

BIOPOL



www.biorefinery.nl/biopol

Project no.: 44336 – FP6-2005-SSP-5A

Project acronym: BIOPOL

Project title:

Assessment of BIOrefinery concepts and the implications for agricultural and forestry POLicy

Instrument: **Specific Support Action**

Thematic Priority: Scientific Support to Policies (SSP)



the international institute for industrial environmental economics
Lund University, Sweden



Box 196, 221 00 Lund, Sweden. Telephone: +46 40 222 0200 Fax: +46 40 222 0210 Web: www.iiiee.org



D 2.2.3: Report with the assessment results concerning the impact of biorefineries on rural development, employment and environment

Due date of deliverable: September 2008

Actual submission date: April 2009

Start date of project: 01.03.2007

Duration: 26 months

Organisation name of lead contractor for this deliverable: EC BREC

Version: 2.0

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Content

1	Introduction	3
2	Methodology	6
3	Summary of survey on socio-economic impacts of biorefinery operations.....	7
3.1	Companies' overview.....	7
3.2	Similarities and differences for analysed case studies	9
3.2.1	<i>Biorefineries at the existing facilities</i>	9
3.2.2	<i>Sustainability as the driver of setting up of a biorefinery</i>	9
3.2.3	<i>Involvement of local communities</i>	10
3.2.4	<i>Direct and indirect employment effects</i>	10
3.2.5	<i>Raw material origin</i>	11
3.2.6	<i>Indirect impacts on rural areas</i>	11
3.2.7	<i>Waste strains as raw materials</i>	12
3.2.8	<i>Sustainable water management</i>	13
3.3	Impact Analysis.....	13
3.3.1	<i>Biorefinery impact on regional development</i>	14
3.3.2	<i>Biorefinery impact on employment issues</i>	17
3.3.3	<i>Biorefinery impact on environment</i>	21
4	Biorefinery concept diffusion factors.....	27
4.1	Future developments	28
4.2	Main findings - summary	29
5	Acknowledgements	29
6	References	30
	Appendix A Questionnaire for assessment of impact	32

1 Introduction

Biorefining is a worldwide growing technology. Biorefineries use biotechnological methods and processes that ultimately may make it possible to partially produce range of goods such as sports shoes, CDs or kitchen surfaces using crops. Biotechnology is being applied for novel uses other than food. For example, oilseed can be modified to produce fatty acids for detergents, substitute fuels and petrochemicals. Establishment of biorefineries would not be possible without development in the 'biotechnology' sector. The investments and economic output of all types of applied biotechnologies form what has been described as **the biobased economy**. The question is arising about impacts of biorefineries on regional development, employment and environment. This report is showing some impacts resulting from analysis of interviews conducted in 8 existing biorefineries or enterprises close to biorefinery concepts.

Task 2.2 within WP2. *Assessment of social and environmental implications* (leader: UNIWEH) deals with the assessment of social and environmental implications, in particular with the assessment of the impact of biorefineries on rural development, employment and environment. This report is based on the relevant survey and desk research plus conclusions from the **Parallel session on Sustainability of Biorefineries at BioreFuture 2009** held on 30th March 2009 in Brussels. The aim of the Session on Sustainability was to disseminate information gathered from the interviews with representatives of the biorefinery sector. The session was also a good opportunity for the participants to make contributions in the discussion. Their opinions are also reflected in this report.

In the survey of industry acceptance (D 2.1.3) of biorefinery concepts, industry representatives amongst other answers, delivered their opinion on whether they think the biorefinery concept is a promising concept most respondents answered 'yes' and with regard to the subsequent results of our survey under WP2, it is interesting to know that:

1. Almost 80% of respondents denied that the biorefinery concept is not implement able in their company
2. Over 80% agreed to the statement that 'biorefinery concept' is characterized by high environmental performance'

The first statement (1) holds true with regard to most to our 'interview-based' part of the task where the following companies have been the subject of our research:

- Chemrec biorefinery in Piteå, Sweden
- British Sugar, Wissington, Norfolk, UK
- Greenmills/Amsterdam, The Netherlands
- BioMCN, The Netherlands
- Domsjö Fabriker in Örnsköldsvik, Sweden
- Biowert, Brensbach, Germany
- Nedalco, The Netherlands
- Cargill/Cerestar Trafford Park, Manchester, UK

Most of these biorefineries have evolved from the existing industrial plants, whereas only 2 were greenfield investments(Greenmills, Biowert).

