Integration of Wastewater Treatment Plants into Regional Energy Supply Concepts

Wastewater treatment plants do not only treat wastewater but can also provide different types of energy and other resources.

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Abstract

The main purposes of sewer systems and wastewater treatment plants are to ensure public health and safety as well as environmental protection. To achieve this, different types of energy are consumed. But wastewater treatment plants do not only consume but also produce energy (and other resources). The produced energy can be reused internally to increase the energetic self-sufficiency of a treatment plant and/or externally to supply the adjacent areas and infrastructures. In the latter case the related wastewater treatment plant could be considered as a regional energy cell. This paper will give a brief overview on the different aspects of energy consumption and production at wastewater treatment plants and some basic ideas on the approach of integrating wastewater treatment plants into regional energy supply concepts.

Introduction

Climate change and energy sustainability is one major target of the current growth and jobs strategy of the European Union. By 2020 greenhouse gas emissions shall be 20 % lower than 1990, 20 % of energy consumed shall come from renewables and energy efficiency shall be increased by 20 % (European Commission, 2014).

Heat recovery from wastewater can make a contribution to reaching the targets. Heat exchangers extract thermal energy from wastewater. Heat pumps then bring the extracted energy even to a higher level of temperature. The heat gained can be used for the heating of buildings or even for the production of hot water. Depending on the technical equipment heat pumps are also able to produce cold for the cooling of buildings. Figure 1 gives an overview of the basic concept for heat recovery from wastewater.

Current Austrian research work shows that from a theoretical point of view up to 10 % of the households could be supplied with heat from wastewater. This number is consistent with experiences from Germany and Switzerland. However, it is assumed that only about one third of the potential heat recovery is economically feasible (Project Consortium “Energie aus Abwasser”, 2012).

The main purposes of sewer systems and wastewater treatment plants are public health and safety as well as environmental protection. Thermal use of wastewater may in no case impede these functionalities. In spite of inbuilt elements trouble-free sewer operation and maintenance must be possible at all times. And heat extraction from wastewater may not have any negative effects on the treatment efficiency of a wastewater treatment plant.

Negative impacts on the wastewater infrastructure can be avoided, if heat extraction is located in the effluent of a wastewater treatment plant. Other advantages of this extraction site are high and steady discharge quantities and increased water quality (treated instead of raw wastewater). One major disadvantage of this extraction site can be its remoteness and thus long supply distances to possible energy consumers.

Key messages:

- Wastewater treatment plants do not only treat wastewater but produce different types of energy and resources.
- The energy and resources produced may not only be reused internally but also externally.
- From an internal point of view the reuse of produced energy can help to increase energetic self-sufficiency of a wastewater treatment plant.
- From an external point of view wastewater treatment plants can be integrated into regional energy supply concepts serving as regional energy cells.
- Wastewater shall not be considered as waste but as a resource.

