based on the offer from GEA for the free flow heat exchangers FA 184 B-6 with 34 plates, the investments including piping, labour and VAT are 24,514 € for heat recovery from 35°C wastewater of PM2. The very low annual cleaning and maintenance expenses of only 300 € are realistic due to the small size of the fibres. Free flow plate heat exchangers typically require cleaning every 3 to 6 month (Kaimer, 2009). Decreasing the paper-mill's primary energy demand, the heat exchangers help to reduce the fuel costs. The heat recovery of 5 K would substitute 7.91 GWh of heating energy for freshwater preheating. This increase of 1% in efficiency of the paper machine helps to reduce the total fuel demand by 1% in total. Calculated with a gas price of 66.10 € per MWh, the savings of 1% total gas demand are worth 5,228.51 € per year. An interest rate of 7% is used for the calculations in Table 7-4 as a quite conservative assumption. A positive discounted cumulative cash flow for this application is not reached until the 7th year of operation. After 10 years, the NPV is 10,101.79 € constantly growing due to the low maintenance demand and long lifetime (<30 years) of the plate heat exchangers.

Table 7-4: Economic feasibility calculations for PM2 (own calculations)

Interest rate 7%

Year	Expenses [€]	Savings [€]	Cash-flow [€]	Present value [€]	Disc. cum. cash-flow [€]
0	24,514.00		-24,514.00	-24,514.00	-24,514.00
1	300.00	5,228.51	4,928.51	4,606.08	-19,907.92
2	300.00	5,228.51	4,928.51	4,304.75	-15,603.16
3	300.00	5,228.51	4,928.51	4,023.13	-11,580.03
4	300.00	5,228.51	4,928.51	3,759.94	-7,820.10
5	300.00	5,228.51	4,928.51	3,513.96	-4,306.14
6	300.00	5,228.51	4,928.51	3,284.07	-1,022.06
7	300.00	5,228.51	4,928.51	3,069.23	2,047.17
8	300.00	5,228.51	4,928.51	2,868.44	4,915.60
9	300.00	5,228.51	4,928.51	2,680.78	7,596.39
10	300.00	5,228.51	4,928.51	2,505.40	10,101.79

NPV (€)	10,101.79

Figure 7-3 visualises the discounted cumulated cash-lows for PM2 as listed in Table 7-4. The savings on gas would finally pay off the investment at the end of the 6th operating year. Yet the PI for heat recovery from 35°C wastewater from PM2 is 0.41 after 10 years.

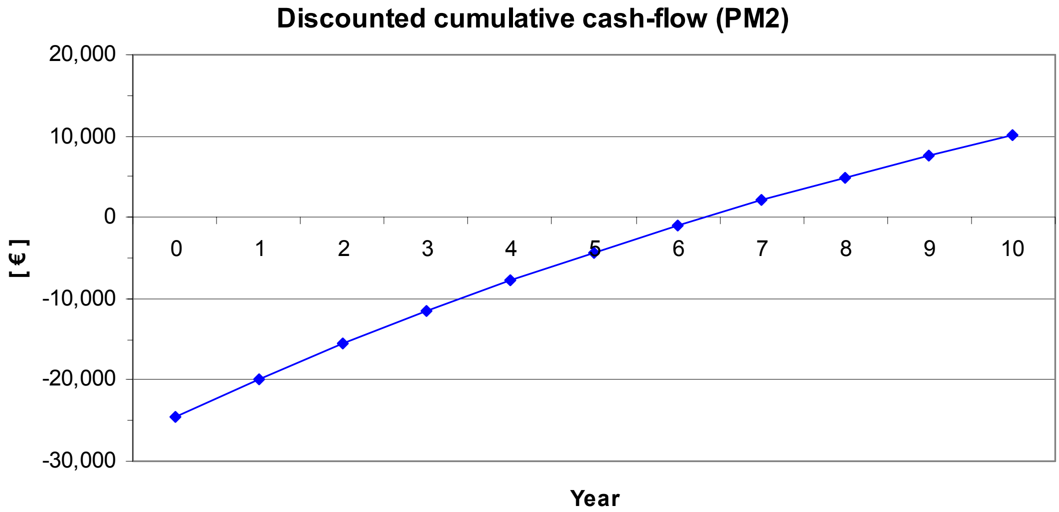


Figure 7-3: Discounted cumulated cash-flow for PM2 (own diagram)

7.4.2. Feasibility for PM3

Analogous to PM2, a GEA free flow heat exchanger FA 184 B-6 with 50 plates is used for heat recovery from the 35°C wastewater of PM3. Investments including piping, labour and VAT accumulate to 29,274 €, annual cleaning and maintenance expenses are 300 €. Substituting 11.64 GWh of heating energy for freshwater preheating, the increase of 1% in efficiency for the paper machine reduces the total gas costs by 7,394.04 € per year. A conservative estimation for the interest rate is 7%, which is also used for the calculation in Table 7-5.

Table 7-5: Economic feasibility calculations for PM3 (own calculations)

Interest rate 7%

Year	Expenses [€]	Savings [€]	Cash-flow [€]	Present value [€]	Disc. cum. cash-flow [€]
0	29,274.00		-29,274.00	-29,274.00	-29,274.00
1	300.00	7,694.04	7,394.04	6,910.32	-22,363.68
2	300.00	7,694.04	7,394.04	6,458.24	-15,905.44
3	300.00	7,694.04	7,394.04	6,035.74	-9,869.70
4	300.00	7,694.04	7,394.04	5,640.88	-4,228.82
5	300.00	7,694.04	7,394.04	5,271.85	1,043.02
6	300.00	7,694.04	7,394.04	4,926.96	5,969.98
7	300.00	7,694.04	7,394.04	4,604.64	10,574.62
8	300.00	7,694.04	7,394.04	4,303.40	14,878.02
9	300.00	7,694.04	7,394.04	4,021.87	18,899.89
10	300.00	7,694.04	7,394.04	3,758.76	22,658.64

NPV (€)	22,658.64

A positive discounted cumulative cash flow for PM3 is reached in the 5th year of operation, the NPV is 22,658.64 € after 10 years. Figure 7-4 shows the results of calculations for the utilisation of heat from wastewater to preheat freshwater in PM3. Due to the higher volumes and heat demand, the PI is 0.77 for this scenario.

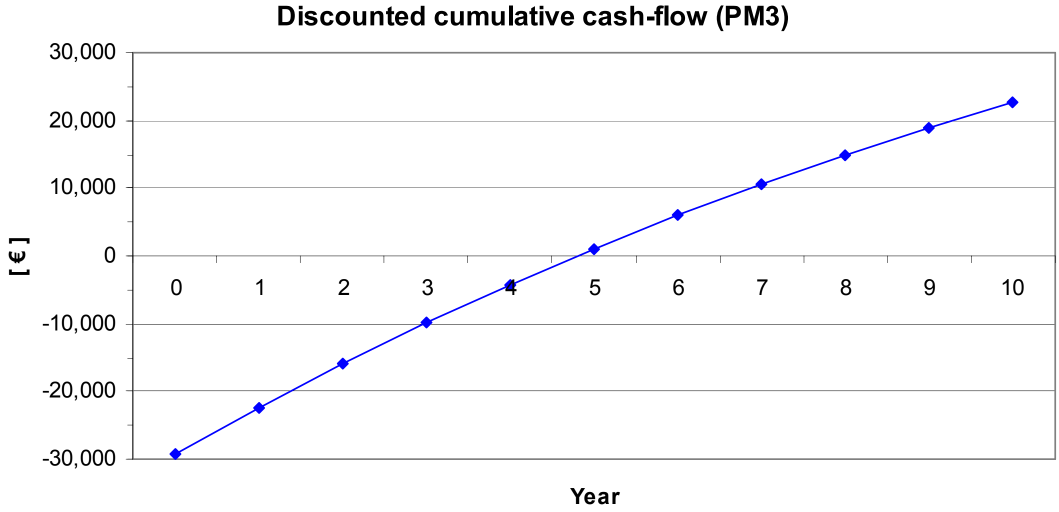


Figure 7-4: Discounted cumulated cash-flow for PM3 (own diagram)

7.4.3. Economic comparison

The heat recovery of 5 K from the 35°C warm wastewater could increase the paper machines' efficiency by approximately 1%, resulting in savings of gas. Currently the investment plans of UPM-Kymmene (like most other companies) are not focused on long term projects, as a profit should be achieved in the shortest period of time.

Based on average temperatures of 35°C, the larger volumes of wastewater from PM3 result in higher heat recovery. Hence, the larger substitution of primary energy reduces the operation costs due to lower fossil fuel demand. The expenses for PM2 would pay off at the end of the 6th year, for PM3 during the 5th year of operation. A comparison after 10 years shows the higher NPV for the larger plate heat exchanger (PM3) as well as the higher PI. If only one paper machine would be equipped with the additional heat recovery, PM3 should be selected although being more modern and more efficient than PM2.

On the other hand, during the study the higher outflow temperatures of PM2 were discovered. A cooling of this 70°C wastewater by 10°C would save double the amount of fossil fuel. The layout of the offered plate heat exchanger is suitable for this temperature level and would pay off at the beginning of the 3rd year.

8. Ecological impact

The large potential of heat from wastewater utilisation of paper-mills is also very promising with respect to the ecological benefits. If recovered close to high potential users such as the paper production itself, swimming pools, large industrial buildings or larger condominiums, the amount of heat can substitute conventional heating systems. Immissions otherwise produced can be seen as “saved” and taken into full account for low temperature applications such as water preheating or by parts in case of heating systems with a heat pump.

Depending on the fossil fuel used for the substituted heating devices, airborne immissions and CO_2 can be drastically reduced with heat recovery from wastewater. In case of the example from PM2 in Augsburg, where the 70°C wastewater could easily heat water from 15°C to 30°C and provide an equivalent of 23.7 GWh heating energy, the ecological benefit is huge. Table 8-1 gives a rough estimation of the immisions from fossil fuels with respect to heat generation.

Table 8-1: Immission factors with respect to useful heat (LfU, 2008)

[t/GWh]	SO_2	NO_x	HCl	HF	Dust	CO	CO_2
Coal	3.051	0.380	0.110	0.02	1.25	19.48	556.8
Oil	0.621	0.281	0.001	< 0.01	0.035	0.218	375.2
Gas	0.016	0.235	0.001	< 0.01	0.010	0.166	266.6

The best ecological solution (as well as technical and economical) is the direct implication of heat exchangers in the water system of the paper-mill. Most modern paper machines already use highly sophisticated systems for heat recovery; state of the art technology lowers the heat demand to approximately 4.17 to 5.28 kWh per produced kilogram of paper (LfU, 2008). Compared to the enormous annual heat demand of the paper-mill in Augsburg (2,085 GWh to 2,640 GWh), the savings on primary energy for a temperature difference of 5°C at the outflow of the heat exchanger are less than 1%. Heat recovery of 7.9 GWh and 11.6 GWh for the two paper machines (refer to chapter 4.3) are still large numbers! The reduction of CO_2 would be more than 5,000 tonnes per year.

Although the energy demand for municipal projects is lower, the reduction of primary energy and CO_2 immisions makes these applications worth the investment. The following Table 8-2 compares the final energy demand of a conventional gas heating system with two multivalent wastewater heating systems; one with electric heat pump and the second in combination with a CHP. For both systems, about 33% of useful heat is generated by a peak demand boiler. The electric heat pump has a final energy demand of 45.6% compared to the conventional system. The savings are 54.4% resulting in a 40% share of heat recovery from the wastewater.

Table 8-2: Comparison of final energy demand (Rometsch, 2004)

	conventional heating	electric heat pump	heat pump and CHP
Fuel demand (peak) boiler	100%	33%	33%
Fuel demand heat pump/CHP	0%	0%	27%
Electricity demand heat pump/CHP	0%	12.6%	0%
Total	100%	45.6%	60%
Savings final energy	0%	54.4%	40%
Losses		14.4%	9.3%
Heat recovery from wastewater		40.0%	30.7%

Multivalent heating systems with heat recovery from wastewater can reduce immisions of CO_2 and further greenhouse gases up to 60% in comparison to conventional systems with fossil fuels (DBU, 2005). The immissions of CO_2 are lowered by almost 40% with multivalent wastewater heating systems as shown in Table 8-3. The possibility of reverse heat pump operation for cooling can additionally improve the ecological benefits.