The second statement (2) was also confirmed by our survey of the above eight case studies. Since we already know that for the most part of the industry biorefineries are associated with

higher environmental performance which means positive impact on environment, then it was interesting to validate this thesis by checking the environmental implications of existing biorefineries (case studies).

Our survey under WP2 satisfies this requirement. Nevertheless it goes beyond just analyzing the impacts on environment. Namely Task 2.2 deals also with the assessment of social implications, in particular with the assessment of the impact of biorefineries on rural development and employment. The objective of this task was to analyze the specific effects on rural development, employment, and the environment. In general the criteria we chose for impact assessment very often fit in very tightly to the criteria of sustainability. Therefore our analysis aims to provide answer to what extent a given biorefinery is sustainable in its operations.

Altogether the interviews conducted, desk research and the analysis of particular impacts of biorefineries on environment, regional development and employment resulted in several conclusions that can be drawn. Nevertheless in many cases the conclusions shall be treated rather as questions which could be answered convincingly only in the course of further detailed research.

The desk research continued after concluding of interviews, enables us to formulate the following theses:

- Transition of existing plants to biorefineries usually helps in the maintenance of current jobs.
- New labor-saving technologies in biorefineries change the manufacturing processes and may cause job redundancies. Can those be offset by the more jobs in the non-manufacturing sectors i.e. supply-chain or business services ?
- Effects on employment in agriculture are mostly positive but also depend on the geographic supply chain structure.
- Biorefineries are catalyst for innovation in the economy: they strengthen job creation effects in the industry and especially R& D area.
- Biorefineries constitute a more environment friendly proposition for various industries: because of their lower carbon footprint, enhanced energy efficiency and mostly zero-waste production processes
- In cases where biorefinery is at the existing facility – the impacts are less visible, but on the other hand – the impacts are heavily dependent on the scale of production.
- Product-derived positive impacts on environment (i.e. due to the low carbon footprint of new fuels) are usually seen in places where those products are mostly applied and not necessarily in the region
- Biorefineries help in the economic utilization of previously unwanted or low-value feedstock
- The existing biorefineries apply the most advanced technologies in terms of energy efficiency and waste processing because the technology providers/project developers want them to showcase their inventions with the purpose of further commercial deployment worldwide.
- Sometimes the biorefineries are not invested optimally because of the learning-curve.

In order to summarize the research data we prepared the Table 1 which highlights the intensity of particular impacts for each refinery. The intensity of a given impact has been expressed graphically either through ‘+’ or ‘-’. Nevertheless the above estimation is a subjective view of the authors and shall not by any means constitute or be viewed as a way of auditing of the biorefineries.

For environment we have taken the following criteria into account:

Biopol - Deliverable 2.2.3

- carbon footprint GHG emissions (plant and/or product)
- water use
- handling residues
- reuse of co-products as a feedstock/energy carrier
- process improvements i.e. for better energy efficiency

Although covered by our analysis, the below classification does not include the potential effects of the land use change (LUC) due to the insufficient data. For rural & regional development as well as employment we have taken the following criteria into account:

- Job creation in the agriculture, industry and R&D
- Local vs. abroad job creation
- Strengthening of local vs. overseas industries
- Local vs. overseas feedstock base
- Impacts of new technologies introduced

Table 1 Summary of particular impacts for each case study

Biorefinery	Impact Categories & Intensity of impacts		
	Rural & regional development	Employment	Environment
Chemrec	+	+++	+++
British Sugar	+++	++	+++
Greenmills	++	+ -	++
BioMCN	+	++	+++
Domsjö	++	++	++
Biowert	++	+++	++
Nedalco	+	+	+
Cargill/Cerestar	++	-	+

Table 2 Brief description of the eight case studies impacts on the rural development, employment and environment.