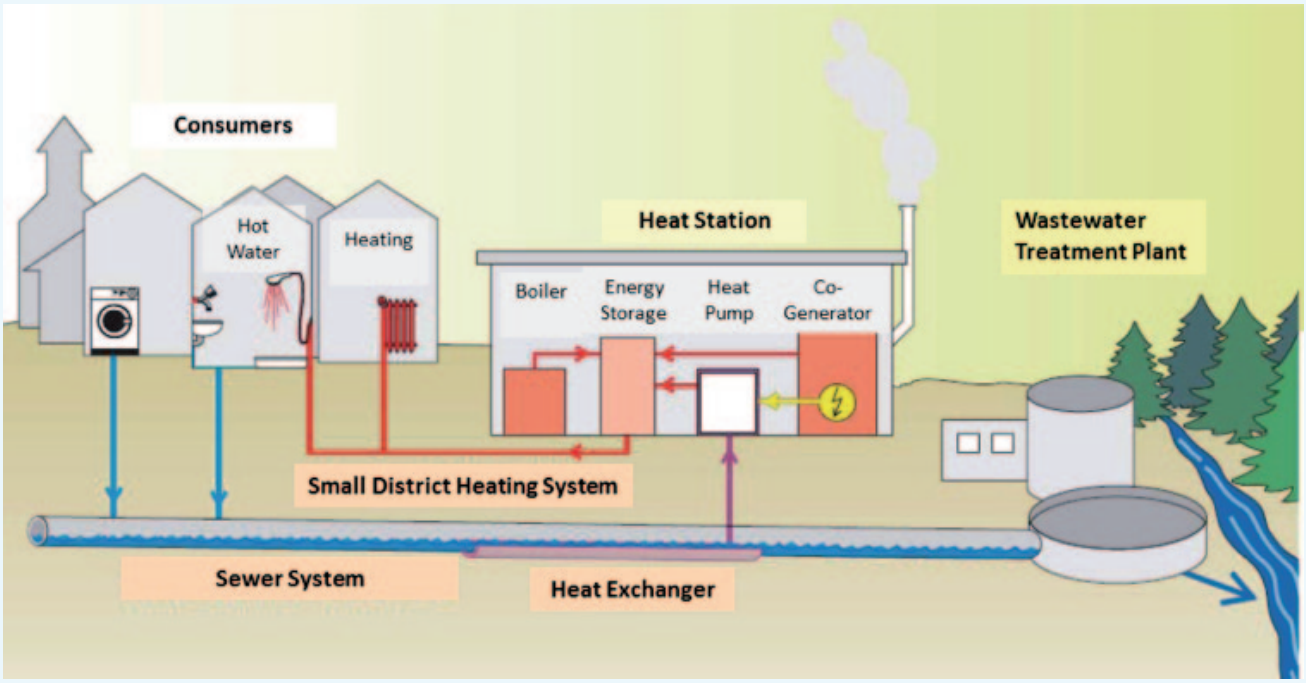

Figure 1: Basic concept for heat recovery from wastewater (Mueller et al., 2009, adapted)

In order to make the most efficient use of the heat from wastewater possible consumers should be brought into closer distance to wastewater treatment plants. This can be achieved be means of regional land use and energy planning (definition of energy zones, identification of priority development areas, etc.). The targeted location of companies and industries with high heat demand in close range to wastewater treatment plants can be seen as a first step towards the integration of wastewater infrastructure into regional energy supply systems.

Wastewater treatment plants may not only deliver thermal energy extracted from wastewater but different types of energies and resources are being produced. However, wastewater treatment plants also consume different types of energies and resources. From a sustainable sanitation and energy point of view wastewater treatment plants may therefore be viewed in a larger context: Wastewater treatment plants do not only treat wastewater but could also serve as regional energy cells.

Wastewater treatment plants and regional energy supply

On a macroeconomic level (national economy of a country) the energy demand of wastewater treatment plants is only of little significance. Anyway, on microeconomic level (business economy of a community) it is considered to be a major cost driver.

From an economic point of view two aspects are imperative regarding the wastewater and energy context: One the one hand the energy demand of a wastewater treatment plant shall be minimised. On the other hand the production of reusable and processible energies shall be maximised. Both aspects contribute to increase energetic self-sufficiency of wastewater treatment plants. Internal reuse of produced energy can be seen as a key factor.

However, surplus energy as well as certain resources cannot be used at a wastewater treatment plant (excess heat, stabilized sludge, etc.). In this case an external use of energy and resources in the surrounding area and infrastructure shall be striven. Hereby the technical and economic feasibility always depend on different local boundary conditions (wastewater treatment performance, infrastructural constraints, existing energy suppliers, energy prices, available energy demand, legal constraints, etc.).

Thus the integration of wastewater treatment plants into regional energy supply systems comprises three different aspects:

- Energetic optimisation of the wastewater treatment plant: Efficient use of electrical and thermal energy, increase of energy production output, internal reuse, etc.
- Targeted reuse of surplus energy and resources in the vicinity of the treatment plant: Identification of current and future energy demands, coordination with community and existing energy suppliers, etc.
- Optimisation of internal and external energy and resource flows: Identification of most appropriate points of energy and resource consumption from economic and ecologic points of view (inside and outside of a wastewater treatment plant)

Energy and resource consumption, production and reuse

Prior to an energetic optimisation of a wastewater treatment plant the major energy consumers have to be defined. At common wastewater treatment plants (activated sludge systems) these are the following (Lindtner, 2008):

- Regarding electrical energy
  - Inflow pumping station
  - Mechanical pre-treatment (automated screen and grit chamber cleaning, etc.)
  - Biological treatment (aeration, stirring, sludge recirculation, etc.)
  - Sludge treatment (mechanical sludge thickening, anaerobic digestion, dewatering, etc.)
  - Infrastructure (power supply of operational buildings and offices, electric lightning, heating and cooling of operational buildings and offices, etc.)
- Regarding thermal energy
  - Sludge treatment (sludge preheating, digester heating, heat loss compensation, etc.)
  - Infrastructure (heating of operational buildings and offices, hot water production, etc.)

Additionally, other resources as for instance nutrients (carbon, nitrogen, phosphorus, etc.) could also be considered as being "consumed" during the treatment process.

