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Waste Water Treatment Plants as Regional Energy Cells – Evaluation of Economic and Ecologic Potentials in Austria

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Waste water treatment plants not only treat waste water, they can also act as a source of energy. The produced energy is either used to fulfil in-house energy requirements or fed into public energy distribution grids. Research in Austria and other countries has shown that waste water treatment has high energy potential which is yet unexploited. The project “Integration of Wastewater Infrastructure into Regional Energy Supply Concepts” is a national Austrian project which deals with the investigation of energy potentials from waste water treatment.
An integration of energy production systems at waste water treatment plants into energy networks to meet energy demands of urban areas can foster economically feasible use of so far wasted energy. In this study the waste water energy system will be optimised using Process Network Synthesis (PNS), based on the p-graph method. PNS-Studio (2011) is utilised to perform this optimisation. Starting from a maximum structure of all possible technological options the programme calculates an optimum energy network as a solution. The ecological evaluation of the scenarios is executed with Sustainable Process Index (SPI) methodology. A free online tool SPIonWeb (2014) is used to calculate ecological footprint of energy production process.
The paper discusses the economic and environmental aspect of the PNS-Studio calculations and the different fields of application for the produced resources (heat, electricity and biogas), using a real world case study. Furthermore the approach of integrated waste water treatment plants into regional energy supply infrastructure will be explained.

1. Introduction

There is a clear coherency between human’s energy use, especially with fossil energy and increasing greenhouse gas emissions in our atmosphere. These greenhouse gases are responsible for a good portion of global warming. One of the biggest challenges humanity faces right now is to avoid or at least slow down climate change. Especially if climate change is going so fast that the ecosystem cannot assimilate anymore to the fast changing conditions. Climate change is a global problem, which is why it affects everyone directly or indirectly.
Mankind has to focus on which resources we are using and keeping sufficiency in mind how much of these resources we should use in a more efficient way. That change of behaviour would reduce the ecological pressure on our environment.
Considering these issues the European Commission defines goals to be reached till 2020. Five headline targets have been agreed for the whole EU, which are translated into national targets in each EU country, reflecting different situations and circumstances. Besides employment, research and development, education and poverty, the field of climate change and energy is one of the main sub-targets. This sub-target is focusing on lowering greenhouse gas emissions by 20 % (or even 30 %, if the conditions are

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right) compared to 1990, while 20 % of the consumed energy has to come from renewable sources as well as energy efficiency has to be increased by 20 % (European Commission, 2014). The efficient use of energy out of waste water can be one of the options to attain these targets.

2. Background

Waste water treatment plants not only treat waste water, they can also act as a source of energy and other resources. Research in Austria and other countries has shown that the energy content in waste water of households, industry, commercial and public buildings is considerable (Frijns et al., 2013). The efforts include that waste water can be used as an energy source due to its year around availability. In winter it could be used as heat provision source while in summer it can be used for cooling.

Considering the sewage plant infrastructure as a kind of energy cell, it is also possible to produce biogas from sewage sludge and using the spare area on the plant areal to install photovoltaic or solar thermal panels. Heat and electricity produced out of these technologies can either be used internally at the sewage plant (in-house use) or externally feeding into the adjacent public power infrastructure. An integration of waste water into existing energy networks can save resources, reduce waste streams and with that make regional energy systems more feasible (Narodoslawsky et al., 2008).

3. The Project

“Integration of Wastewater Infrastructure into Regional Energy Supply Concepts” is a national Austrian project including several partners, launched in April 2013 enduring three years, which deals with the investigation of energy potentials from waste water (treatment). This new project can already revert to some results of the former project “Energy from Wastewater – Heat and Cold Extraction from Wastewater Using High Efficient Heat Pumps”. The feasibility of technical and regulatory frameworks has been evaluated. This former project shows that an extraction of heat after the sewage plant is technically easier and faces less problems related to the regulatory framework. However the main problem is to find appropriate heat consumers in the closer vicinity. The main goal is to investigate the integration of energy from waste water into local energy networks utilising land use planning instruments and other technical tools. As well as thermal heat provision for in-house building heating demand at the plant or energy for other purposes of the sewage plant e.g. sewage sludge drying and fulfilling of heating/cooling demand of buildings nearby. Other forms of energy like thermal energy as well as biogas or electricity will also be investigated. The above mentioned forms of use shall be quantified by means of energy potential and CO_2 reduction potential for Austria (Project Consortium „Energie aus Abwasser“, 2012).