Biorefinery	Impact categories & intensity of impacts		
	Rural & regional development	Employment	Environment
Chemrec	<ul style="list-style-type: none"> • Supports the local pulp & paper industry. • Feedstock always sourced from the surrounding region, forests. 	<ul style="list-style-type: none"> • Unknown 	<ul style="list-style-type: none"> • Full implementation of the technology in all Swedish pulp mills would yield about 6,000,000 tons of CO2 reduction per year (~10% of current Swedish CO2 emissions), and supply 25% of current automotive fuel consumption in Sweden.
British Sugar	<ul style="list-style-type: none"> • The local workforce and local economy will benefit if British Sugar can stay globally competitive • Is a major local employer. • Renewable energy industry will benefit from the learning experience. 	<ul style="list-style-type: none"> • Keeps farmers able to grow sugar beet in the region. • Farmers will have greater diversity and more resilience for their produce. • Only some research in UK as most technology has been outsourced or purchased. 	<ul style="list-style-type: none"> • British Sugar's bioethanol is certified at 71% less greenhouse gas emissions than gasoline (residual sugar from betaine production is fermented to bioethanol) • CO2 and waste heat are used to grow tomatoes.
Greenmills	<ul style="list-style-type: none"> • Five new enterprises co-operating will benefit from the existence of the plant. 	<ul style="list-style-type: none"> • No contracts with farmers. 	<ul style="list-style-type: none"> • Lower emissions reduce the carbon footprint of biofuels.

Biopol - Deliverable 2.2.3

BioMCN	<ul style="list-style-type: none"> • Revival of a former natural gas-to-methanol plant. • Creation of a biorefinery complex. 	<ul style="list-style-type: none"> • Maintenance of 100 jobs (direct employees of the former natural gas-to-methanol plant). • Overall boost in indirect employment (supply chain and clients) could ultimately amount to 4-5,000 jobs. 	<ul style="list-style-type: none"> • Low-carbon fuels will be possible, including: biomethanol, biodiesel, bio-DME, biogas, biopower and heat, bio-LPG, bio-coal.
Domsjö	<ul style="list-style-type: none"> • Has influence on business investment and location decisions of other companies/industries. • Local feedstock base: 70% local forests, 30% imported. 	<ul style="list-style-type: none"> • Gradual change to more local employment anticipated. 	<ul style="list-style-type: none"> • Considered to be an efficient use of natural resources.
Biowert	<ul style="list-style-type: none"> • Strengthens market for injection moulding companies in the region, which buy bio-granulate and produce bioplastics. 	<ul style="list-style-type: none"> • Strengthens farmers' jobs through contracting of raw materials from 7 farmers within radius of 13 km. 	<ul style="list-style-type: none"> • Energetically neutral process thanks to integration with with biogas plant. • Bio-plastics recyclable but not biodegradable.
Nedalco	<ul style="list-style-type: none"> • Unknown 	<ul style="list-style-type: none"> • Not significant locally as materials are mostly shipped in. 	<ul style="list-style-type: none"> • Feedstock is lignocellulosic waste from wheat processing, straw or even wood residue.
Cargill/ Cerestar	<ul style="list-style-type: none"> • Has contributed to the continuing regeneration of an old industrial site. 	<ul style="list-style-type: none"> • Supports wheat growing and the wheat price in the UK. • Agriculture and food industry benefit the most from it. • The move to wheat feedstock from corn caused a loss of jobs at a plant that was shut near London. 	<ul style="list-style-type: none"> • 2000-2007 (under UK Climate Change Levy) reduced energy input by 33% for a tonne of glucose syrup. • Possible negative effect is the greater number of road deliveries of wheat compared to corn shipments, but cost-effective prevailed.

2 Methodology

Task 2.2 deals with the assessment of social and environmental implications, in particular with the assessment of the biorefineries impact on rural development, employment and environment. The objective of this task was to analyze the specific effects on rural development, employment and the environment in comparison to traditionally used approaches or products.

In each participating country (Germany, Greece, Netherlands, Poland, UK) partners were asked to help in selection of the adequate plants which approach the biorefinery concepts. Altogether there were 8 case studies chosen for interview and further analysis. This report aims to summarize the outcomes of the interviews conducted and the desk research.