Table 8-3: Comparison of CO_2 immissions (Rometsch, 2004)

	conventional gas heating	electric heat pump	heat pump and CHP
Electricity	0%	50%	0%
Fuel	100%	33.1%	60.4%
Total	100%	83.1%	60.4%
CO_2 savings		16.9%	39.6%

9. Outlook for communal wastewater heating projects

9.1. Planning phase and risks

In the case of no demand on site of the paper-mill or proximity, potential customers of heat (> 150 kW) have to be located within 100 m distance along major sewer canals (>800 mm). The dry-weather flow rates should be > 15 l/s and temperatures > 10°C in winter. As mentioned already in chapter 3.1, most projects become energetically and economically interesting when realised as multivalent, low-temperature systems with the heat exchanger, heat pump and buffer combined with a peak demand boiler. The consumers, e.g. public and office buildings, swimming pools, sport facilities, hotels or industriesa with low temperature heat demand (or cooling demand) can be connected to a small district heating network.

For heat recovery from wastewater, it is most important to know the technical and financial risks of such a project, experiences from pilot projects and basic conditions. A feasibility study for possible heat consumers should be conducted and based on the demand profile during the year, cooling demand should also be considered. For a highly efficient and ecological utilisation of heat from wastewater, detailed comparisons of existing and alternative heating solutions have to be undertaken. Only in case of necessary refurbishment or new constructions of the supplied buildings, economical and ecological benefits are achieved.

If the orientation phase and feasibility study were successful, the most important but also most difficult part of the project can be approached: the political acceptance and authorisation. This process can be very time consuming, as many different parties are involved. Legal aspects pertaining to the clean water act have to be considered and contracts need to be concluded.

Realisation of heat recovery from wastewater has a direct influence on the municipal sewer system and therefore several points of interaction have to be checked carefully. These projects can bear several risks which should be avoided.

- Nffect on the effluent flows in the sewage canals by forming flow barriers
- Heat supply failure due to lack of wastewater flows (construction, diversion, cleaning, maintenance)
- Rise in costs for useful heat from unknown costs (e.g. frequent cleaning)
- Lack of experience with large scale heat pumps
- Health hazard in low-temperature systems due to legionella

Besides political and legal obstacles, the costs for the heat recovery and the useful heat should not exceed certain economic limits. The costs for the heat exchanger and installation in the municipal sewer system typically account for more than half of the costs for a project e.g. in Berlin (Biesalski, 2009) as shown in Figure 9-1. If a refurbishment of the canal is planned, the costs for civil and underground engineering can be reduced. For realised wastewater heating systems, the costs for 1 m of heat exchanger vary from 1,070 € to 1,360 € resulting in investments of 325 € to 455 € for 1 kW of useful heat (Wallstein, 2009).

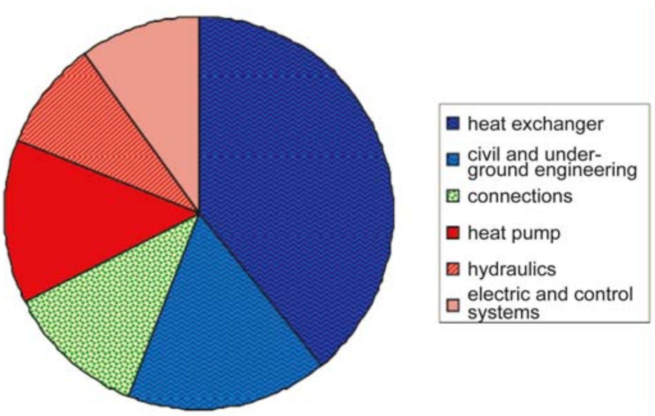


Figure 9-1: Proportionate investments for wastewater heating system (Biesalski, 2009)

The critical heat demand of the customers connected to wastewater heating systems is approximately 1,000 kW for projects to be profitable (see Figure 9-2). Systems combined with cooling lower the break-even point and raise the ecological benefits.

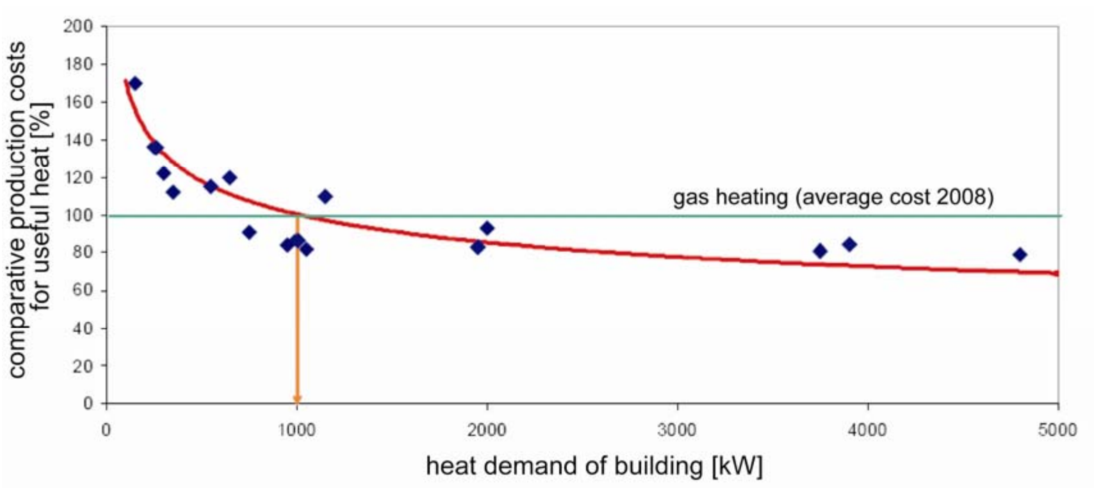


Figure 9-2: Comparative production costs for useful heat of installed wastewater heating systems in Switzerland (Schmid, 2009)

9.2. Pilot projects

The technology of heat recovery from wastewater is not new. In contrary, some pilot projects are in operation for more than 20 years now. The majority of the projects are located in Switzerland, fewer projects in Germany. In Waiblingen, the city hall, other public buildings and privates homes are heated with this technology since 1986. Especially the tri-border region between Germany, Switzerland and France has a high density of such projects, e.g. the city of Schaffhausen and several districts of Basel which use heat recovery from wastewater in larger scales. Two projects are described in the following with more details and economic evaluations.

9.2.1. Winterthur "Wässerwiesen"

Located at the main interceptor canal of the city, 400 units in the residential area of "Wässerwiesen" cover their heat demand with a share of approximately 70% from wastewater. The heat pump produces 820 kW of the total 1150 kW heat demand (EnergieSchweiz, 2005). Initiated by a study of the city for efficient energy planning, new constructions along larger sewer canals require a feasibility study on heat recovery from wastewater. If the potential is economically justifiable, the construction permit is only granted with incorporation of this technology. Despite higher investments, one advantage is lower operation costs. Swiss law also requires at least 20% of heat demand covered with sustainable technology. In this example, the wastewater heating system substitutes for costs of building insulation. The following Figure 9-3 shows the economic evaluation for this project.

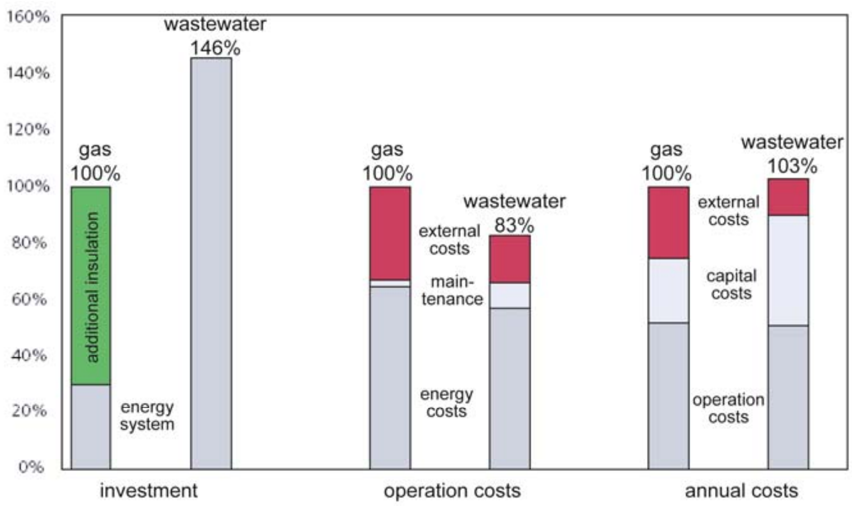


Figure 9-3: Economic evaluation of wastewater heating in Winterthur "Wässerwiesen" (EnergieSchweiz, 2005)

9.2.2. Leverkusen „Health-Care Zentrum"

The "Health-Care Zentrum" in Leverkusen comprises a shopping mall and office space with 12,500 m^2 area. The building has a heat demand of 1,030 kW and cooling demand of 470 kW which implies best conditions for the utilisation of a heat pump. A major sewer canal in 40 m distance covers approximately 68% of heating and cooling demand from wastewater. The heat pump capacity is 242 kW for heat and 200 kW for cooling (DBU, 2005). Although a connection to the district heating network was possible, the necessary refurbishment and expansion of the sewer canal made the investment in wastewater heat recovery profitable. Investment costs for this pilot project accumulated to 350,000 € for the heat recovery system, 30,000 € for the underground engineering, 70,000 € for a small CHP and approximately 70,000 € for planning, resulting in a total of 520,000 € (Rometsch, 2005). The project received 50% funding from the federal government of North-Rhine-Westphalia. Calculations for 5,700 h annual operation result in costs for useful heat of approximately 9.5 ct/kWh (Rometsch, 2005) and therefore are slightly lower than district heating. Nevertheless, the major advantage is the reverse operation of the heat pump in summer. The project reduces the electricity consumption for air cooling in comparison to conventional alternatives and CO_2 immissions.

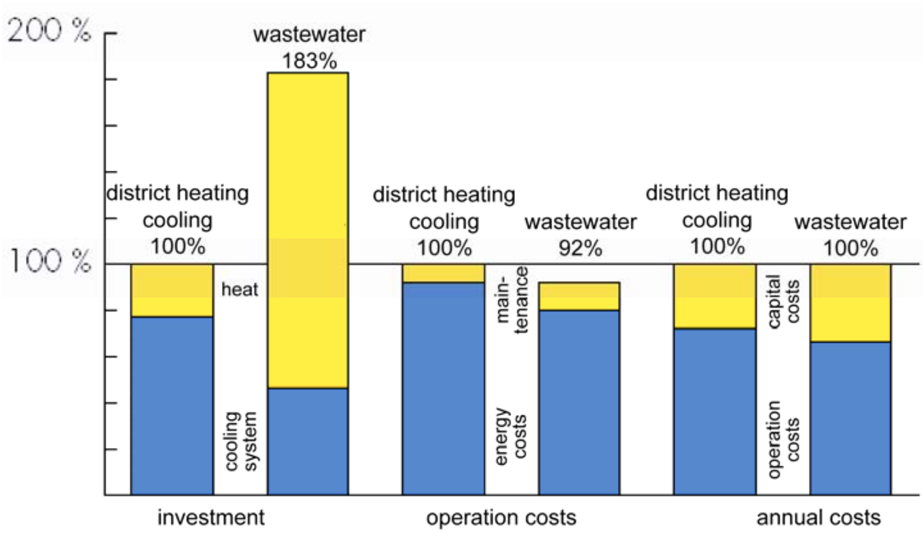


Figure 9-4: Economic evaluation of wastewater heating and cooling in Leverkusen "Health-Care Zentrum" (DBU, 2005)

9.3. Potential in Augsburg

Generally the potential for heat recovery from wastewater rises with constantly high flow rates and temperatures. These conditions are preferentially found in interceptor sewers. The discharge of wastewater from a paper-mill increases the potential, if not used directly. The sewer canals in Augsburg merge into 3 major interceptors, each with average flow rates of at least 500 l/s (Stadt Augsburg, 2009b). The UPM-Kymmene paper-mill has an average discharge of approximately 47 l/s from PM2 (170 m^3/h) and 70 l/s from PM3 (250 m^3/h). The high inflow temperatures in the municipal wastewater treatment plant with large volumes (see Figure 5-5) are precondition for heat recovery without affecting the biological cleaning efficiency of the plant.