On the production side of a common wastewater treatment plant, the following intermediate products could be incurred:

- Treated wastewater
- Sludge containing nutrients (phosphorus, etc.)
- Digester gas (only at wastewater treatment plants with anaerobic sludge treatment)
- Solar energy (only with appropriate technical equipment)

Depending on the availability and the further "processing" of intermediate products different types of energies and resources could finally be provided by common wastewater treatment plants (activated sludge systems):

- Electrical energy
  - Electricity (production through digester gas powered co-generator or micro turbine, through hydroelectric turbine in the effluent, through photovoltaic)
- Thermal energy
  - Low temperature heat (production through wastewater heat exchange or solar heat)
  - High temperature heat (production through digester gas combustion or cogeneration)
  - Cooling (production through wastewater heat exchange)
- Resources
  - Treated wastewater
  - Subsequently processible stabilized sludge

Figure 2 gives an overview on the connections between energy and resources consumption and production at wastewater treatment plants. "Raw materials" consumed are wastewater (including nutrients, etc.), energy from public supply (electricity, natural gas, etc.) and occasionally bio-waste as a co-substrate for anaerobic sludge treatment. The goal of cogenerating bio-waste together with sewage sludge is to increase digester gas production.

Depending on the type of sludge stabilisation two different kinds of treatment "technologies" are distinguished (aerobic and anaerobic stabilisation).

The "intermediate products" can be further processed to final "products" mentioned above (heat, cold, reusable water, electricity, gas, sewage sludge).

The possible applications of heat, cold and electricity inside and outside of a wastewater treatment plant (internal and external use) are obvious. Energy from public supply systems could partly be substituted. The reuse of wastewater does not play an important role in Austria. The treated wastewater might be used internally for the cleaning of basins or the like. The digester gas can be used for heat and power production (co-generation, etc.) at the wastewater treatment plant itself or in remote "satellite" heat and power plants. In this case both plants would by connected by a digester gas pipeline. Alternatively pre-treated digester gas could also be used as a green-house-neutral fuel for cars and buses (e. g. public buses in the Swiss (capital-) city of Bern). Common application possibilities of sewage sludge are reuse in agriculture and incineration. In agriculture sewage sludge serves as a natural fertiliser and improvement for soil structure. Incineration of sludge delivers additional excess heat. The produced thermal energy can be used for heat supply or electric power generation. The ashes of mono-incinerated sludge can serve as a future source for the recovery of nutrients or other contents (phosphorus, etc.).

Energetic optimisation of wastewater treatment plants

Energetic optimisation of wastewater treatment plants on the one hand means reduction of electrical and thermal energy consumption. On the other hand the production of reusable and/or processible products has to be increased. As mentioned before, there are several measures which can make their contribution to the rise of energetic outputs.

