Optimal Integration of Sustainable Technologies in Industrial Parks

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Industrial parks are an important instrument to close material cycles as well as to raise the efficiency of industrial production. Spatial closeness allows the exchange of by-products at low costs as well as energy cascades utilising precious raw materials and energy resources most efficiently. This is of particular interest if industrial parks utilise renewable resources. The utilisation of renewable resources poses new technological but also logistical challenges (Narodoslawsky et al., 2008).
Industrial parks offer the possibility to treat different raw materials (and blends of raw materials) as input to various. The problem arising is to create a technology network that optimally utilises resources while at the same time maximises the value added for the members of parks and minimises the ecological pressure from the production within the park.
The contribution will deal with three different case studies of industrial parks, one in Austria, one in Germany and one in Egypt. It will present a coherent and systemic approach to find the best technology network in existing industrial parks facing a retrofit situation.
Process synthesis using the p-graph method (Friedler et al., 1995; Halasz et al., 2005) is employed to find a stable basic technology network, integrating existing facilities and integrating new technologies (such as CHP and direct solar energy utilisation) that utilise available resources.

1. Process Network Synthesis (PNS)

Process Network Synthesis is a method to optimize material and energy flow systems. The main aim is to find a network consisting of operations of processes technologies to transform raw materials into products (including energy). This method allows the optimization of process structures as well as energy and material flows. It is possible to factor in time dependencies regarding resource availability (e.g. harvesting times for renewable resources) as well as product or service demand (e.g. varying heat demand for district heating over the year). The input necessary for this optimization includes mass and energy balances, investment and operating costs for the technologies considered, costs for resources and utilities, prices for products and services as well as constraints regarding resource supply and product/service demand.

1.1 P-Graph

The P-Graph (Process graph) represents the structure of a process system. According to Fig. 1 raw materials (B and C) are an input for the operating unit O2 to produce a product which is an input to the operating unit O1. The operating units are representing some kind of technologies. This process leads to the final product A. For every input and operating unit it is possible to define a maximum flow and the costs. The definition of all raw materials, technologies and products in a process system leads to a huge network which represents the maximum structure.

This structure includes all theoretical combination of the whole process network.

Based on input data about flows and costs (variable and fixed costs) an optimal structure is generated.

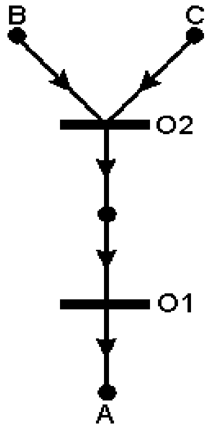

Fig.1: Sample process network path

2. Case Studies

2.1 : Multifunctional energy center, Austria

Within a research study PNS was used for the optimization of a regional-multifunctional energy center. Such a center is characterized by generating energy carriers (e.g. biofuels) or services (e.g. heat or power) as well as industrial products based on regionally available renewable resources. Multifunctional energy centers could either be linked to existing installations (e.g. a biomass heating unit serving a district heating network or an existing biogas plant) or conceived as a completely new installation.

The location of the features an existing biogas plant with corn silage and manure as input and an electrical output of 500kW_{el}. Electricity is sold to the grid and heat is provided to a district heating grid. A furnace producer operates a research and development unit for chips and pellets furnaces that provides additional heat.

Besides district heating agriculture drying, pelletizing and an oil press may be operated based on the raw materials potential from 8 communities around the site (within appr. 10 km radius).

A generalized maximum structure comprising feasible technology pathways based on the resources from agriculture and forestry in the region was used in this project (see fig. 2). The goal of the optimization was to find a technology pathway generating the highest added value for the region based on the maximum structure in fig. 2. The optimum structure resulting from this optimization is shown in fig.3.