For the evaluation of potential in Augsburg, a map of the canalisation has to be compared to locations of potential heat consumers. An overlap with areas connected already to the district heating network should be avoided. In general, district heating is also very environment-friendly and cheaper in competition with heat recovery from wastewater. An unpublished and not public study of the canalisation authority of Augsburg and Stadtwerke Augsburg (2008) identified canals with a diameter larger then 800 mm, which are suitable for the integration of heat exchangers. Several potential customers such as larger condominiums with intermediate as well as public, office and industrial buildings with higher heat demand are located along these stretches of major sewer canals. The following Figure 9-5 gives a rough overview of two major canals with good potential. Detailed cadastral maps are available, but the distinct content of this study is not subject for public access.

The larger canals are often situated underneath larger streets, so are the indicated canals with large diameter in Figure 9-5. If refurbishment of these canals becomes necessary and heat demand is determined in the proximity, the integration of heat exchangers should be considered. Especially the sewer with the large discharge volumes of the paper-mill is favourable due to the slightly higher temperatures.

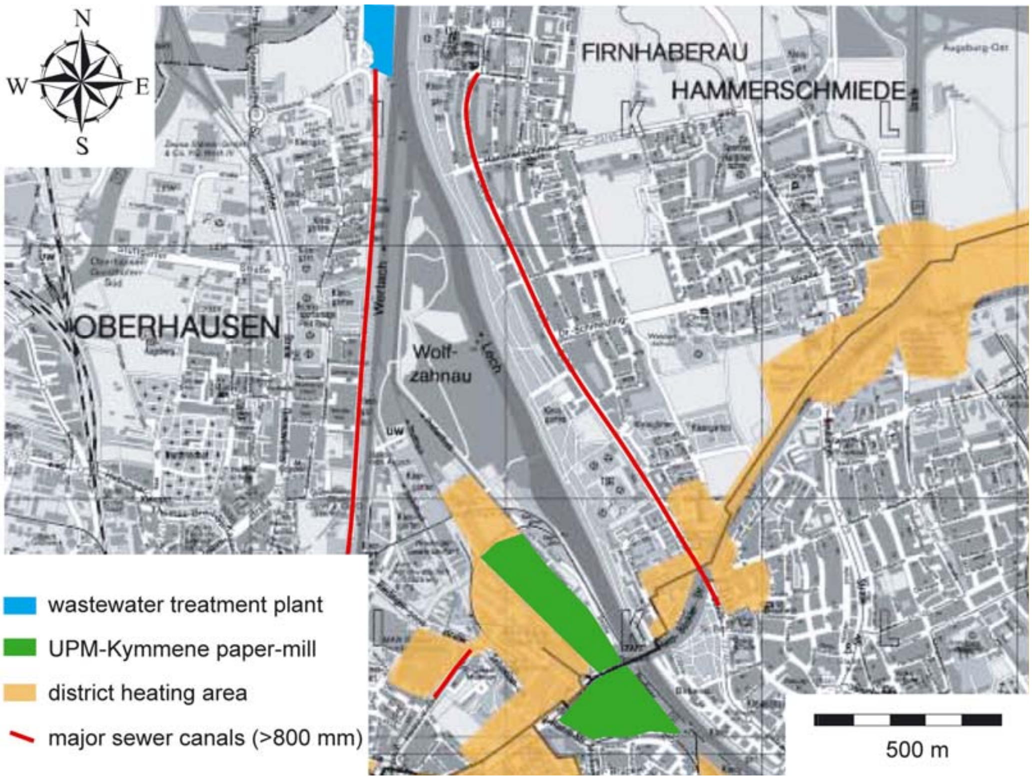


Figure 9-5: Overview map potential sewer canals north of UPM in Augsburg (Stadtwerke Augsburg, 2008; Stadtwerke Augsburg, 2009)

10. Summary and conclusions

This study is conducted to show the high potential of heat recovery from wastewater, especially from large industrial discharge volumes as produced by paper machines. The location of the UPM-Kymmene paper-mill adjacent to the city centre of Augsburg is very interesting for a utilisation. On the one hand, the large energy demand of paper production could be lowered by little increases of the machines efficiencies. On the other hand, if low-caloric heat demand exists close to the paper-mill or implementations of heat exchangers in the municipal sewer canals are feasible for heating systems, the wastewater from paper-mills is advantageous due to large volumes and temperatures of 35°C in average.

A large variety of heat exchanger designs is available for the recovery of heat from wastewater. An application in existing canals is only possible, where good access into the sewer system is given. Refurbishments of existing canals are often used for integration of heat exchanger surface into the new segments. Depending on the local situation, bypass solutions with tubular or plate heat exchangers allow the perfect adjustment to the flow rate and heat demand. For municipal wastewater, a water strainer should be installed ahead to keep off coarse material. The utilisation of paper-mill wastewater is less complicated due to very homogenous properties with fibres rarely exceeding 10 mm in length.

Both paper machines require large amounts of preheated freshwater (300 m^3/h and 200 m^3/h). The waste heat in the discharge of 250 m^3/h from PM3 and 170 m^3/h from PM2 can be directly used for the preheating of cold water from the borehole. The most realistic application is the heat recovery from 35°C wastewater, cooling it down by 5°C and heating the freshwater from 15°C to 20°C in a heat exchanger. This would substitute a primary energy demand of 11.6 GWh for PM3 and 7.9 GWh for PM2 in Augsburg.

For small municipal wastewater treatment plants, the heat recovery from the sewer can result in problems with the biological nitrogen elimination. Low temperatures, especially in winter can “freeze” the bacteria activity in the activated sludge basin, which has to be avoided. The investigations on discharge temperatures from UPM-Kymmene and inflow temperatures at the Augsburg wastewater treatment plant have shown no direct interactions. Inflow temperatures average around 14°C in January; the influence of large volumes from other streams is dominant. A heat recovery from the paper-mill’s wastewater resulting in a 5°C lower discharge

temperature would only have a small or no effect. Temperature levels at the inflow of the biological cleaning basins would only sink by parts of a tenth.
The best technical solution for heat recovery on site is a plate heat exchanger with single passage of the wastewater and double passages of the cold freshwater. In comparison to tubular heat exchangers, they have limited diameters (>12 mm) for solids in the wastewater but higher thermal coefficients. The major advantage of tubular designs for the application with wastewater is the larger diameter causing less maintenance and cleaning demand.
Considering the large potential in the wastewater from paper-mills, the heat (and cooling) demand of many larger buildings can be covered in combination with a heat pump. Funding is available from the BAFA as stated in §13 of the EEWärmeG. The homogenous wastewater from paper-mills allow, if utilised directly on site, the application of cheap and highly efficient plate heat exchangers. Yet, the full amount of this low-caloric heating energy can only be used for the preheating of process water. An increase in efficiency of paper machines by 1% saves a large amount of fossil fuel. The annual savings of 5,228.51 € and 7,694.04 € result from approximately 200,000 m^3 less gas demand. The long lifetime and low maintenance costs for plate heat exchangers in paper-mills result in a NPV (after 10 years) of 10,101.79 € for PM2 and 22.658.64 € for PM3, respectively.
As mentioned before, the reduction of primary energy demand by only few percent for such an energy intensive industry as pulp and paper production has a huge ecological impact. Reductions of CO_2 immisions are immense. For the most likely application with a rise in efficiency of 1%, the paper-mills CO_2 immissions would be reduced by approximately 5,000 t annually. Heating systems with recovery from the municipal sewer for heating can reduce the final energy demand by at least 40% to 55% and CO_2 up to 40% in comparison to conventional heating systems.
Although the technique of heat recovery from sewer canals is not very new or sophisticated, it is not very common. Several pilot projects exist, but high investment costs, as well as legal and political issues impair the interest of private companies. The larger projects in combination with cooling become economically feasible with rising fossil fuel prices. The very constant flow rates and temperatures from the UPM paper-mill, as well as the quite high inflow temperatures in the communal wastewater treatment plant indicate great potential for the utilisation of this waste heat. Also multivalent wastewater heating systems along major sewer canals would be possible. Considering all risks and obstacles, the heat recovery from wastewater can help to reduce our primary energy demand and CO_2 immissions.

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12. Appendices

Appendix A

GEA Ecoflex offer No. 10 46833 239 Rev.,0 for plate heat exchangers

GEA

GEA Ecoflex GmbH • Postfach 1165 • D-31151 Sarstedt

Bifa Umweltinstitut
Herr Bratzdrum
Am Mittleren Moos 46
86167 Augsburg
Deutschland

Process Equipment

31.07.2009

ANGEBOT – Nr. 1046833239 Rev. 0

Ihre Anfrage:	**Machbarkeitsstudie UPM**
Ihr Ansprechpartner:	Herr Bratzdrum, Tel.:0151 14319417
Unser Ansprechpartner:	Stefan Kaimer, Tel.: +49 (0) 5066 601 - 424 / Fax: -104 E-Mail: stefan.kaimer@geagroup.com
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Sehr geehrter Herr Bratzdrum,

wir danken Ihnen für Ihre Anfrage und bieten Ihnen die beiliegenden Positionen – unter ausdrücklicher Bezugnahme auf unsere als Anlage beigefügten und unter www.gea-ecoflex.de einsehbaren Bedingungen für Lieferung von Maschinen und Komponenten für Inlands-/Auslandsgeschäfte in der jeweils gültigen Fassung – an:

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10	0	N40 L, 46Pl., 1.4401, 0.8, EPDM, CDS-10, S235-JRG2 Kundenposition: 2 x 100% beidseitig 5 mm Spalt	2	3.800,00 Euro	7.600,00 Euro
10	**1**	**FA184 K, 34Pl., 1.4401, 1.0, EPDM, B-6, S235-JRG2** **Kundenposition: 2 x 100%**	**2**	**7.800,00 Euro**	**15.600,00 Euro**
20	**0**	**FA184 K, 50Pl., 1.4401, 1.0, EPDM, B-6, S235-JRG2** **Kundenposition: Freistromwärmetauscher 12 mm Spalt abwasserseitig**	**2**	**9.500,00 Euro**	**19.000,00 Euro**

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Die Gewährleistung beträgt 24 Monate nach Lieferung ab Werk Sarstedt.
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Angebotsnummer	1046833239	**Anfragenummer:**	Machbarkeitsstudie UPM			
Sachbearbeiter:	Kaimer		**Position:**	10	**Alternative:**	0
Kundenposition:	2 x 100% beidseitig 5 mm Spalt		**Datum:**		27.09.2009	

Einzelpreis:	3.800,00 Euro	**Gesamtpreis:**	7.600,00 Euro	**Anzahl:**	2

GEA ECOFLEX Plattenwärmetauscher: N40 CDS-10

Betriebsdaten für 1 Apparat(e) parallel und 1 Apparat(e) seriell

	warme Seite		kalte Seite		
Medium:	Abwasser 200mg/l		Kühlwasser		
Fluidgruppe gem. DGR 97/23/EG:	Gruppe 2 - andere		Gruppe 2 - andere		
Wärmeleistung:		978,18			kW
Massenstrom:	46,93		55,48		kg/s
Volumenstrom:	170,00		200,00		m³/h
Temperatur Eintritt:	35,00		15,00		°C
Temperatur Austritt:	30,00		19,21		°C
Druckverlust:	800		850		mbar
Geschwindigkeit Spalt / Anschluß:	1,16	4,18	1,30	4,91	m/s
Betriebsdruck Eintritt:	3,00		3,00		barg
Wandschubspannung:	82		111		Pa

Stoffdaten

Dichte:	993,75	998,60	kg/m³
Wärmekapazität:	4168,97	4186,61	J/kgK
Wärmeleitfähigkeit:	0,62140	0,59564	W/mK
Viskosität Eintritt:	0,719	1,144	cP
Viskosität Austritt:	0,798	1,026	cP

Apparatedaten

Plattentyp:	N40 L			
Wärmetauscherfläche (total / je Apparat):	19,80		19,80	m²
Plattenanzahl (total / je Apparat):	46		46	
Plattenstärke:	0,80			mm
Mittl. Log. Temperatur-Differenz:	15,39			K
k-Wert erforderlich / sauber:	3210		3467	W/m²K
Flächenreserve / Foulingfaktor:	8,0	%	0,000023	m²K/W
Plattenwerkstoff:	1.4401			
Dichtungswerkstoff / Dichtungstyp:	EPDM		kleberlos	

Innere Schaltung (Wege x Spalte):	1 x 22	1 x 23	
Gestellanzahl (parallel / seriell / gesamt):	1	1	1
Gestellwerkstoff und -ausführung:	S235-JRG2	lackiert	RAL5002
Spannbolzenmaterial and -oberfläche:	8.8 galvanisch verzinkt		

Die Anschlussausführung und die Anschlusslagen entnehmen Sie bitte dem beiliegenden Maßblatt.

