CHEMICAL ENGINEERING TRANSACTIONS Volume 18, 2009
Editor Jiří Klemeš

 ISBN 978-88-95608-04-4 ISSN 1974-9791
DOI: 10.3303/CET0918083

Tailor-made Solutions for a Local Industrial Centre

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Local industrial centres become more and more important, as climate change and the maximum production for crude oil require new approaches to resources and industrial structures. Utilising renewable resources will favour local and regional solutions for their utilisation as they are de-centrally produced and require large transport capacities. The structure of local industrial centres however is strongly dependent on regional resource potentials and local demand profiles. Their design therefore calls for tailor made solutions. The paper explores the possibilities to use combinatorial process synthesis to local settings. Application to an existing landfill site in Germany that intends to develop itself into a centre for bio-resource and waste utilisation will be reported exemplarily. The paper will summarize the experiences, challenges and open questions attached to applying process synthesis to the problems of restructuring industry in the 21st century.

1. Introduction

According to European Commission Report of Competitiveness and Economic Reforms (EC, 2007), the industrial structure of the economy and the distribution of value added across sectors is the result of long-term trends, in particular productivity developments, the increase in the standard of living, changes in the structure of demand and in international trade. The sectoral trends in the EU are characterised by the dynamism of market services, which record growth rates higher than the economy as a whole. Unfortunately, current state of the economic growth and the pattern of development have driven the increment of both energy and material resources consumption, which has a strong relation to the environmental impact of human activities (EEA, 2005).
The US as well as the EU and some national governments (e.g. Germany) recently shift their policy to put more investment focus on environmental protection and renewable energy utilization. The hope is, that the eco-industries and the utilisation of renewable resources will create jobs across European countries (EEA, 2005) while lowering the ecological impact considerably. One particular route the European Union is pursuing is the creation of “bio-refineries” utilising local and regional renewable resources and the utilisation of waste flows from society, agriculture and industry in order to increase resource efficiency of society.

Please cite this article as: Tomo H., Eder M., Sandor N., Halsz L. and Narodoslawsky M., (2009), Tailor made solutions for local industrial centers, Chemical Engineering Transactions, 18, 511-516 DOI: 10.3303/CET0918083

Renewable resource utilisation and the introduction of bio-based or waste based processes to local industrial centre is usually defined as a retrofit problem, aiming for added-value by utilising alternative resources and innovative processes around an existing industrial infra structure. The first task is to generate scenarios for decision makers that render an encompassing picture of future chances and possible lines of development. These scenarios have to take into account the interdependencies of processes, the possibilities for synergies as well as possible competitions for resources and space at a given site.

In this paper, Process Network Synthesis (PNS) algorithm to optimize the combinatorial feasible structure was selected to solve this problem. PNS Algorithm has capability on generating maximal structure, solution structure and following by optimization respectively (Friedler et al., 1992). This particular approach has already shown its value in other related applications, namely the optimisation of regional technology networks and renewable resource utilisation (Halasz et al., 2005, Halasz et al., 2006, Narodoslawsky et al., 2008).

2. Status quo of the local industrial centre "Leppe"

The local industrial centre "Leppe" is located near Cologne (Germany) and has been operated as sanitary landfill since the 1980ies for the region of the Bergischer Kreis. The site has an area of 45 ha and may contain 10 Mio m³ of waste when it reaches its full capacity. Since 1995 a small industrial/commercial park is operated on the site.

Currently, the site produces electricity and heat from two main sources: landfill gas and biogas. From both resources, electricity is supplied to the grid with a maximum of approx. 22.000 MWh in 2004. This production is in decline, as seen in Fig. 1, as the landfill gas production falls off due to the maturity of the dump. The activities at the site currently include mainly operations linked to waste and recycling activities.