The waste water energy system will be optimised using Process Network Synthesis (PNS), based on the p-graph method (Friedler et al., 1996). The ecological evaluation of the scenarios is done by using Sustainable Process Index (SPI) methodology (Krotscheck, 1996). A free online tool SPIonWeb is used to calculate ecological footprint of energy production process available at:<spionweb.tugraz.a>t.

At present state numerous examples in other countries show that heating and cooling from waste water can be used in a technologically and economically reasonable way for buildings in a distance of a few kilometres from the sewage plant (McCarty et al., 2011). In this project it will be shown how energy supply for buildings can be realised and if further regional resources can be used. Furthermore it will be investigated, how the heating and cooling demand near sewage plants can be increased, especially at buildings with steady low temperature consumption profiles throughout the year, e. g. greenhouses, sports halls, some industrial or commercial buildings.

Even if it would be ecologically and economically feasible, energy from waste water is often not recovered simply because the possibilities are not known. This problem shall be overcome with further dissemination activities. Among them the project team plans to build up a national website with all sorts of information about this topic (available at: www.abwasserenergie.at).

4. Case Studies

Every waste water treatment plant is a bit different and especially geographical conditions and surrounding areas are variable at the diverse locations. In order to account these factors different case studies were chosen for applied project work.

One of them will be a medium scale waste water treatment plant in the Austrian province of Upper Austria. It is located in an urban area, shown in Figure 1 and Figure 2, therefore a high potential for possible heat consumers in the surrounding is given. Potential consumers would be a hospital which is 700 m away and a manufacturing company. The site is appropriate for a case study in this project because it has an average size for the specifics of Austrian companies and a high potential for optimisation.

However for an integration of waste water treatment plants into regional energy supply infrastructures not only technical and operational data concerning the treatment plants has to be considered but also information on spatial planning in the adjacent area. The first steps for the spatial planners were to investigate the surrounding area of the sewage plant via Geographical Information Systems (GIS).

Figure 1 and Figure 2 help to get a better impression of this work and to provide an insight into the "real world" scenario. In Figure 1 the sewage plant is shown in a remote sensing image, a circle with a 1 km radius includes potential heat consumers. Figure 2 identifies the different development areas.

Figure 1: Sewage Plant, remote sensing image adapted with GIS-Tool, potential heat consumers within 1 km circle are shown (created by Neugebauer G., 2014)

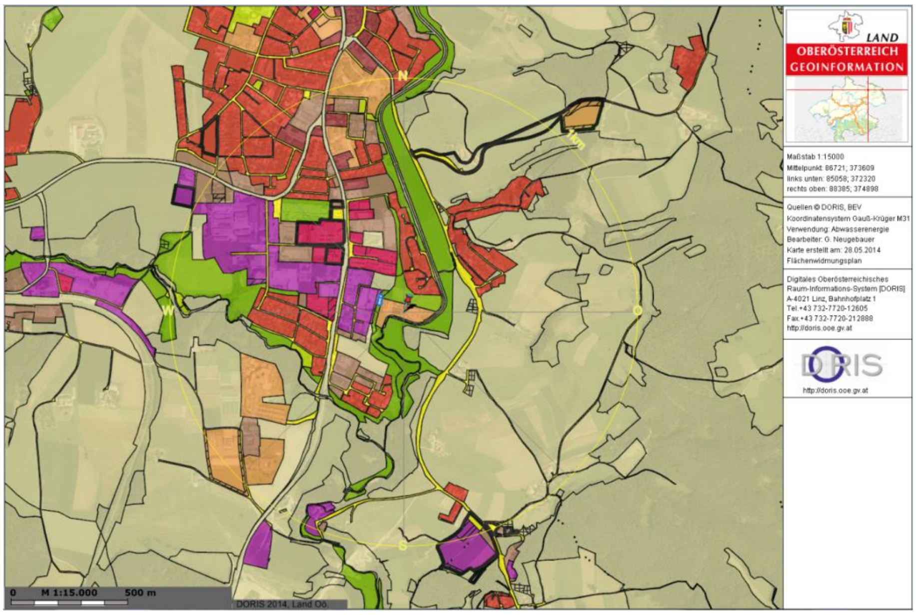

Figure 2: Sewage Plant, adapted map with different coloured development areas, potential heat consumers within 1 km circle are shown (created by Neugebauer G., 2014)

After investigating potential heat demand consumers it is needed to identify the existing heat supply and future alternatives.

5. Methodologies

Two of the methodologies used in this project are PNS and SPI. They are adapted into two software tools, the PNS methodology is used as PNS-Studio and the SPI as an online ecological footprint calculator SPIonWeb freely available at: spionweb.tugraz.at.