Auslegungstemperatur:	**Min.:**	0,00 / 0,00	**Max.:**	100,00 / 100,00	°C
Auslegungsdruck:	**Min.:**	0,00 / 0,00	**Max.:**	10,00 / 10,00	barg

Prüfdruck: 13,00 / 13,00 barg **Auslegungscode:** DGR 97/23/EG AD-2000 Prüffaktor 1,3

DGR Kategorie: Art. 3, Abs. 3, , ohne CE-Zeichen

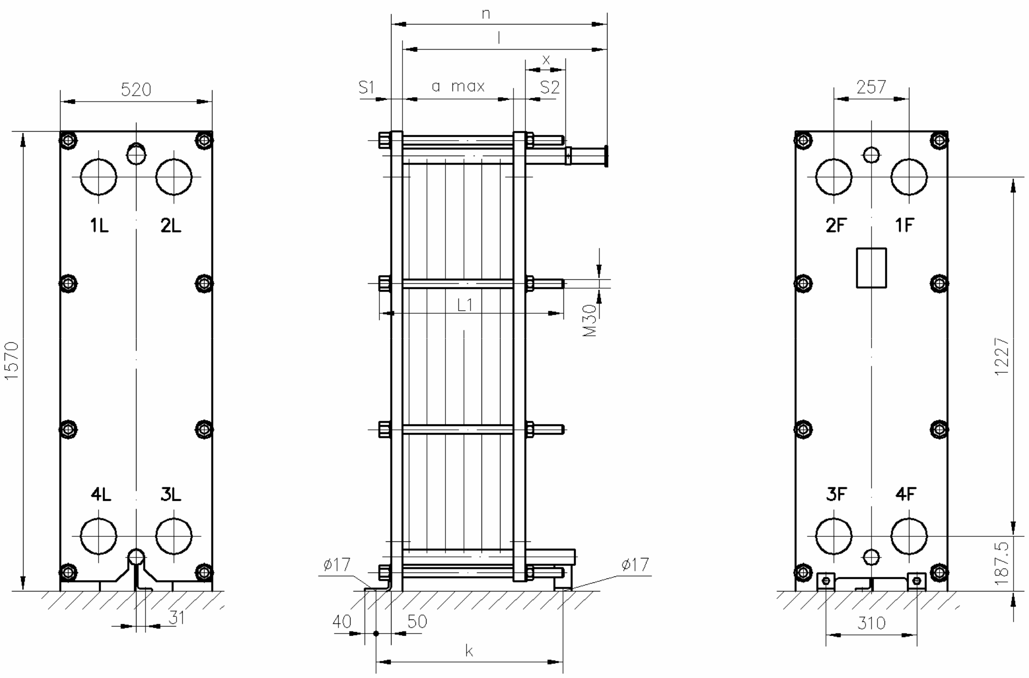
Konformitätsbewertungsdiagramm: Medium ungefährlich und Dampfdruck bei TAusl <= 0,5 barg

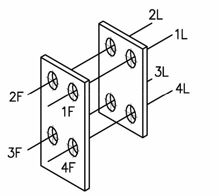
Bemerkung:

Maßblatt Plattenwärmetauscher

Kunde:	Bifa Umweltinstitut		
Angebot.:	**1046833239**	**Positions-Nr.: 10**	**Alternative-Nr.: 0**
Kundenposition:	2 x 100% beidseitig 5 mm Spalt		

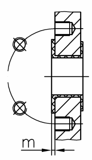
Typ: N40 CDS-10 Abmessungen der Zeichnung in [mm] 0135-123-Model.tif





n:	660 mm	s_1:	40,00 mm	a-max Gestell:	310 mm	Leergewicht:	721 kg
k:	570 mm	s_2:	40,00 mm	a-max aktuell:	263 mm	Füllgewicht:	814 kg
l:	620 mm			x:	179 mm		
Gestellerweiterung:			8 / 18,1	Platten / %	Spannbolzenerw.:	8 / 18,1	Platten / %

Pos	Größe	Typ	Medium	Ein	Aus	Zusatz	m-Maß
1F	DN125	Gummi-Formteil DIN 2633 EPDM	Abwasser 200mg/l	x	-	-	4 mm
2F	DN125	Gummi-Formteil DIN 2633 EPDM	Kühlwasser	-	x	-	4 mm
3F	DN125	Gummi-Formteil DIN 2633 EPDM	Kühlwasser	x	-	-	4 mm
4F	DN125	Gummi-Formteil DIN 2633 EPDM	Abwasser 200mg/l	-	x	-	4 mm

			
Gummi-Formteil			
DIN2633			
PN16			
1F;2F;3F;4F			

Technische Änderungen vorbehalten. Farbschichtdicke bei lackierten Gestellen gemäß DIN EN ISO 12944-5, Gestellplattenoberflächengüte gemäß DIN EN 10029. Die konstruktiven Angaben gelten für die von der GEA Ecoflex GmbH/Sarstedt hergestellten PWT.

Kunde:	Bifa Umweltinstitut				
Angebotsnummer	1046833239	**Anfragenummer:**	Machbarkeitsstudie UPM		
Sachbearbeiter:	Kaimer		**Position:** 10	**Alternative:**	1
Kundenposition:	2 x 100%		**Datum:**	27.09.2009	

Einzelpreis:	7.800,00 Euro	**Gesamtpreis:**	15.600,00 Euro	**Anzahl:**	2

GEA ECOFLEX Plattenwärmetauscher: FA184 B-6

Betriebsdaten für 1 Apparat(e) parallel und 1 Apparat(e) seriell

	warme Seite		**kalte Seite**		
Medium:	Abwasser 200mg/l		Kühlwasser		
Fluidgruppe gem. DGR 97/23/EG:	Gruppe 2 - andere		Gruppe 2 - andere		
Wärmeleistung:		978,18			kW
Massenstrom:	46,93		55,48		kg/s
Volumenstrom:	170,00		200,00		m³/h
Temperatur Eintritt:	35,00		15,00		°C
Temperatur Austritt:	30,00		19,21		°C
Druckverlust:	650		600		mbar
Geschwindigkeit Spalt / Anschluß:	0,92	1,67	1,04	1,96	m/s
Betriebsdruck Eintritt:	3,00		3,00		barg
Wandschubspannung:	101		123		Pa

Stoffdaten

Dichte:	993,75	998,60	kg/m³
Wärmekapazität:	4168,97	4186,61	J/kgK
Wärmeleitfähigkeit:	0,62140	0,59564	W/mK
Viskosität Eintritt:	0,719	1,144	cP
Viskosität Austritt:	0,798	1,026	cP

Apparatedaten

Plattentyp:	FA184 K			
Wärmetauscherfläche (total / je Apparat):	24,80		24,80	m²
Plattenanzahl (total / je Apparat):	34		34	
Plattenstärke:	1,00			mm
Mittl. Log. Temperatur-Differenz:	15,17			K
k-Wert erforderlich / sauber:	2599		2859	W/m²K
Flächenreserve / Foulingfaktor:	10,0	%	0,000035	m²K/W
Plattenwerkstoff:	1.4401			
Dichtungswerkstoff / Dichtungstyp:	EPDM		geklebt	

Innere Schaltung (Wege x Spalte):	2 x 8	1 x 16	
Gestellanzahl (parallel / seriell / gesamt):	1	1	1
Gestellwerkstoff und -ausführung:	S235-JRG2	lackiert	RAL5002
Spannbolzenmaterial and -oberfläche:	8.8 galvanisch verzinkt		

Die Anschlussausführung und die Anschlusslagen entnehmen Sie bitte dem beiliegenden Maßblatt.

Auslegungstemperatur:	**Min.:**	0,00 / 0,00	**Max.:**	100,00 / 100,00	°C
Auslegungsdruck:	**Min.:**	0,00 / 0,00	**Max.:**	6,00 / 6,00	barg

Prüfdruck: 7,80 / 7,80 barg **Auslegungscode:** DGR 97/23/EG AD-2000 Prüffaktor 1,3

DGR Kategorie: Art. 3, Abs. 3, , ohne CE-Zeichen

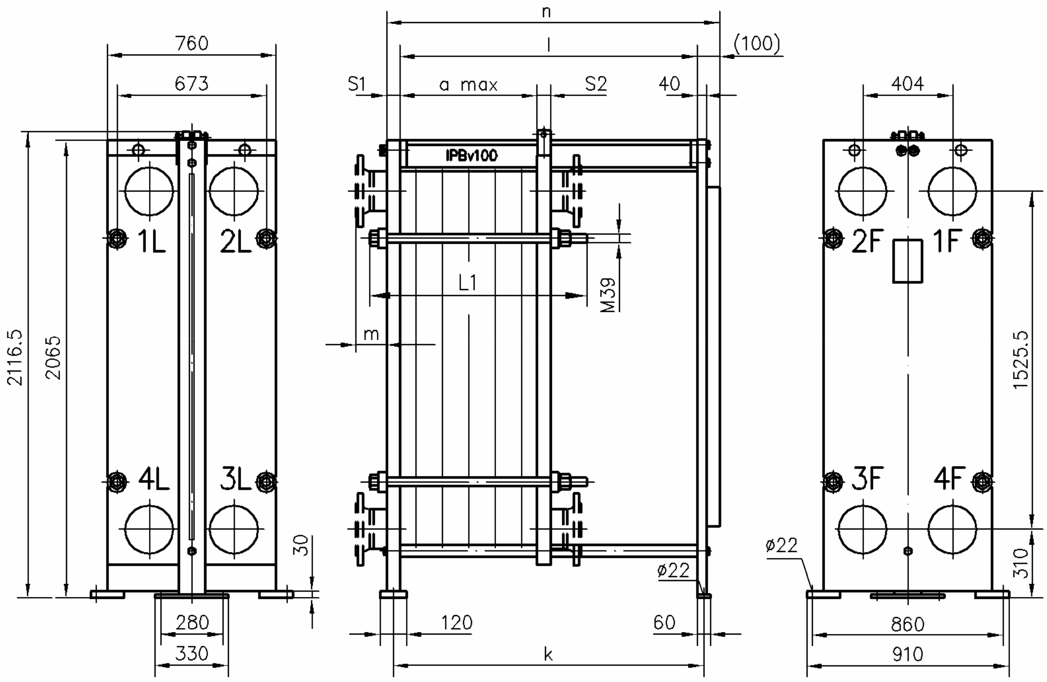
Konformitätsbewertungsdiagramm: Medium ungefährlich und Dampfdruck bei TAusl <= 0,5 barg

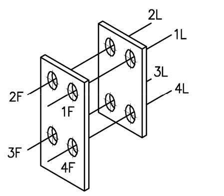
Bemerkung:

Maßblatt Plattenwärmetauscher

Kunde:	Bifa Umweltinstitut		
Angebot.:	**1046833239**	**Positions-Nr.: 10**	**Alternative-Nr.: 1**
Kundenposition:	2 x 100%		

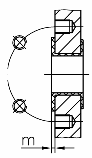
Typ: FA184 B-6 Abmessungen der Zeichnung in [mm] 0174-101-Model.tif





n:	1510 mm	s_1:	70,00 mm	a-max Gestell:	490 mm	Leergewicht:	2121 kg
k:	1405 mm	s_2:	70,00 mm	a-max aktuell:	332 mm	Füllgewicht:	2380 kg
l:	1340 mm						
Gestellerweiterung:		16 / 47,8	Platten / %	Spannbolzenerw.:	8 / 25,5	Platten / %	

Pos	Größe	Typ	Medium	Ein	Aus	Zusatz	m-Maß
2F	DN200	Gummi-Formteil DIN 2633 EPDM	Kühlwasser	x	-	-	4 mm
3F	DN200	Gummi-Formteil DIN 2633 EPDM	Kühlwasser	-	x	-	4 mm
4F	DN200	Gummi-Formteil DIN 2633 EPDM	Abwasser 200mg/l	x	-	-	4 mm
4L	DN200	Gummi-Formteil DIN 2633 EPDM	Abwasser 200mg/l	-	x	-	4 mm

			
Gummi-Formteil			
DIN2633			
PN16			
2F;3F;4F;4L			

Technische Änderungen vorbehalten. Farbschichtdicke bei lackierten Gestellen gemäß DIN EN ISO 12944-5, Gestellplattenoberflächengüte gemäß DIN EN 10029. Die konstruktiven Angaben gelten für die von der GEA Ecoflex GmbH/Sarstedt hergestellten PWT.

