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Revamping a Waste Processing Site with Process Synthesis

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Improved waste stream management will play an ever increasing role among possible energy sources in the future. This paper analyses a waste company situated in Western Austria. Currently a considerable amount of waste is sent to a waste incineration plant. Costs thereby incurred have to be borne by the company. On the other hand heat is required, mainly for waste drying. Therefore an optimal network with an improved internal use of available materials should be generated. Within an economic optimization carried out by the P-graph method (Friedler et al., 1995; Halasz et al., 2005, Friedler, 2010) this network is developed. The results offer a wide range of future scenarios for the waste company, which could enhance the existing process; both from an economical and ecological point of view.

1. Introduction

The waste company analysed in this case study is located in Western Austria and serves as a waste hub for approximately 300,000 inhabitants as well as the industry in the region. Incoming waste is partly sorted and undergoes typical treatment procedures. Some unsorted waste is directly forwarded to nearby waste sorters in Austria and neighbouring countries, i.e. Switzerland. The waste hub processes about 350,000 t of waste a year. The majority stems from commerce and industry as well as from municipalities of two Austrian provinces. There is an existing biogas plant to produce heat and electricity using lop and organic waste. Furthermore, the company holds 10% of a nearby Organic Rankine Cycle (ORC) plant (Obernberger and Thek, 2008) whereto the main part of waste wood is contracted to be delivered for a fixed price until 2013.

New concepts for future pathways are presently discussed by the waste company’s management. In order to find the optimum with respect to economic questions taking ecological issues into account, this analysis explores some possible future scenarios for technology networks utilising the material and energy flows at the site of the company.

2. Methodology

Finding an optimum solution for the company can be done by using Process Network Synthesis (PNS). In a first step a maximum structure of a possible technology network is set up, including all input materials and feasible processes as well as all products with corresponding prices. Any contextual conditions and plans for the future have to be

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considered and included into this maximum structure. In a next step different scenarios are created using various contexts via optimization of the technology networks within the maximum structure. Comparison of these scenarios offers a valuable basis for the strategic decision making process of the company management.

3. Case Study

3.1 Point of departure

The work on the case study started by discussing contextual parameters and and strategic questions with the waste company's management and operators. It turned out that the existing ORC plant has not necessarily to be part of a future technology network as contracts will run out soon. Preference would be to run a proprietary plant without being dependent on other partners. The biogas facility should still be included but a gas cleaning process to sell the biogas as a fuel can be investigated. An economic study concerning biogas cleaning has already been carried out. The data of this study are included in this work. At present a part of the plastic fraction is used to produce refuse derived fuel. Depending on the two different material qualities the market price for this product differs. With a mono-fraction plastics material, DSD material and the content of Yellow Bag collection (sorted plastics from municipalities) a recycle product for low-grade plastics application is produced on-site.

The splitting facility, depicted in Figure 1, constitutes the core of the waste sorting process.

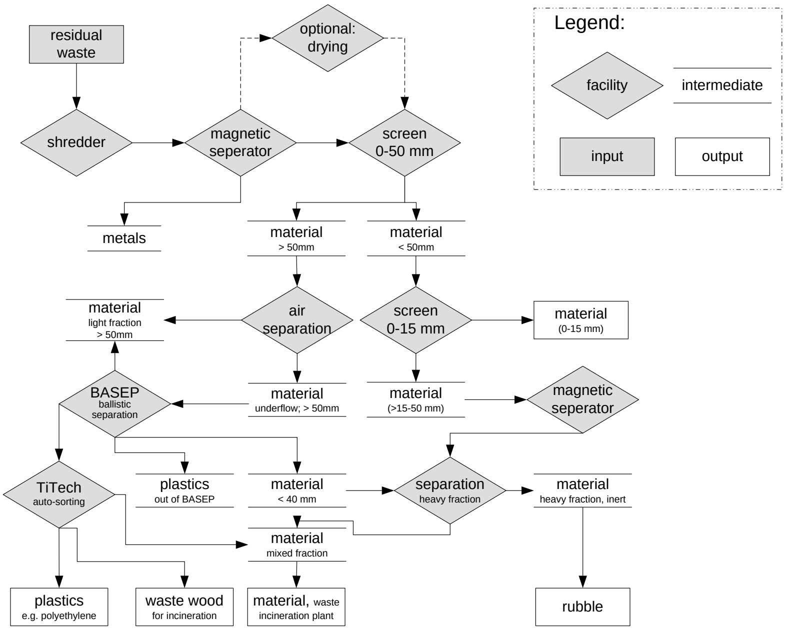

Figure 1: Splitting facility material flows

The use of the split waste streams should be utilised more efficiently as currently. The waste processing site already uses heat to dry part of the incoming waste. This heat is contracted free of charge from another company close by. One strategic aim is to increase the total amount of dried waste, as each ton which has to be sent to waste incineration increases costs. As more waste can be dried less mass is sent there, decreasing costs accordingly. Any additional heat necessary to achieve this should be produced with the available waste materials.