Following subtasks were realised within the task 2.2:

- Development of a draft version of a standardized interview guide
The interview guide (see Annex 1) contains following sections:
 - I. General questions about the biorefinery in focus
 - II. Economic drivers & net economic impact of biorefinery
 - III. Impact on job market and community welfare
 - IV. Effects on Land & Property Value
 - V. Biodiversity & Environment

- VI. Energy efficiency
- VII. Other impacts

- Definition of case studies in terms of region, feedstock, biorefinery type, etc.
- Development of the interview guide (see Annex 1) taking into account mathematical calculations of different scenarios concerning the diffusion of biorefinery concept
- Choice of adequate plants/regions, experts, and stakeholders
- To make appointments with interviewees
- Realisation of the interviews
- Parallel desk research activities with relevance to the case studies

3 Summary of survey on socio-economic impacts of biorefinery operations

This chapter contains conclusions that can be drawn based on interviews and desk research, but also generates some questions which could be answered only in the course of further research. Especially similarities (i.e. similar impact on environment) and differences (different supply chains, feedstock and different effects on employment) for analyzed 8 case studies are highlighted in this chapter.

3.1 Companies' overview

The classification of biorefinery types introduced in WP1 by prof. B.Kamm and used within BIOPOL consortium consists of the following types:

1. Whole Crop Biorefinery (dry mill)
2. Green Biorefinery
3. Lignocellulosic Feedstock Biorefinery
4. The Two-Platform Concept

According to the above classification and adding three more criteria: (1) scale up stage (pilot, demo, full scale¹), (2) new or at the existing plant, (3) biomass type used, we can classify our case studies in the following way (Table 3).

Table 3 Brief description of 8 case studies

Biorefinery	biorefinery type	scale up stage	new / existing	biomass type used
Chemrec	Lignocellulosic Feedstock Biorefinery	demo	Existing /waste industrial plant/	Waste from pulp process ²
British Sugar	The Two-Platform Concept	full scale	Existing /sugar industrial plant/	Sugar beet
Greenmills	Other Type	full scale ³	New /Waste industrial plant/	Frying fat, food waste.
BioMCN	The Two-Platform	pilot to full-	Existing /Waste	Glycerin waste from

¹ The whole-crop biorefineries are very large (e.g. 1 mln. tons/year feedstock input), whereas green biorefineries are smaller e.g. 5-10 thousand tons/year.

² Actually it is syngas from black liquor gasification, from pulp and paper mill. Chemrec is helping pulp and paper mills transform into Biorefineries with a unique, proprietary black liquor gasification technology

³ 100 thousand a year (at least 100 ml. liters)

	Concept	scale ⁴	industrial plant/	biodiesel plants
Domsjö	Lignocellulosic Feedstock Biorefinery	demo	Existing /Waste industrial plant/	Wood 1,5 mln m3 into black liquor
Biowert	Green Biorefinery	full scale	New	Biomass /grass, lucerne/
Nedcalco	The Two-Platform Concept	full scale	Existing /starch industrial plant/	Starch and starch derivatives (by product of Cargill)
Cargill/ Cerestar	The Two-Platform Concept	full scale	Existing /starch industrial plant/	Starch (by-product of wheat processing)

Another criterion for classification of case studies could be ‘the product type manufactured’ as presented in the Table 4;

Table 4

Biorefinery	Types of biobased products manufactured
Chemrec	Electricity, ‘green’ automotive fuels
British Sugar	Bioethanol – 70 million liters, Sugar , Tomatoes , Stones recovered from crop, used for aggregate , Topsoil from sugar on beet, Betaine
Greenmills	Biodiesel (200 million liter/year), bioethanol (5 million liter/year), biogas (25 million m ³ /year)
BioMCN	Bio-methanol
Domsjö	Specialty cellulose, bioethanol, carbon dioxide, methane, Lignosulfonates for feed industry, Soil conditioners
Biowert	Insulation material from cellulose - AgriCell BW AgriPlast BW (40-45% cellulose fibers and 55 - 60% polyethylene or polypropylene) Protein component – AgriProt BW Natural fertilizer – AgriFer BW
Nedcalco	Bioethanol 95%: 400000 hectoliters/year (food quality), mauvais, fusel oil Rest material is returned to Cargill → and used for feed? CO ₂ → last year plans were made to send this to greenhouses
Cargill/Cerestar	Bioethanol

On basis of 8 case studies interviews analysis following general remarks can be formulated:

- Most facilities interviewed were in the pilot phase (or before major scale-up). The only exception here was the facility of Biowert.
- All biorefineries assumed the necessity of a pilot-phase (construction of pilot plants) as a way to showcase and justify the scale-up later. However, major differences regarding the capacity of such pilot plants could be observed.
- Almost all biorefineries were already placing some of their products on the transportation fuel market.