Kunde:	Bifa Umweltinstitut						
Angebotsnummer	1046833239	**Anfragenummer:**	Machbarkeitsstudie UPM				
Sachbearbeiter:	Kaimer		**Position:**	20	**Alternative:**	0	
Kundenposition:	Freistromwärmetauscher 12 mm Spalt		**Datum:**		27.09.2009		

Einzelpreis:	9.500,00 Euro	**Gesamtpreis:**	19.000,00 Euro	**Anzahl:**	2

GEA ECOFLEX Plattenwärmetauscher: FA184 B-6

Betriebsdaten für 1 Apparat(e) parallel und 1 Apparat(e) seriell

	warme Seite		kalte Seite		
Medium:	Abwasser 80 mg/l		Kühlwasser		
Fluidgruppe gem. DGR 97/23/EG:	Gruppe 2 - andere		Gruppe 2 - andere		
Wärmeleistung:		1438,51			kW
Massenstrom:	69,01		83,22		kg/s
Volumenstrom:	250,00		300,00		m³/h
Temperatur Eintritt:	35,00		15,00		°C
Temperatur Austritt:	30,00		19,13		°C
Druckverlust:	750		700		mbar
Geschwindigkeit Spalt / Anschluß:	0,91	2,45	1,04	2,94	m/s
Betriebsdruck Eintritt:	3,00		3,00		barg
Wandschubspannung:	98		123		Pa

Stoffdaten

Dichte:	993,75	998,61	kg/m³
Wärmekapazität:	4168,97	4186,69	J/kgK
Wärmeleitfähigkeit:	0,62140	0,59556	W/mK
Viskosität Eintritt:	0,719	1,144	cP
Viskosität Austritt:	0,798	1,028	cP

Apparatedaten

Plattentyp:	FA184 K			
Wärmetauscherfläche (total / je Apparat):	37,60		37,60	m²
Plattenanzahl (total / je Apparat):	50		50	
Plattenstärke:	1,00			mm
Mittl. Log. Temperatur-Differenz:	15,22			K
k-Wert erforderlich / sauber:	2514		2765	W/m²K
Flächenreserve / Foulingfaktor:	10,0	%	0,000036	m²K/W
Plattenwerkstoff:	1.4401			
Dichtungswerkstoff / Dichtungstyp:	EPDM		geklebt	

Innere Schaltung (Wege x Spalte):	2 x 12	1 x 24	
Gestellanzahl (parallel / seriell / gesamt):	1	1	1
Gestellwerkstoff und -ausführung:	S235-JRG2	lackiert	RAL5002
Spannbolzenmaterial and -oberfläche:	8.8 galvanisch verzinkt		

Die Anschlussausführung und die Anschlusslagen entnehmen Sie bitte dem beiliegenden Maßblatt.

Auslegungstemperatur:	**Min.:**	0,00 / 0,00	**Max.:**	100,00 / 100,00	°C
Auslegungsdruck:	**Min.:**	0,00 / 0,00	**Max.:**	5,00 / 5,00	barg

Prüfdruck: 6,50 / 6,50 barg **Auslegungscode:** DGR 97/23/EG AD-2000 Prüffaktor 1,3

DGR Kategorie: Art. 3, Abs. 3, , ohne CE-Zeichen

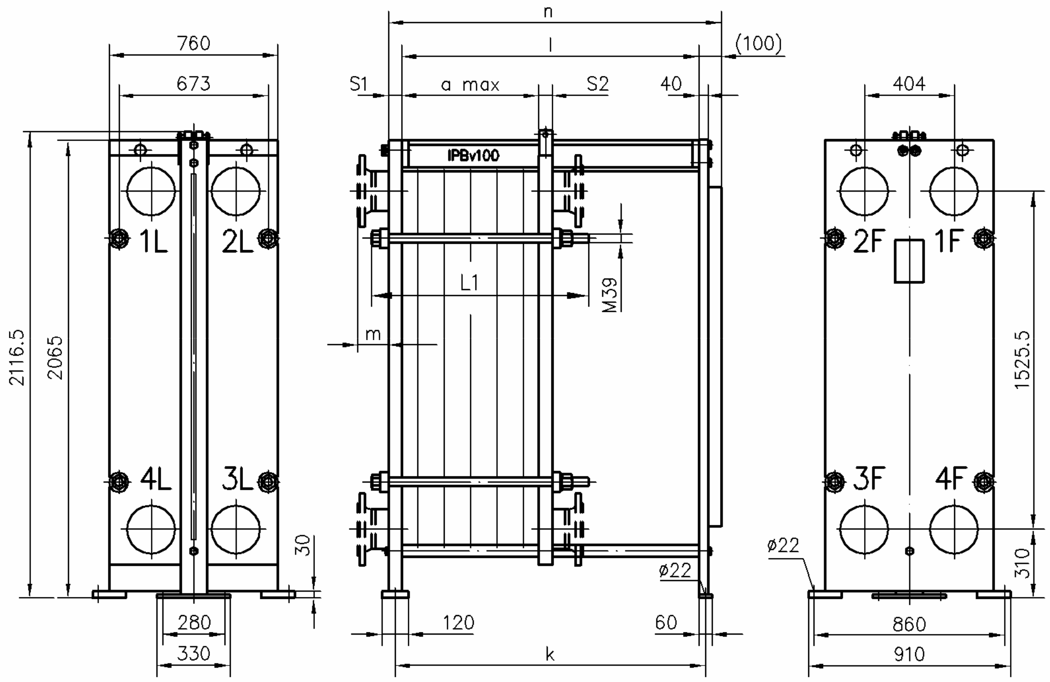
Konformitätsbewertungsdiagramm: Medium ungefährlich und Dampfdruck bei TAusl <= 0,5 barg

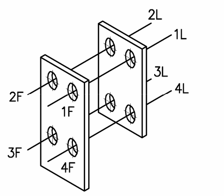
Bemerkung:

Maßblatt Plattenwärmetauscher

Kunde:	Bifa Umweltinstitut		
Angebot.:	**1046833239**	**Positions-Nr.: 20**	**Alternative-Nr.: 0**
Kundenposition:	Freistromwärmetauscher 12 mm Spalt abwasserseitig		

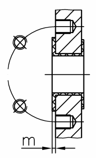
Typ: FA184 B-6 Abmessungen der Zeichnung in [mm] 0174-101-Model.tif





n:	1510 mm	s_1:	70,00 mm	a-max Gestell:	490 mm	Leergewicht:	2299 kg
k:	1405 mm	s_2:	70,00 mm	a-max aktuell:	488 mm	Füllgewicht:	2684 kg
l:	1340 mm						
Gestellerweiterung:		0 / 0,5	Platten / %	Spannbolzenerw.:	32 / 64,3	Platten / %	

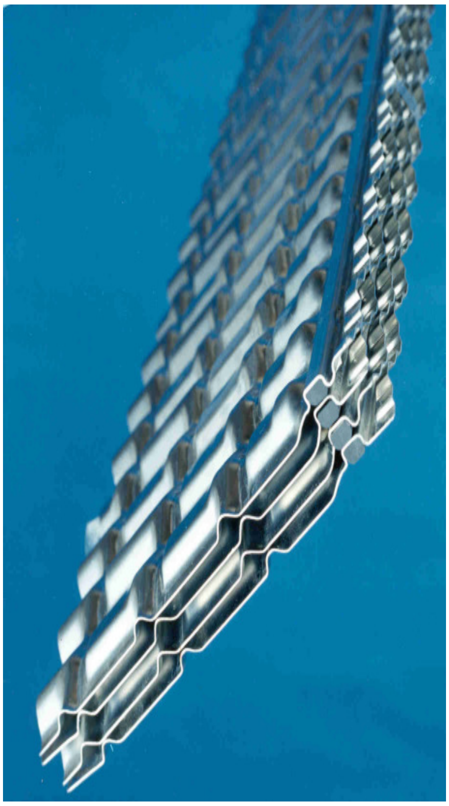
Pos	Größe	Typ	Medium	Ein	Aus	Zusatz	m-Maß
2F	DN200	Gummi-Formteil DIN 2633 EPDM	Kühlwasser	x	-	-	4 mm
3F	DN200	Gummi-Formteil DIN 2633 EPDM	Kühlwasser	-	x	-	4 mm
4F	DN200	Gummi-Formteil DIN 2633 EPDM	Abwasser 80 mg/l	x	-	-	4 mm
4L	DN200	Gummi-Formteil DIN 2633 EPDM	Abwasser 80 mg/l	-	x	-	4 mm

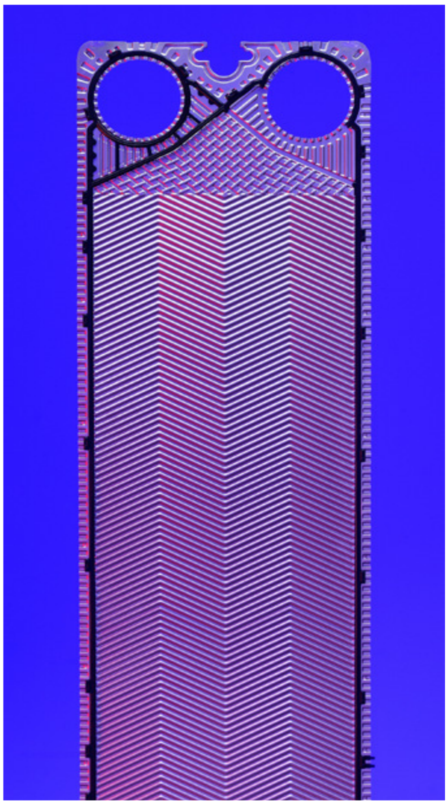
			
Gummi-Formteil			
DIN2633			
PN16			
2F;3F;4F;4L			

Technische Änderungen vorbehalten. Farbschichtdicke bei lackierten Gestellen gemäß DIN EN ISO 12944-5, Gestellplattenoberflächengüte gemäß DIN EN 10029. Die konstruktiven Angaben gelten für die von der GEA Ecoflex GmbH/Sarstedt hergestellten PWT.