3.2 Feasible technologies and optimum structure

With the PNS it is possible to build up a technology network by linking different material and energy flows with respective technical processes utilising and/or producing them. A major advantage in case of the waste company is that all input materials needed are on-site. No additional logistic considerations are therefore required.

The various material fractions can be used in different processes. Biogas can be produced from lop and organic waste, which is an already existing process. The gas can either be utilised in a CHP plant with heat and electricity as products or a gas cleaning facility is considered providing clean methane. Paper sludge and reject from paper mills can be dried and used like waste wood for combustion, catalytic low pressure pyrolysis or gasification. Plastic fractions can undergo several treatments. They can be used either for recycling material, refuse derived fuel production or for combustion, catalytic low pressure pyrolysis and gasification.

Figure 2 shows the technology network resulting with the highest added value for the waste company, as a result from the PNS optimization.

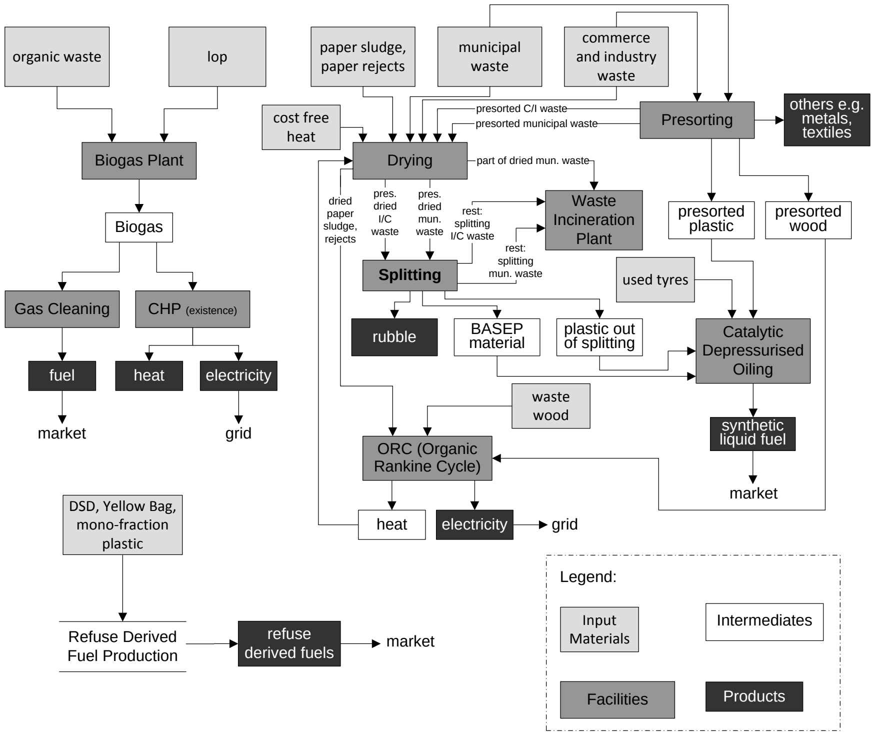

Figure 2: Optimum structure of a technology network generated with the PNS

Technologies considered in the maximum structure generated before are:

- Biomass combustion for heat production
- Biogas plant with block heating station and biogas cleaning
- Organic Rankine Cycle (ORC) as a process to produce heat and electricity. The heat can be used internally for drying. Electricity can be fed into the grid of electricity providers, thus benefiting from feed in tariffs according to the Austrian’s Eco-Electricity Act gain is increased.
- Synthetic Natural Gas (SNG) Plant with gasification of biomass to heat, electricity and SNG (Mozaffarian et al., 2004; Chandel and Williams, 2009)
- Catalytic low pressure pyrolysis (KDV) to produce synthetic liquid fuel out of waste. For this technology a proven capacity of 13.600 t/a liquid fuel was taken into account (EcoKat Applied Technologies), as no experience with larger facilities is currently available and the technology is still in the stage of industrial demonstration.

It turns out that the technology network providing the most benefit for the company includes at least three new technologies, which are not part of the current process. Waste wood is used in a new ORC generating electricity which is fed into the grid and heat used to dry incoming waste. The ORC plant produces excess heat which could be used in a heating network linking either residential districts or neighbouring industrial sites with the waste company site. For this purpose a detailed demand research is necessary to identify optimal network size.

Biogas cleaning after the existing biogas plant is also part of the optimal network. This cleaning facility is restricted in its capacity, as investment costs of 200,000 € should not be exceeded. Therefore a CHP is still included in the structure although the heat is not used. Drying of fresh wood from a nearby saw mill could be a possible use for this excess heat, realising an additional profit for the waste company.