5.1 The Process Network Synthesis (PNS)

PNS is based on the P-graph method (Friedler et al., 1996). PNS-Studio (Friedler et al., 2011) and (PNS, 2011) is used in this study to figure out the optimal planning and implementation of strategies. First a maximum structure of all flows and cost for possible technological options, materials, energy and transport distances is created. In the next step, the programme calculates an optimum energy network as a solution presented in Figure 3. This optimal technology network contains the most feasible structures that can be generated and executed with a branch and bound algorithm.

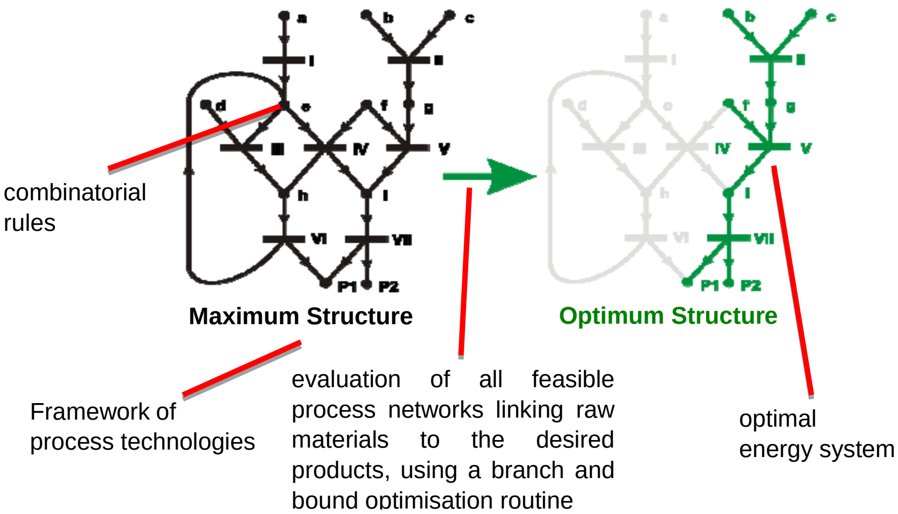

Figure 3: Maximum structure and Optimum structure of a technology network (Friedler et al., 1995, adapted)

5.2 The Sustainable Process Index (SPI)

The SPI is a tool for the evaluation of environmental impacts of processes, products or services. It is a member of the ecological footprint family and is compatible with the procedure of the life cycle analyses described in the EN ISO 14000. With SPI, it is possible to describe the relevant ecological pressures of a process including pre-chain and product usage.

The SPI is calculated by evaluating material and energy flows of a product or service extracted from and dissipated to the ecosphere and compares them to natural flows. In detail the following areas add up to the overall footprint as shown in Figure 4 (Kettl, 2013).

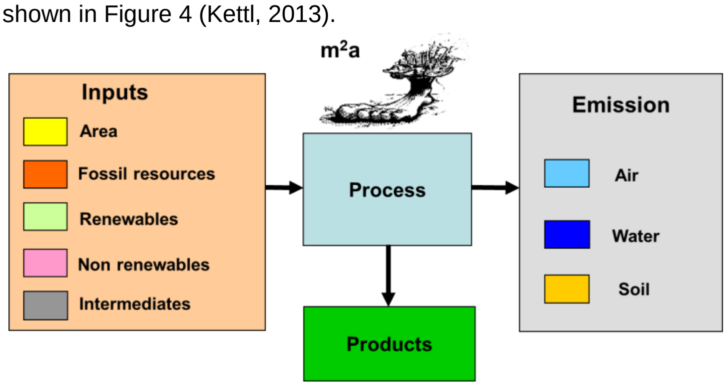

Figure 4: SPI calculation, material and energy flows of a process (SPIonWeb, *2014)*

SPI provides the opportunity to aggregate and compare environmental pressures exerted by a process or activity in the form of single unit, namely area "m^2".

6. Project outlook

The preliminary collected data about existing energy supply systems, transport/pipe network infrastructure and definition of all possible energy supply technologies will be entered following the Process Network Synthesis method. Together with this information all flows within the technology network, energy demand, possible energy suppliers, cost and prices form the maximum structure. This structure provides all possible alternatives for energy production and uses of all available (renewable) resources at the sewage plant.
Figure 5 shows a first draft of a material flow structure including all resources and material flows considered in this project. On the one hand all raw materials (input flows) including the area for building photovoltaic or solar thermal panels are given. The area is shown in Figure 5 in the upper right corner (green rectangular shape) and the raw materials are presented as light grey oval structures. These inputs are transformed using different technologies (shown as grey rectangular shapes in the middle) into intermediate products, drawn as blue oval structures (e. g. biogas or sewage sludge) which can be used again in various technologies, resulting in final products like hot or cool water, electricity or other kind of resources shown on the bottom of that graph.