GEA Ecoflex GmbH • Postfach 1165 • D-31151 Sarstedt

Plattenvergleich Fischgrätmuster und Freistromtechnik





Freistromplatte N40

- Abstützreihen, daher für feststoffbelastete Medien geeignet.
- Druckfestigkeit wird aus der Materialstärke bezogen
- Einsatzbereich: Abwasser, chemische Prozessmedien mit Feststoff- oder Faseranteilen
- freier, durchgehender Fließspalt
- ungehinderter Durchfluss
- sorgt für sicheren und kontinuiertlichen Betriebsablauf
- wartungsarmen Betrieb
- hohe Prozesssicherheit

Platte mit Fischgrätmuster:

- viele Abstützungspunkte im Plattenpaket
- hohe Wärmeübergangsraten
- optimierte Medienverteilung
- schneller und einfacher Dichtungswechsel
- geringer Platzbedarf
- kostengünstig
- Einsatz des Apparates auch unter höherer Drucklast
- niedrige Investitionskosten
- hoher Wirkungsgrad

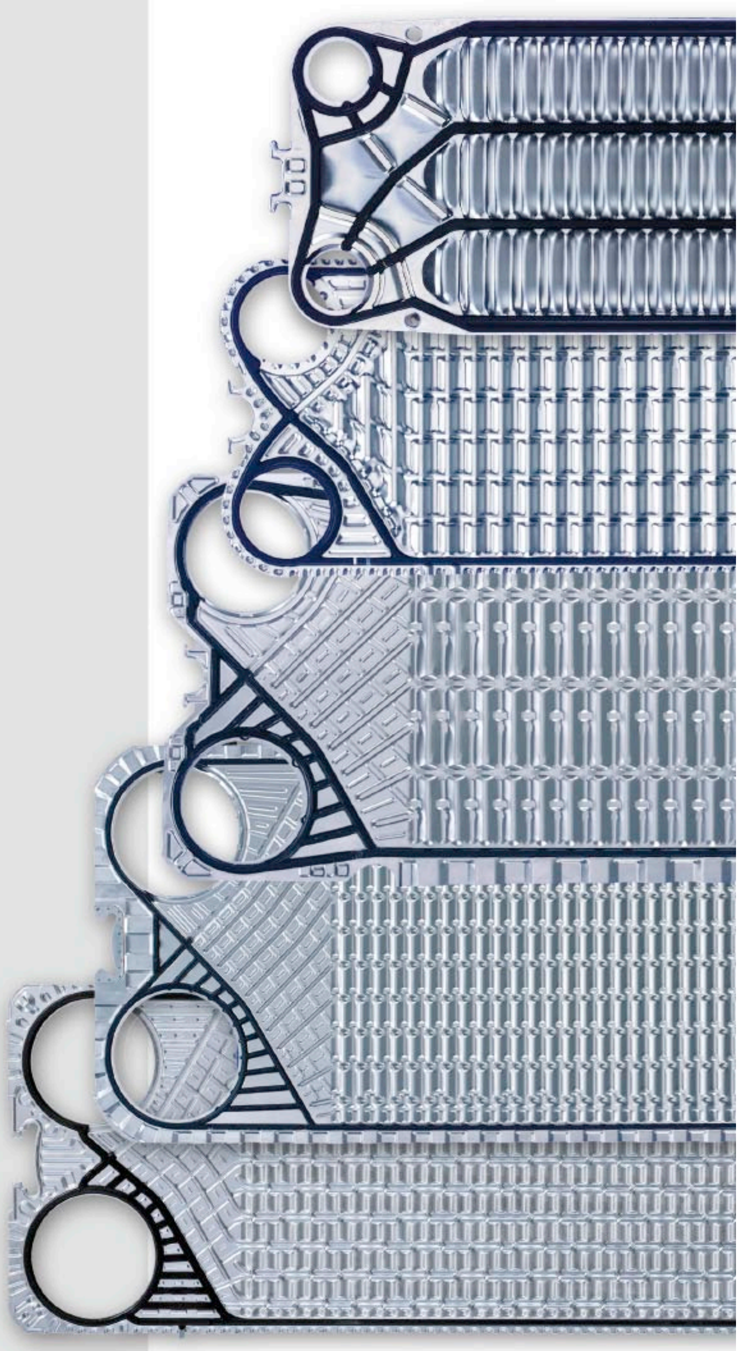
Freistrom Plattenwärmetauscher

Lange Standzeiten durch freie Fließkanäle

Wo konventionelle Plattenwärmetauscher ihre Grenzen erreichen, beginnt das Einsatzgebiet der Freistrom-Plattenwärmetauscher. Die Besonderheit ist der konstant breite Strömungsquerschnitt zwischen den einzelnen Platten sowie die grobwellige Profilierung der Platten. Der Abstand zwischen den Platten beträgt bis zu 12 mm.

Ihre Vorteile auf einen Blick

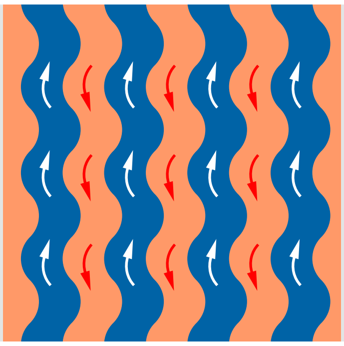
- blockagefreier Betrieb durch konstant breite Spalte
- DIE Alternative zu Rohrbündel- und Spiralwärmetauschern, aufgrund geringerer Investitions- und Betriebskosten sowie geringerem Platzbedarf
- FA 159 und FA 161 ohne metallische Abstützungen
- Platten in verschiedenen Größen, Spaltweiten und Werkstoffen
- Dichtungswerkstoffe NBR und EPDM. Sonderdichtungen wie z.B. FPM bei einigen Typen möglich
- geeignet für faser- und feststoffhaltige Medien (faser- und pulpenhaltige Fruchtsäfte, Abwässer der Papier- und Zellstoffindustrie, Textil-und Zuckerindustrie sowie hochviskose Medien)



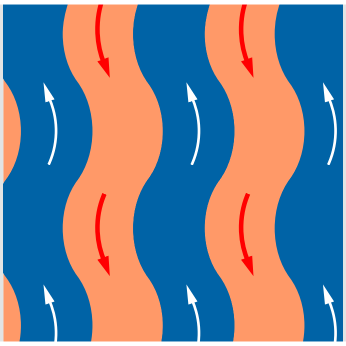
Process Equipment Division

GEA PHE Systems

Querschnitte der GEA PHE Systems Freistrom-Platten

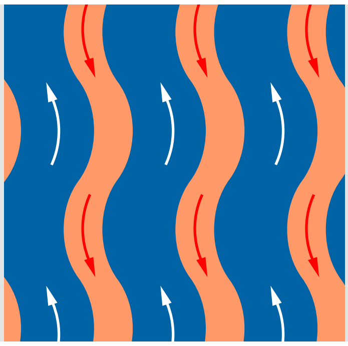


N 40 — 5 | 5



FA 159
FA 161 — 6 | 6

NF 350 — 10 | 10



FA 161 — 6 | 12
FA 184
FA 192

Die Freistrom-Produktpalette

	Breite	Länge	Max. Volumenstrom	Max. Anschlussgröße		Max. Betriebsdruck	Gestelle			Plattenmaterial					Kleberloses Dichtungssystem
				lackiertes Gestell	Edelstahlgestell		lackiert	mit Edelstahl-Verkleidung	Edelstahl	1.4401 AISI 316	1.4439 AISI 317	1.4547 254 SMO	Alloy C-276	Titan	
Type	mm	mm	m³/h	DN	DN	bar									
FA 159	320	1082	40	50	50	6	•	•		•	•	•			
FA 161	472	1455	130	100	80	6	•	•		•	•	•			
N 40	432	1406	220	125	100	10	•	•	•	•	•	•	•	•	•
FA 184	678	1794	590	200		6	•			•	•	•	•		
FA 192	985	2305	1490	350		8	•			•					
NF 350	985	2772	1900	350		(10)	•			•					

Technische Änderungen vorbehalten · Freistrom · D · 01/09 freitag van geigk

GEA PHE Systems – Competence in Heat Transfer

Mit dem Anspruch auf höchste Qualität und wegweisender Innovation baut GEA PHE Systems seine Marktstellung kontinuierlich weiter aus: Innerhalb der GEA Process Equipment Division bildet GEA Ecoflex zusammen mit GEA ViEX, GEA WTT, GEA Ecobraze, GEA PHE Systems NA sowie GEA EcoServe die GEA PHE Systems, das Kompetenz- und Servicezentrum für gedichtete, vollverschweißte und gelötete Plattenwärmetauscher in den Anwendungsgebieten:

- HVAC
- Kältetechnik
- Zucker
- Chemie
- Papier
- Food
- Power
- Marine
- Allgemeine Industrie
- Erneuerbare Energie

Die in diesem Druckwerk enthaltenen Angaben dienen lediglich der unverbindlichen Beschreibung unserer Produkte und Serviceleistungen und erfolgen ohne Gewähr. Verbindliche Angaben, insbesondere zu Leistungsdaten und Eignungen zu bestimmten Einsatzzwecken, hängen von individuellen Gegebenheiten am Einsatzort ab und können daher nur im Rahmen konkreter Anfragen gemacht werden.

Ihr Ansprechpartner:

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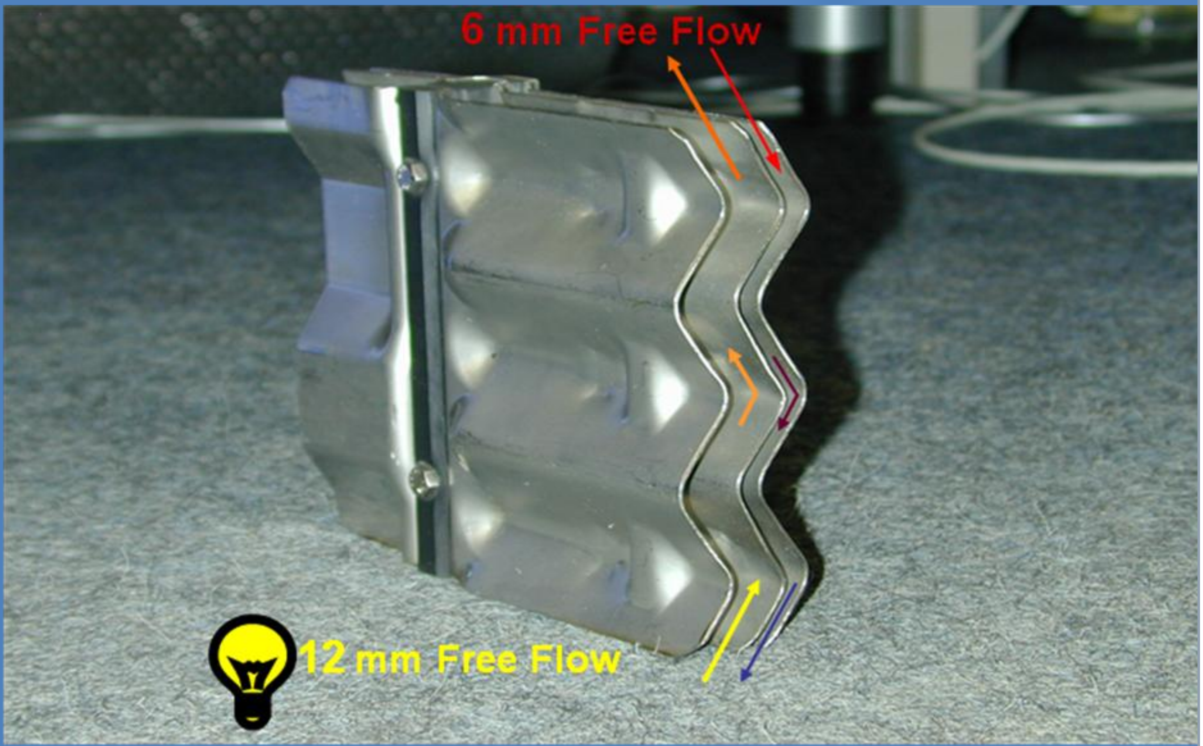
Karl-Schiller-Straße 1-3 · 31157 Sarstedt · Deutschland
Tel. +49 5066 601-0 · Fax +49 5066 601-104
info@gea-ecoflex.de · www.gea-phe.com



Cut of a FA 184/192 Free Flow Unit

Appendix B

Cited e-mail correspondence

Von: "Ralph Joachim Balzer" <r.balzer@wilhelm-deller.de>
An: Christian.Bratzdrum@gmx.net
Kopie:
Betreff: Re-2: Abwasserwärme Papiermaschine Augsburg
Datum: 03.09.2009 08:21:02

Sehr geehrter Herr Bratzdrum,

aufgrund des hohen Feststoffanteiles ist der K-Wert kleiner als 1000
ein Plattenwärmetauscher ist preislich mehr als 1/10 günstiger als ein Rohrbündelwärmetauscher.
der Hohe Preis für einen Doppelrohrwärmetauschers ist bedingt durch den höheren Arbeitsaufwand/Wärmeaustauschfläche.
Der Wartungsaufwand richtet sich nach dem Leistungsabfall des Wärmetauschers. je weniger Flächensicherheit Sie vorsehen, desto häufiger müssen Sie reinigen.
Wir stellen Wärmetauscher bis ca. Ø2000mm und einem Gewicht bis 25000kg her.