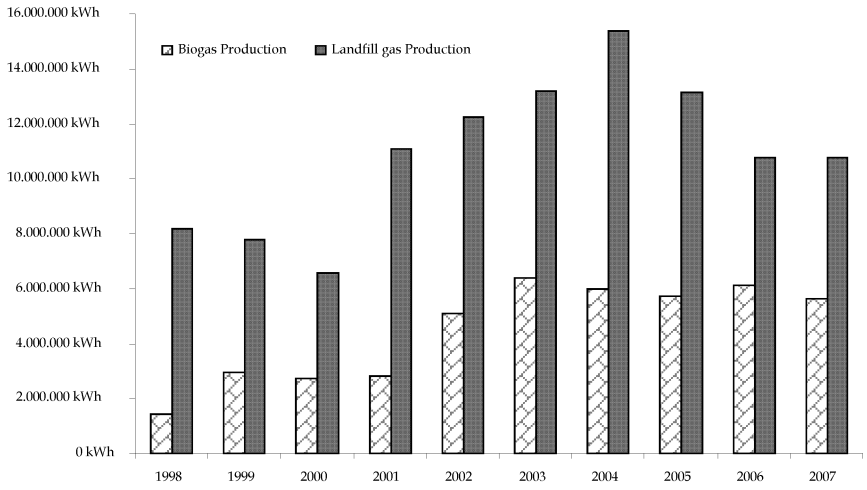

Fig. 1: Existing Electricity Production

The sanitary landfill is approaching its maximum capacity. As required by German law the dump has to be secured (by supplying sufficient cover against precipitation and collecting dump gases), entailing further operation of the site for another 30 years minimum. The operator of the dump, the “Bergische Abfallwirtschaftsverein” decided to explore possibilities to use the site of the dump for a future oriented project within the larger regional effort “Gardens of Technology” within the “Regionale 2010” program. The goal of this particular project at the site of the Leppe dump, called “:metabolon”, is to create an innovative industrial pilot park for technologies based on waste streams from society and agriculture.

3. Base for scenario development

As a first step scenarios for the immediate future development using status quo operating units as a core will be developed in this paper. They are based on current market prices for products, including heat. The goal of this analysis is to investigate possible changes and additions to the core installations at the Leppe that may be implemented within the next couple of years, acting as a nucleus for further development in the direction of a pilot park for waste and renewable resource utilisation.

Keeping in mind the general task of finding solutions that may be implemented immediately, the analysis only involves tried and tested technologies as well as resources that are either already available or may be mobilised around the site quickly. The list of additional resources therefore encompasses wood (as the site is surrounded by considerable forests), used wood (as this resource is available at the site in large quantities) and direct solar radiation (as the site offers the possibility for installing photovoltaics as well as thermal solar panels on its ample area). Possible products/services included in the analysis were electricity, heat, cooling (driven by off-heat via absorption cooling machines), compost/fertilizer, wood pellets, gas to a gas grid and gas for transportation purposes (mainly to be used in the trucks of the waste company itself). Technologies employed in the study encompassed (besides existing technologies like anaerobic digestion and collection of dump gas) wood and waste wood furnaces, organic rankine cycles (ORC), gas cleaning, absorption cooling machines, wood pelettising (from fresh wood only), photovoltaics and thermal solar panels. For some resources limitations for the supply were introduced. This was true for waste wood (limited to the current amount) and the area available to PV and solar thermal panels (limited to 1 ha).

4. Scenario results and general recommandations

4.1 Scenario results

For the sake of a clearer picture on future chances and challenges a number of scenarios were developed with some of them discussed here.

A first scenario operated with current prices for all products and services. The structure based on this assumption may be seen in fig. 2.