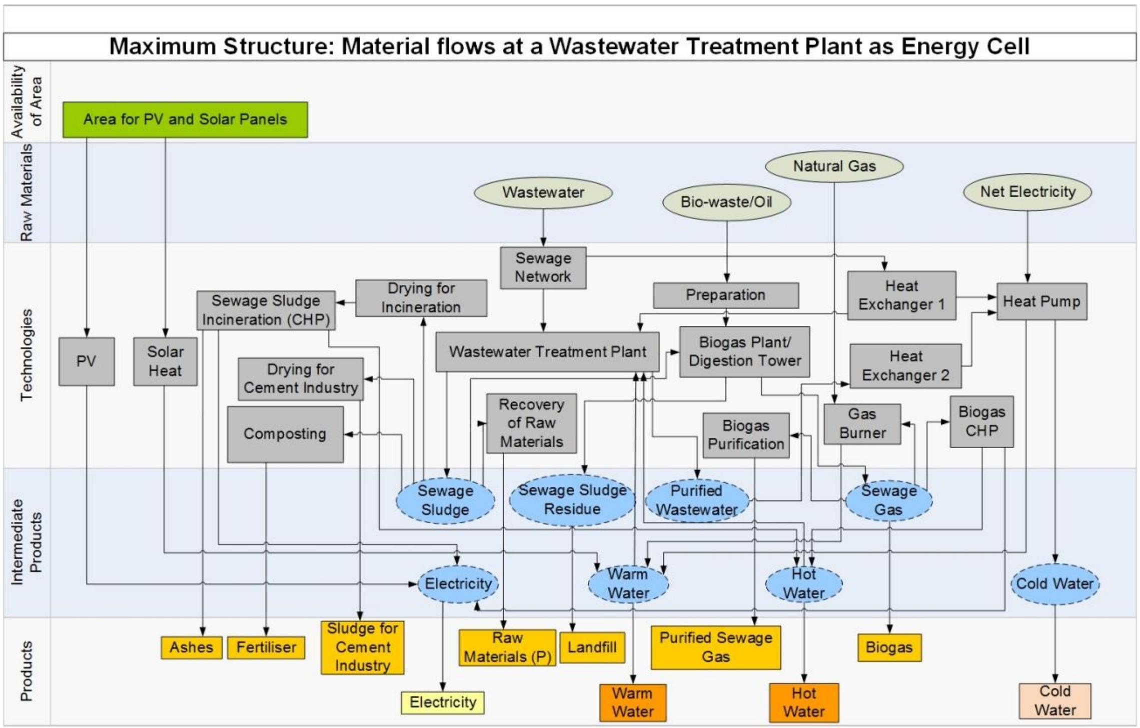

Figure 5: All possible material flows at a waste water treatment plant seen as an energy cell – first draft

The results of PNS calculation will show the most efficient products and the best way for integration into the energy system. The produced resources can either be used internally at the waste water treatment plant itself or externally at the adjacent infrastructure (industrial and commercial sites, green houses, etc.). The internal use would be the simplest realisation; it is much easier as the application on an external level. An external use is far more complex, it has to consider a lot of different factors such as the availability of potential energy consumers, the existing energy supply infrastructure and land use.
One main outcome of the project "Integration of Wastewater Infrastructure into Regional Energy Supply Concepts" will be the result of the PNS-Studio calculations for the selected case studies. These will reveal the economic and environmental aspects along with the optimal applications for the produced resources (heat, cooling, electricity and biogas) integrated in the local energy supply system. Furthermore an ecological evaluation of the scenarios using SPI methodology will provide an additional benefit.

7. Conclusions and Outlook

The results will illustrate the optimal economic and ecological solution for producing heat, cooling, biogas and electricity on the sewage plant area. This can help the operator of a waste water treatment plant, political decision makers in the region and other stakeholders neighbouring the plant to achieve sustainable decisions in the case of energy supply for the plant and its surrounding areas in the future. The plant itself, industrial and residential areas nearby will benefit from the intelligent used, no more wasted energy, but additional supplied energy by the regional energy cell. The exploitation of this energy resource will help to attain renewable energy targets set for 2020 in Europe. However, it is not possible to present any calculated results in this early phase of the project. An overview of the future challenges and already handled tasks is provided. Still it will be a challenge to get all useful datasets about sewage plant and potential energy consumers in the surrounding for the calculation with tools PNS-Studio and SPIonWeb. Considering the waste water treatment plant as an energy cell all possible renewable energy sources will be explored at the area and plant surroundings.

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