Mit besten Grüßen,
Kind regards

Ralph Joachim Balzer
Verfahrenstechnik
Engineering

Tel.: +49-271-806-228

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www.wilhelm-deller.de
e-Mail
info@wilhelm-deller.de

Wilhelm Deller GmbH & Co. KG, HRA 3415, AG Siegen, Pers. haftende Gesellschafterin: Deller Verwaltungs-GmbH, HRB 5247, AG Siegen, Geschäftsführung: Dipl.-Bw. Gerd Volker Jost

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-------- Original Message --------
Subject: Re: Abwasserwärme Papiermaschine Augsburg (03-Sep-2009 7:13)
From: Christian Bratzdrum <Christian.Bratzdrum@gmx.net>
To: r.balzer@wilhelm-deller.de

> Sehr geehrter Herr Balzer,
>
> ich würde mich freuen, wen Sie mir aus ihren Erfahrungen noch folgende
> Fragen zum Thema Doppelrohr-Wärmetauscher für unser Projekt Abwasser-
> Wärmerückgewinnung beantworten könnten:
> - Mit welchem k-Wert kann man bei Doppelrohr-WT im Gegenstrom rechnen?
> - Bis zu welchen Innendurchmesser werden ihre WT hergestellt?
> - Sind die hohen Kosten materialbedingt?
> - Würde ein WT mit k=1000 bei den genannten Temperaturen 35->30 und 15->20
> und 250m3/h bzw 300m3/h nicht nur etwa 100m2 Fläche benötigen? Preis dafür?
> - Wartungs und Reinigungsaufwand im Vergleich zu Platten-WT?
>
> Mit freundlichen Grüßen
> Christian Bratzdrum
>
>
> -------- Original-Nachricht --------
> > Datum: Tue, 1 Sep 2009 13:34:10 +0000
> > Von: "Ralph Joachim Balzer" <r.balzer@wilhelm-deller.de>
> > An: Christian.Bratzdrum@gmx.net
> > Betreff: Re: Abwasserwärme Papiermaschine Augsburg
>
> > Sehr geehrter Herr Bratzdrum,
> >
> > Das treibende Temperaturgefälle ist zu gering für eine wirtschaftlichen
> > Lösung einer Wärmerückgewinnung unter Zuhilfenahme eines Rohrbündel-
> > oder Doppelrohrwärmetauschers.
> > für eine Frischwasseraufheizung von 14°C auf 25°C beträgt die
> > benötigte Austauschfläche ca. 600m^2 .
> > Die Kosten für einen Rohrbündelwärmetauscher aus C-Stahl für den oben
> > erwähnten Anwendungsfall belaufen sich auf ca. 150.000 Euro
> > Für weiter Informationen stehe ich Ihnen gerne zur Verfügung.
> >
> > Mit besten Grüßen,
> > Kind regards
> >
> > Ralph Joachim Balzer
> > Verfahrenstechnik
> > Engineering
> >
> > Tel.: +49-271-806-228
> >
> >
> >
> >
> > Hausanschrift
> > Langenauer Straße 2

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> > info@wilhelm-deller.de
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> >
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> >
> > -------- Original Message --------
> > Subject: Abwasserwärme Papiermaschine Augsburg (31-Aug-2009 13:28)
> > From: Christian Bratzdrum <Christian.Bratzdrum@gmx.net>
> > To: r.balzer@wilhelm-deller.de
> >
> > > Sehr geehrter Herr Balzer,
> > >
> > > Zur Ihrer Rückfrage, es stehen zwei Abwasserströme der Papiermaschinen
> > zu
> > > Verfügung mit 4000m3 bzw. 6000m3 am Tag bei durchschnittlich 35°C. Der
> > > Feststoffgehalt liegt bei 200mg/l +-20% bzw. ca. 80mg/l +-20%.
> > > Es soll das eingespeiste Frischwasser (14-16°C) maximal vorgewärmt
> > werden,
> > > die Mengen liegen etwa 20% höher als das Abwasservolumen also 4800m3
> > bzw
> > > 7200m3 am Tag.
> > >
> > > Es wäre interessant wie häufig und aufwenige die Wartung bzw.
> > Reinigung der
> > > Doppelrohr-Wärmetauscher sind, haben Sie dazu Informationen wie z.B.
> > > Aufwandschätzung in Stunden?
> > >
> > > Tagsüber bin ich meist erreichbar unter:
> > > 0151-14319417
> > >

> > > Mit freundlichen Grüßen
> > > Christian Bratzdrum
> > >
> > >
> > > --
> > > ---------------------
> > >
> > > Christian Bratzdrum
> > > Dr.-Otto-Meyer-Str. 24c
> > > 86169 Augsburg
> > > +49-821-2481488
> > >
> > >
> > > GRATIS für alle GMX-Mitglieder: Die maxdome Movie-FLAT!
> > > Jetzt freischalten unter http://portal.gmx.net/de/go/maxdome01
> >
>
> --
> ---------------------
>
> Christian Bratzdrum
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> 86169 Augsburg
> +49-821-2481488
>
>
> GRATIS für alle GMX-Mitglieder: Die maxdome Movie-FLAT!
> Jetzt freischalten unter http://portal.gmx.net/de/go/maxdome01

Von: Heiner.Meister@upm-Kymmene.com
An: "Christian Bratzdrum" <Christian.Bratzdrum@gmx.net>
Kopie:
Betreff: Re: bifa Projekt Abwasserwärme
Datum: 13.07.2009 14:07:47

Hallo Herr Bratzdrum,

habe Ihre Fragen teilweise beantwortet. Für alle weiteren Fragen verweise
ich Sie an die Herren Krodel und Kienle. Bitte fragen Sie auch dort nach
welches Infomaterial Sie noch bekommen können.

Mit freundlichen Grüßen

Heiner Meister

Heiner Meister
Senior Specialist Chemistry and Water

UPM-Kymmene Papier GmbH & Co. KG
Augsburg Mill
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Tel. +49 821 3109-319

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Tel. +49 821 3109-0 - Fax +49 821 3109-156/157 - www.upm-kymmene.de

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Alleiniger persönlich haftender Gesellschafter: UPM-Kymmene Komplementär

GmbH

Sitz des persönlich haftenden Gesellschafters: Augsburg - Amtsgericht

Augsburg, HRB 16646

Geschäftsführer des persönlich haftenden Gesellschafters: Dr. Hartmut

Wurster

"Christian

Bratzdrum"

<Christian.Bratzd To

rum@gmx.net> wolfgang.krodel@upm-kymmene.com,

heiner.meister@upm-kymmene.com

13.07.2009 07:12 cc

Subject

bifa Projekt Abwasserwärme

Sehr geehrte Herren Meister und Krodel,

vielen Dank, dass Sie sich vergangenen Mittwoch die Zeit genommen haben und uns durch Informationen und Diskussion weitere Ideen für das Projekt gegeben haben.
An Pforte 2 (Anlieferung) sind mir beim Verlassen des Werks auf einer Tafel mehrere Statistiken wie Strombedarf, Wärme, Wasser, Temperaturen etc. aufgefallen. Gibt es ähnliche Dokumente, die Sie an mich weitergeben könnten? Ich habe online die Umweltbilanz für das Werk Augsburg im Jahr 2007 gefunden, gibt es weitere Dokumente oder Firmen-Präsentationen dieser Art oder evtl. auch in gedruckter Form an der Haupteingangspforte, Besucherinformation oder ähnlichem?
Im Hinblick auf eine Machbarkeitsstudie und Berechnung des Potentials bitte ich Sie, mir folgende Daten zur Verfügung zu stellen (falls verfügbar):

Informationen für beide Papiermaschinen

- Wasserbedarf Produktion, Jahresmengen:

  bei Vollauslastung ca. 4,6 Mio m³/a Frischwasser

- Jahresmengen und Verlauf Abwasservolumen und Temperaturen

  3,9 Mio m³/a, bei Vollauslastung über Jahr konstante

Tagesmengen, Stundenwerte können bis 50% Menge

  schwanken

  -2/5 Werk Süd Durchschnitts T: 38°C, Im Winter: 35-38°C, im

Sommer bis 42°C

  -3/5 Werk Nord Durchschnitts T: 35°C, Im Winter: 33°C, im

Sommer 36-37°C

- Exemplarischer Tagesverlauf Abwassertemperaturen Winter/Sommer

  keine Abhängigkeit zur Tageszeit

- Gibt es nur die 42°C Obergrenze für Einleitung, oder auch eine

Untergrenze

  Es gibt nur 42°C Obergrenze

- Feststoffgehalt im Abwasser vor Einleitung

  Werk Süd: ca. 200mg/l +-20%, Werk Nord: ca. 80mg/l +-20%

- Gibt es Verschmutzungsprobleme oder Korrosion?

  teilweise Verschmutzung der Wärmetauscher, keine Korrosion

• Standardwerkstoff in den Wärmetauschern zur Abwasserkühlung?

???

• Bachkühlung, wie häufig, Jahresmengen? auch im Winter notwendig für <42°C?

häufig im Werk Süd, weniger im Werk Nord, Jahresmenge: ca. 10 Mio m³/a

• Leistung des Bachkühlung-Wärmetauschers?

???

• Wasser-Dampfkreislauf Produktion mit Temperaturniveaus

???

• Einspeisung Frischwasser in Papiermaschinen mit welcher Temperatur? Die Vorwärmung erfolgt teilweise

durch Wärmetauscher von Produktionswässern aber auch fossil, habe ich das richtig verstanden?

Frischwassertemp. 14 - 16 °C, Erwärmung durch WT und auch fossil, durch Bedampfung, bzw. Dampf/Wasser WT

Für mögliche Förderungen des Projekts wären interessant

• Gaskessel: Abzweigung der Gebäudeheizung an welcher Stelle?

??

• Nutzung auch direkt für Vorheizung Einspeisewasser?

??

- Anteil Heizung: Wärmebedarf, Nutzfläche Produktion/Werkshallen

??

Aufgrund meines relativ begrenzten Zeitrahmens würde ich mich freuen, bald von Ihnen zu hören. Gerne auch in Form eines weiteren kurzen Termins bei Ihnen.