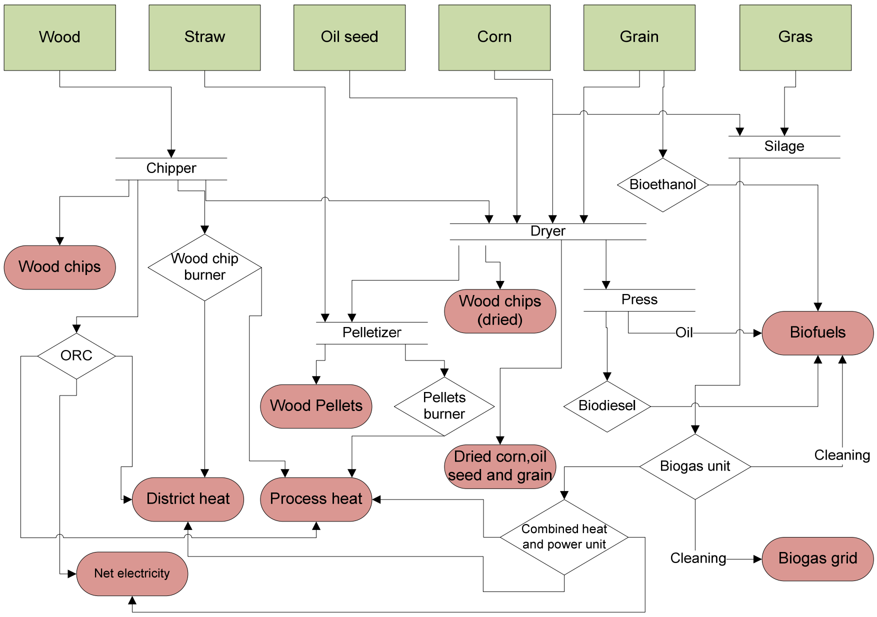

Fig. 2: Maximum Structure

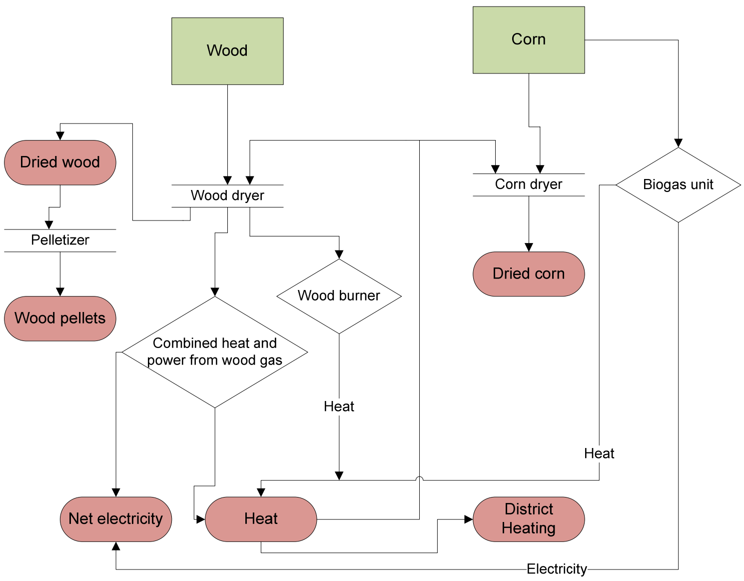

Fig. 3: Optimum Structure

The structure includes besides the existing installations of the biogas unit and the furnace test rig a gasification plant. Heat is used for district heating as well as drying, providing dry wood (e. g. for pelletizing) as well as dry corn for selling, depending on the season.

2.2 Agro-industry complex, Egypt

The study addresses an agro industrial, manufacture and technology centre in Egypt that is currently supplied mainly by conventional energy sources such as electricity from the grid and oil based heating and power systems. A new approach on energy provision, utilizing locally available renewable resources to a greater extend while increasing revenue is the goal of the study in this case. The maximum structure is generated according to existing technologies and follows to a great extend the one shown in fig. 2, including however solar energy technologies and rice straw as an additional resource. Electricity from the grid and fossil based technologies were kept in the maximum structure, too. Cooling as a demand was included reflecting the situation in this agro industry complex that produces food.

PNS generates an optimum structure (fig. 4) where sewage will be treated in biogas plant. Biogas is converted in Combined Heat and Power (CHP) unit. Rice straw is pyrolysed, producing char that is used to improve soil quality. Existing air conditioner units using electricity are included in the optimum structure but supported by new chillers operated by heat to cover additional cooling and air conditioning loads for expansion of production processes. Heat generated by the processes is utilised either for cooling (via absorption units) or for drying purposes. Additional electricity is generated via biogas as well as PV units.