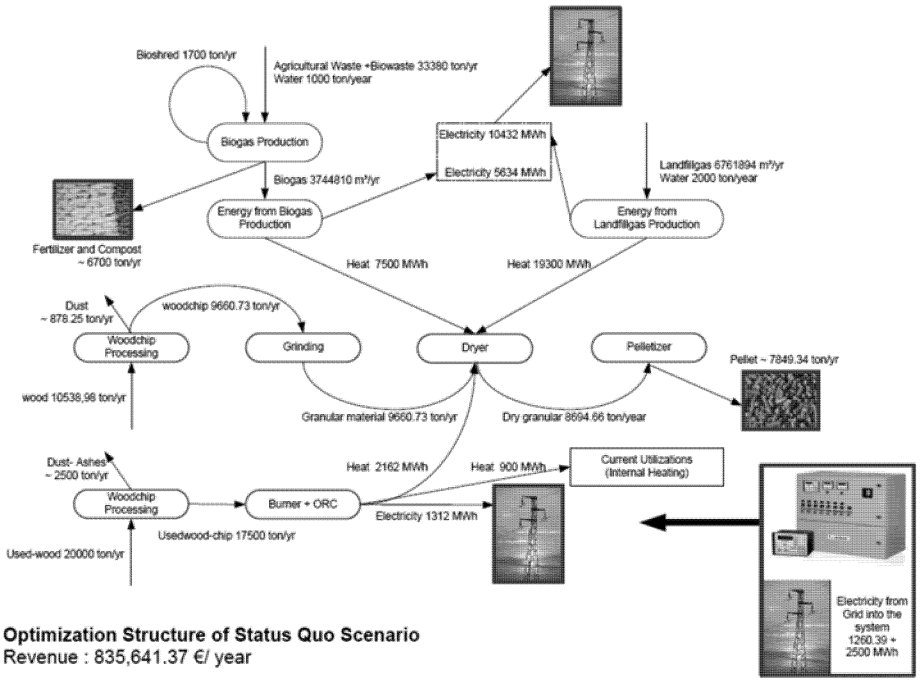

Fig. 2: Diagram of Optimization Result on Current Price Scenario

Biogas production and landfill gas as existing units will operate even we introduce the new technology into maximal structure. Fresh-wood and used-wood as new raw material will be included into the system. Used wood will be utilised in a biomass furnace with an ORC to generate heat and (additional) electricity. Fresh wood will be utilised in a pelettising operation, using off-heat from the biogas and dump gas motors. Fertilizer will be generated from the biogas unit.

Leading profit contribution (41%) in this scenario is given from pellets production. It is very interested that overall electricity production, including from ORC, only supplies 33% to the profit. It shows that local heat integration (for the pellets production) plays very important role.

Other scenarios included changes in the price of gas to the grid. Using a price of 0,52 €/m³ for (cleaned) gas to the grid, the structure changes dramatically. In this case it becomes more profitable to inject the gas into the gas grid than to supply electricity to the electricity grid. In this case the off-heat from the gas motors will not be available anymore. The only source of (waste) heat therefore will be the waste wood burner with the ORC (which is the only source of extra electricity, too). Pellets production in this case will be reduced dramatically as it is bound to low price heat for drying fresh wood. The profit in this case however is larger than in the base scenario with current prices.

Using gas for transportation requires almost the same structure as supplying it to the grid. The structure in this case however includes the investment and operation of a gas filling station on the site. This option becomes viable at a price of gas for transportation of 1.12 €/m³. Table 1 compares key elements of the scenarios discussed here.

Table 1: Comparison Product of Optimization among Scenarios

Scenario	Product				
	Fertilizer-Compost ton/year	Pellets ton/year	Electricity to Grid MWh	Revenue €/year	Remark
Current prices	6700	7850	16000	836000	No Change on Price
Biogas to Grid	6700 r	586 r	1300	850000	Price gas to grid 0.52€/m³
Biogas to Fuel	6700	586	1300	870000	Price of Gas fuel 1.12€/m³

5. General results

The comprehensive scenario calculations done in this project (only three of the scenarios were discussed here as examples) revealed some interesting general results:

- At current prices large scale photovoltaic installations are not particularly interesting. They did never show up in any scenario optimisation.
- Cooling may be a valuable alternative for the use of off-heat, depending on the price that can be achieved for cooling services. This depends very much on the logistical situation of any site, regarding the availability of goods to be cooled as well as the possibilities to ship goods from and to the site. In this particular case, cooling would compete with the production of pellets for off heat. The marketable cooling load would reduce the pellets production.
- Solar heating is only viable for sites that have a high heat demand. Sites such as at Leppe that have a heat surplus from other processes (and these are the majority) are usually not predestined for large scale solar heating installations.
- Providing (bio) gas for grid and transportation may become more interesting as concerns about global warming on the one hand and concerns about security of supply on the other hand intensify. This would have important consequences for de-central industrial parks as biogas units will no longer be available as sources of process heat.

6. Conclusions

Local industrial centre in the future will play very significant role on renewable resource use, environmental protection and also to re-structure industry. Process Network Synthesis (PNS) can be used as important methodology to generate optimized scenarios for this development. Optimization on several scenarios of case study shows the local situation is a key factor to promote renewable energy to local industrial centre. Therefore, PNS may become a major instrument for the policy on regional and local level, showing energy integration strategies as well as trade-offs between different technological development lines.

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