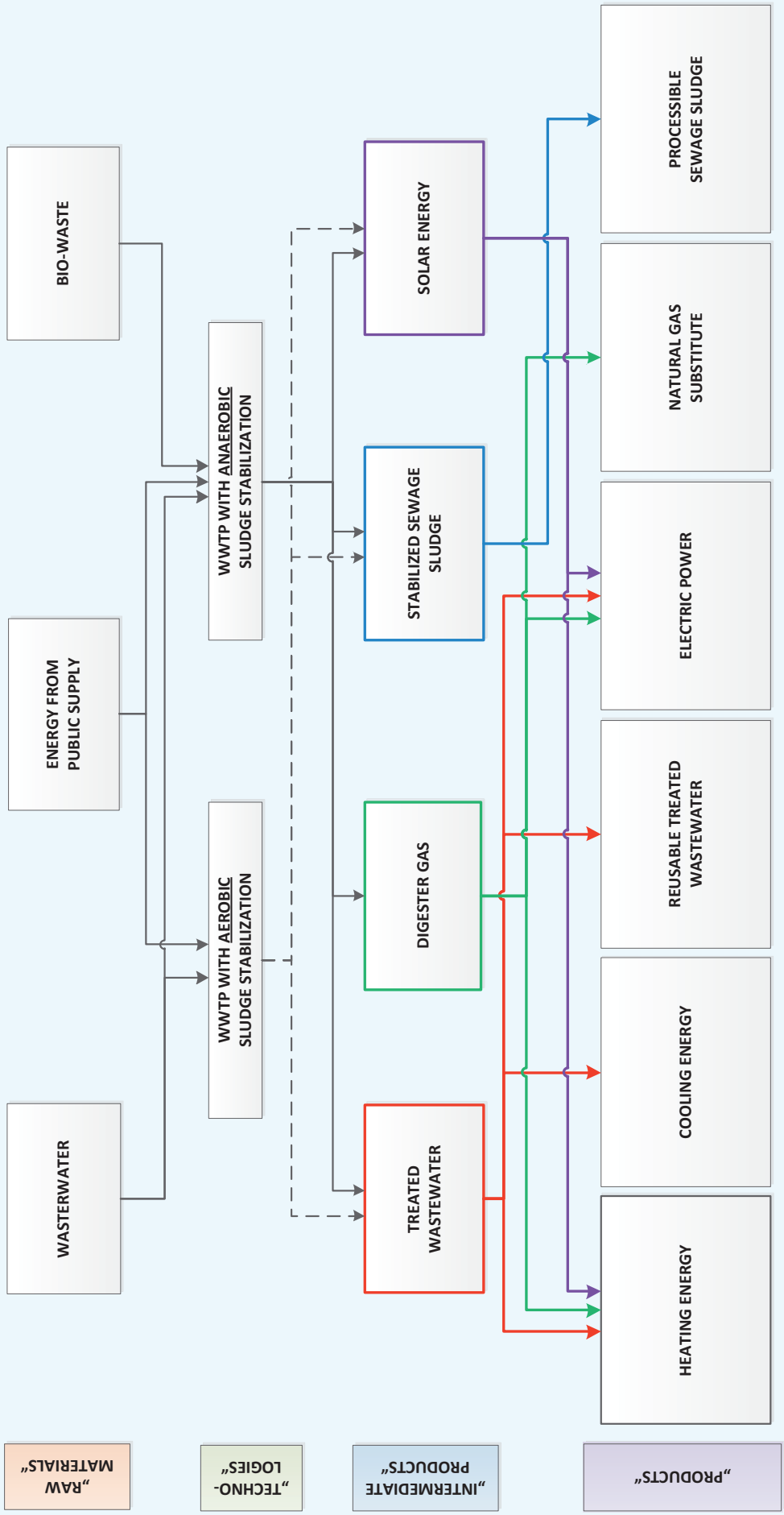

Figure 2: Energy and resource consumption and production at WWTPs

According to Hofmann (2012) some of the main consumers of electric energy are:

- Aeration (by far the biggest consumer)
- Stirring
- Inflow pumping
- sludge recirculation

The consumption of electrical energy can be reduced by the exchange of out-dated (aeration) technologies, the reduction of infiltration water, the shift from aerobic to anaerobic sludge stabilisation and the like.

Thermal energy is mainly used for the pre-heating of the sludge as well as for the heating of the digester tower and the compensation of heat loss (only at treatment plants with anaerobic sludge stabilisation). Thermal energy for heating other operational buildings or the like is of minor importance. Heat loss can generally be reduced by appropriate thermal insulation of related buildings and pipe networks.

Table 1 gives an overview on standard range of energy consumption and production at common wastewater treatment plants per population equivalent (PE) and year in Austria and shows that production of electric energy from digester gas usually will not be enough to cover electrical energy demands (consumption). For electrical self-sufficiency additional power producing measures seem to be necessary. Regarding self-sufficiency of thermal energy it seems that due to combustion or co-generation of digester gas heat demands can be cover in many cases. From an energetic point of view wastewater treatment plants with anaerobic sludge stabilisation (digestion) have advantages compared to those with simultaneous aerobic stabilisation.

Table 1: Standard ranges of energy consumption and production at wastewater treatment plants (Lindtner, 2008)

	Consumption [kWh/PE*a]	Production* [kWh/PE*a]
Electric energy	20 - 50	10 - 20
Thermal energy	0 - 30	20 - 40

*produced from digester gas

Production of energy at a wastewater treatment plants is traditionally equated with the production of digester gas. The amount of digester gas and thus the amount of electrical and/or thermal energy available can be increased due to co-fermentation (bio-solids, sewage sludge from neighbouring treatment plants, etc.). Additional use of solar energy and hydroelectric turbines in the effluent could also contribute to the increase of energetic output of a wastewater treatment plant and thus to its energetic self-sufficiency.

It is obvious that energetic optimisation must never be made at the expense of the performance of wastewater treatment.

Integration into regional energy supply systems

If an internally optimised wastewater treatment plant could produce a surplus of electrical or thermal energy, it might also serve as a regional energy cell. As mentioned above, this depends on different boundary conditions. On the one hand regional energy and land use planning have to be addressed. On the other hand all relevant energy and resource paths inside the wastewater treatment plant as well as their external interactions with the surrounding infrastructure have to be taken into consideration.

Conclusion

The main function of a wastewater treatment plant is the treatment of wastewater for water pollution control. Therefore different types of energy and resources are needed (heat, electrical power, etc.). However, wastewater treatment plants also produce certain kinds of energy and resources.

The energetic performance of a wastewater treatment plant can be optimised if consumption is minimised and production is maximised. The major energy consumers as well as possibilities to increase the energy output at wastewater treatment plants has been described in this paper.

The aim of an energetic sustainable operation of wastewater treatment plants should be a high grade of self-sufficiency regarding electrical and thermal energy. However, if a wastewater treatment plant could produce surplus energy, it should be integrated into regional energy supply concepts and serve as a regional energy cell.

Wastewater and sewage sludge should not be considered as waste anymore. It seems far more appropriate to be considered as resources.

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