Mit freundlichen Grüßen

Christian Bratzdrum

--

Christian Bratzdrum

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86169 Augsburg

+49-821-2481488

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für nur 19,99 Euro/mtl.!* http://portal.gmx.net/de/go/dsl02

Appendix C

Cited internet pages

Gas - Industrieabnehmer - halbjährliche Preise - Alte Methodologie bis 2007

Tabelle drucken
Dieses Fenster schließen

PRODUCT: Naturgas **CONSOM:** Industrie - I1 (Jahresverbrauch: 418.6 GJ; keine Benutzungsdauer vorgeschrieben) (für Belgien: feste Menge (nicht-unterbrechbar) für nicht näher festgelegte Verwendungszwecken, die leicht durch schweres Heizöl zu ersetzen ist (CNE 1 P 1)) **UNIT:** Gigajoule (Oberer Heizwert = OHW) **TAXE:** Alle Steuern inbegriffen **CURRENCY:** Euro (ab 1.1.1999)/Ecu (bis zum 31.12.1998)

time ▸ / geo ▾	2002S01	2002S02	2003S01	2003S02	2004S01	2004S02	2005S01	2005S02	2006S01	2006S02	2007S01	2007S02
DE	10.2500	9.4500	10.3500	10.6760	10.4040	10.9000	11.5800	12.4700	14.5000	14.9800	16.8900	15.4500

Keine Fußnoten vorhanden

Spezielle Werte:

- nicht anwendbares oder reales null oder null durch Rückstellung

0 kleiner als Hälfte der Maßeinheit verwendete

: nicht vorhanden

Dieses Fenster schließen

Gas - Industrieabnehmer - halbjährliche Preise - Ab 2007

Tabelle drucken
Dieses Fenster schließen

PRODUCT: Naturgas **CONSOM:** Gruppe I1 : Verbrauch < 1 000 GJ **UNIT:** Gigajoule (Oberer Heizwert = OHW) **TAXE:** Alle Steuern inbegriffen **CURRENCY:** Euro (ab 1.1.1999)/Ecu (bis zum 31.12.1998)

time / geo	2008S01	2008S02
DE	16.7100	18.3700

Keine Fußnoten vorhanden

Spezielle Werte:

- nicht anwendbares oder reales null oder null durch Rückstellung
0 kleiner als Hälfte der Maßeinheit verwendete
: nicht vorhanden

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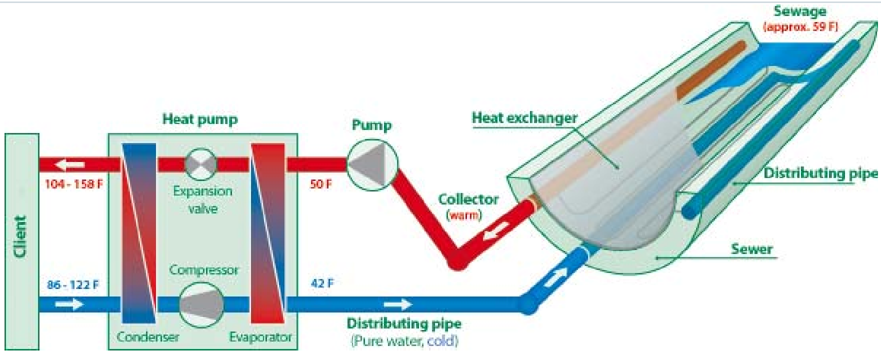
Die neuen gesetzlichen Grundlagen und staatlichen Fördermöglichkeiten in Deutschland unterstützen seit 1.1.2009 die umweltschonende Wärmenutzung aus Abwasser.

The Technology



Criteria for an optimal use of RABTHERM systems:

Sewer min. diameter (400) – 800 mm
Waste water quantity in average min. 12 l/s
Heat exchanger lengths min. 9 max. 200 m
Min. heating power: 80 KW
Distance sewer to consumer max. 200 m (cultivated), 300 m (empty)
Primary temperature (user) max. 70 °C / 158 F
Extraction performance depending on quantity of water, water speed, downward gradient in the channel, contamination approx. 2-6 kW/m2 heat exchanger
Power after heat pump, approx.. 2-5 kW/m2 heat exchanger.

Relation waste water flow and extraction of heat

Out of 1 m3 waste water (contents of 5 bath tubs) the heat exchanger gains approx.. 2-3 kW/h of energy
To produce 1 kWh heat, 420 litres waste water are necessary

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LINKS

Broschüre - EnergieSchweiz
E-Agentur Berlin

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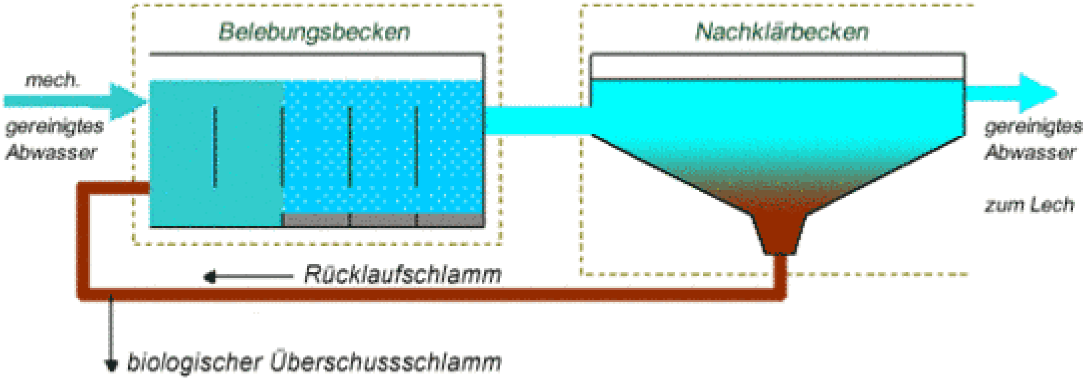
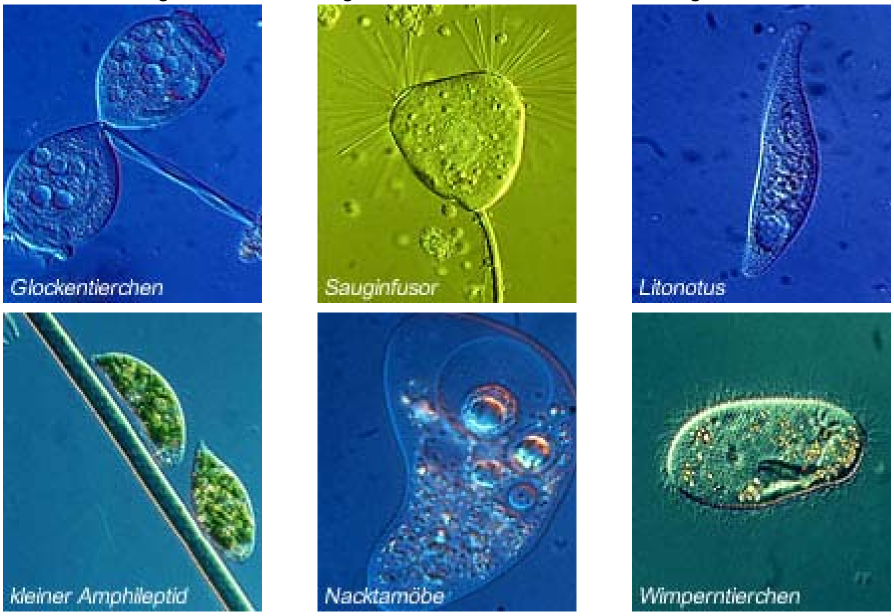
Biologische Reinigung

Mechanische Reinigung Biologische Reinigung Schlammbehandlung Energie Qualität



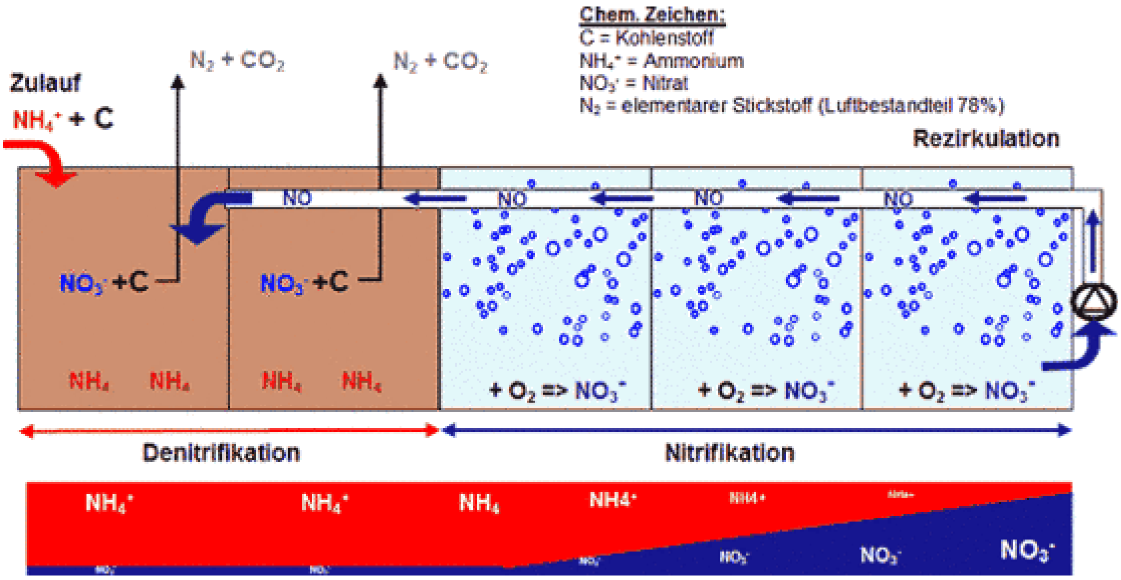
Belebungsanlage:

Dem mechanisch gereinigten Abwasser wird sogenannter Belebtschlamm zugesetzt, dessen organischer Anteil von ca. 80% vorwiegend aus Mikroorganismen besteht. Diese Mikroorganismen



sind in der Lage, organische Abwasserinhaltsstoffe sowie Stickstoff- und Phosphorverbindungen als Nahrung aufzunehmen. Voraussetzung ist eine ausreichende Belüftung des Wasser-Belebtschlamm-Gemisches. Durch Sauerstoffentzug in einem Teil der Belebungsbecken wird erreicht, dass "Nahrungsspezialisten" unter den Mikroorganismen den Nitratsauerstoff aufnehmen, der zuvor im belüfteten Teil bei der Nitrifikation von Ammoniumstickstoff zu Nitratstickstoff entstanden ist: Der Sauerstoff wird veratmet, elementarer Stickstoff gast aus. So kann mit einem rein biologischen Verfahren unter günstigen Bedingungen bis zu 80% der Stickstofffracht ausgeschleust werden.

Biologische Stickstoffelimination:



Phosphatfällung:

Zwischen den Belebungsbecken und der Nachklärung werden dem biologisch gereinigten Abwasser gelöste Eisen- und Aluminiumsalze zugegeben, um Phosphatverbindungen, die nicht vom Belebtschlamm aufgenommen wurden, auszufällen. Dies erfordert eine aufwändige On-Line-Analytik mit deren Hilfe das Fällmittel frachtabhängig dosiert wird, um eine Übersalzung zu vermeiden.

Nachklärung:

In den Nachklärbecken trennt sich der Belebtschlamm vom gereinigten Abwasser. Das gereinigte Abwasser fließt an der Oberfläche ab, der abgesetzte Belebtschlamm wird zum größten Teil wieder zurück in die Belebungsbecken gepumpt. Ein kleiner Teilstrom, der Zuwachs an Biomasse, wird als sogenannter Sekundärschlamm zur Schlammbehandlung gefördert.

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Tel.: +49 (0) 23 61-10 47-0
Fax: +49 (0) 23 61-10 47-47
info@wallstein.de
www.wallstein.de

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Abwasser ist eine regenerative Energiequelle, deren Nutzung nachhaltig und umweltfreundlich ist. Im Vergleich zu Öl- und Gasheizungen oder herkömmlichen Klimageräten verfügen Abwasserenergieanlagen über die bessere Energiebilanz und verursachen weniger Luftschadstoffe.

Das NRW-Umweltministerium, die Rabtherm AG und die Wallstein Ingenieur GmbH sehen in diesem Verfahren einen großen Beitrag zum Schutz der Umwelt, mit dem der CO_2-Ausstoß und der Primärenergiebedarf deutlich verringert wird. Somit trägt dieses Projekt dazu bei, die Vorgaben des Kyoto-Abkommens in die Praxis umzusetzen.

Die bessere Energiebilanz und die positiven Umweltaspekte machen Abwasserenergieanlagen sowohl für innovative Bauherrschaften und Firmen interessant, als auch für Gemeinden, die sich zu einem nachhaltigen Umgang mit Ressourcen verpflichten.

- Idee
- Einsatzgebiete