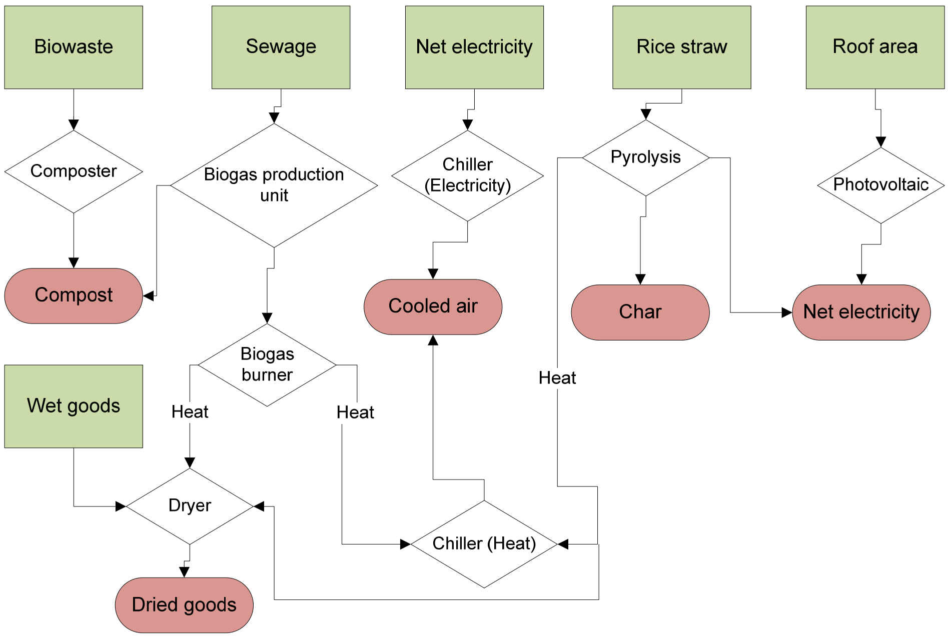

Fig. 4 Optimum structure for the Egyptian agro-industry complex

2.3 Landfill site, Germany

The site of this study has been operated as sanitary landfill since 1995 and is now nearly close to the end of its functionality. The goal in this study is to provide a structure for an industrial park on the now available industrial real estate utilizing regional resources with the highest possible revenue. The maximum structure of fig. 2 also applies to this case. Landfill gas however may be used as an additional resource for a considerable time. In addition to locally available fresh wood, used-wood (from waste collection) may be used but is restricted to thermal utilization.

Fig 5 shows the optimum structure that includes a dryer for fresh wood that will be used to produce pellets. The heat for drying comes from three different sources: (i) a biogas unit which uses agricultural waste and biowaste for the production of electricity, heat and as by-product fertilizer and compost; (ii) a landfill gas CHP for electricity and heat production; (iii) an ORC-unit which uses used-woodchips for the production of electricity and heat. The electricity is sold to the grid at premium prices for renewable resource based electricity.

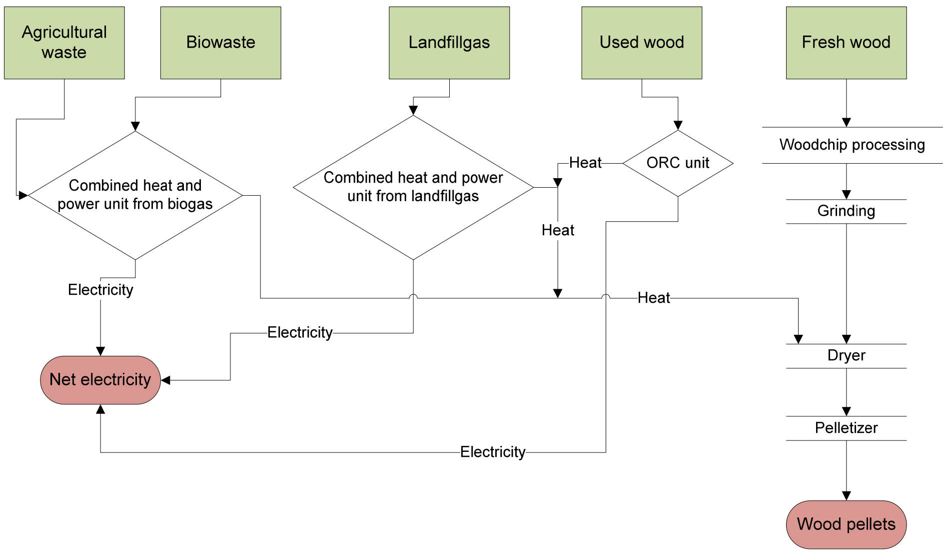

Fig. 5: Optimum structure for German landfill site

3. Conclusions

The case studies deal with very different settings of relatively small industrial parks that are explicitly based on renewable resources that are locally or regionally available. Both the supply side and the local demand for energy services differ widely for these parks. Supply may include a whole variety of crops and resources like in the Austrian case or be restricted to waste material like in the Egyptian case or with an emphasize on wood and used wood as in the German case.

The same holds true for the demand that may vary in time for each site (corn drying, wood drying and district heating, depending on the season in the Austrian case, cooling and power in the Egyptian case).
Despite these wide variety in the resource and demand framework and vast differences in the cost structure between the German/Austrian and Egyptian cases, some interesting common lessons may be drawn from the cases:

- All optimum structures show considerable revenues; this means that utilizing local/regional renewable resources is already a viable business strategy that tends to become even more advantageous as energy prices may increase over time.
- The key to profitability is the rational and complete utilization of heat generated by all technologies. Although other products (e.g. pellets or biofuels) or services (electricity) may fetch higher prices on the market, net positive revenues are only possible if heat is used completely.
- There are many ways to utilize heat rationally; among the most promising are drying (mainly of renewable resources from the region) and cooling (where appropriate).
- A major factor for success is to devise a structure that allows a year round utilization of heat, possibly by providing different services consecutively. Running energy provision technologies in a continuous mode and adapting energy users is a strategy to follow.

References

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