An important question for the waste company was, if keeping the splitting facility in operation is strategically sensible. The optimum structure shows that although some maintenance investment has to be done in the near future it is still advantageous to keep it in operation. All the plastics fractions sorted out by this process will be used in a catalytic low pressure pyrolysis plant as well as used tyres, producing synthetic liquid fuel which can be profitably marketed.

The production of refuse derived fuel runs on higher quality plastics than required for the catalytic low pressure pyrolysis producing a readily marketable product. The recycled plastic production is not included in the structure as the raw materials for this process are more efficiently used by other technologies.

The amount of waste to be sent to waste incineration is considerably decreased. This is desirable from an ecological point of view, too, as not only the necessary transport would be reduced but the content of the waste will be utilised in a more efficient way.

3.3 Scenarios

Scenarios based on the optimum structure described above have been devised according to the waste company's interests by changing contextual parameters e.g. by modifying input material flows or omitting technologies. This section briefly describes a selection of these scenarios.

3.3.1 Scenario 1: No refuse derived fuel production

In this scenario the production line for refuse derived fuel is cut and plastics with higher quality than those sorted out at the splitting plant are used as input for catalytic low pressure pyrolysis. No plastics recycle material is produced in this scenario. The pyrolysis has a restricted capacity, so some of the low quality plastics are sent to the incineration plant. If recycled plastic production is involved, using almost two third of DSD, Yellow Bag and mono-fraction plastics, the amount of lower quality plastics to be incinerated may be reduced. Used tyres are granulated by a different company.

3.3.2 Scenario 2: Higher capacity of catalytic low pressure pyrolysis

As already mentioned the Catalytic pressure-less depolymerisation is restricted in its capacity. The upper bound of one module is 13,600 tons of synthetic liquid fuel per year. As this is a novel technology it is still unclear how scaled-up plants using this technology operate. In this scenario therefore the PNS set up a structure wherein no upper bound on the capacity of the plant is attached in order to examine an option of a large scale pyrolysis plant for the waste company. It turned out that a plant with up to four times the capacity of the proven technology can be sustained by the resources available at the waste company site. Plastics, used tyres, dried paper and almost all waste wood are utilised in this plant. As a result there is not enough biomass available to run an ORC. The heat for waste drying in this scenario comes mainly from the biogas CHP and a small part from biomass combustion. Due to the marketability of synthetic liquid fuel this scenario has the highest revenue of any considered alternatives.

3.3.3 Scenario 3: Maximisation of biogas cleaning

In the optimum structure described above the biogas cleaning is restricted to 1.25 million m³ per year. This can be traced back to the fact that the investment costs for the cleaning facility are covered by another stakeholder with an investment limit of 200,000€. In the third scenario the biogas CHP disappears as soon as the upper limit for cleaning is taken away. All the biogas, produced out of lop and organic waste is cleaned. Although the investment costs are higher than in the optimum structure it leads to a more profitable solution, as more fuel can be sold on the market. Else, the technology network is similar to the one described in section 3.2.

3.3.4 Scenario 4: Reduction of the profit for incoming waste

Currently, the waste company is paid for each ton of residual waste it takes in. Given that the price per ton decreases by no more than one third compared to current price levels, the optimization renders a feasible structure without noticeable changes compared to the optimum structure described above – the overall revenue is lower than before, though.

3.3.5 Scenario 5: worst case scenario

A worst case scenario was discussed with the waste company's management and operators and analysed with the PNS. It includes no biogas cleaning, combined with profit loss for incoming waste and the loss of cost-free heat. The prices for incoming materials were set to zero. In this scenario the company could not make any profit. Selling excess heat to residential customers or using heat for drying of agricultural or forestry products however turns this scenario back to profitability. It clearly shows that finding customers for heat is a prime challenge for the management of the company.

4. Conclusions

Optimising an existing waste processing site using contextual parameters as well as a few innovative technologies reveals new possibilities to manage on-site material and energy flows. These structures are mainly based on technologies that increase the usage of waste and energy recovery. Resources can be used in a more energy efficient way while reducing ecological pressure. The scenarios described provide new perspectives not only for the company's management by investigating the overall process and open a wide range for decision making. Innovative process lines have been identified, leading to new perspectives for the company management. An important strategic question for the waste company could be answered as well: the splitting facility will be important in the future. In every scenario it is a main part of the technology network. An interesting fact is the importance of catalytic low pressure pyrolysis as a key technology in all developed scenarios. This novel technology has the potential to play a significant role for waste management. The case study showed that a huge amount of potential heat production is currently untapped. The optimization with the PNS indicates how this potential can be fully utilised resulting directly in higher profit. The analysis proves that if heat is produced an important necessity is to use it in the largest possible quantity on-site. Summing up the application of PNS is only one step in a strategy development process. It is the starting point to generate ideas to step forward to sustainable development in decision making. For the waste processing site in question it rendered a broad range of innovative technology networks. Choosing from these scenarios will improve the economic as well as the ecological performance of the company.

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