⁴ The feasibility of the glycerin-to-methanol process was demonstrated on a pilot plant scale in March 2008.

- Almost all biorefineries with fuel market outreach were planning introduction of 2nd generation biofuels.
- Biorefinery activities in all cases are not negatively influencing food production (at local level, at national level or at global level)

3.2 Similarities and differences for analysed case studies

3.2.1 Biorefineries at the existing facilities

As mentioned above, biorefineries usually are set up at the existing facilities (6 of 8 cases). Only Biowert and Greenmills – greenfield ones. This might be due to the fact that biorefineries are still risky investment and the learning curve is less costly when they are established at the existing plants (i.e. by utilizing current processing infrastructure). Since biorefineries are usually set up at the existing facilities, also the socio-economic impacts are less visible or harder to measure than in case of the setup of a new greenfield facility.

3.2.2 Sustainability as the driver of setting up of a biorefinery

The impact on environment (and sustainability) plays an important role as to whether the biorefinery shall be established or not. It is mainly due to the fact that biorefinery products can achieve competitive advantage in the long term so the investors/operators want to see their benefits through their products' environmental excellence. Nevertheless **the bottom line is the economics**, the investors want to capture market opportunity employing biorefinery processes. On the other side the environmental legislation is somehow a driver too, at least for some products i.e. biofuels as it is in case of RFTO obligation in UK. The below Table 5 highlights some motivations for the launch of biorefineries.

Table 5

Biorefinery	Motivations for the launch of biorefineries:	
	Economics	Environment
Chemrec		to provide more environmentally friendly way of utilisation of spent cooking liquors from pulping processes
British Sugar	to effectively address political reforms: Economics is a big factor due to the EU sugar reforms, so British Sugar needed a new outlet for surplus sugar beet . But bioethanol would not be viable without the biofuels incentives provided by the RTFO; these are crucial to the economic success.	
BioMCN	to revive the existing facility natural gas – to – metanol facility (production from natural gas became too expensive)	to provide more environmentally friendly way of utilisation of waste glycerine from biodiesel production (transesterification of vegetable oils).
Domsjö	to increase overall production and	

	availability	
Biowert	to make an economic use of abundant resources: wet biomass, grass (maximum. can handle grass harvested from 600-900 hectares)	
Cargill/Cerestar	to improve the plant economics: wheat is now 20% cheaper than maize.	

3.2.3 Involvement of local communities

Most biorefineries are at the scaling-up process so they want to concentrate on the capacity building. They rather do not want to put energy now in managing of a diversified stakeholders' structure i.e. as it could be the case when local entrepreneurs or even farmers would be invited to purchase capital shares in a biorefinery. Nevertheless for future investment, biorefineries may encourage such participation (Biowert) to strengthen bonds with local community. On the other side the raw materials supply chain sometimes make it unnecessary to build close relations with farmers at least not for the time being (i.e. BioMCN).

Besides, most biorefineries (= those set up at the existing facilities), have already have their integrated environmental permits for a given location so they actually do not need more consultation work to be done with local communities as regards environmental impacts (i.e. noise, bad smell etc.)

3.2.4 Direct and indirect employment effects

We can observe that both direct and indirect employment effects are existing in case of greenfield biorefineries. Additionally they activate local labour in the construction phase which on average can take as long as 12 months. On the other hand mostly indirect employment effects are observed in case of biorefineries built at the existing facilities. Indirect Impact on employment is hard to measure, especially for biorefineries at the existing facilities, since biorefining usually utilizes/involves the same supply chain organisation and only residues are handled more efficiently thanks to addition of biorefining (cases of Nedalco, British Sugar and Cargill). Nevertheless the addition of biorefining helps in the maintenance of current jobs (i.e. jobs that could be lost due to the sugar reform in the EU). Anyway, we should be cautious in assessing indirect impacts. The presented results are only rough extrapolations based on some assumption available (indicator from Ecofys study). The employment effects of the case studies are summarized in the **Table 6**.

Table 6

Biorefinery	Direct	Indirect
BioMCN	100	<i>1 job is created per each 1000 ton of newly installed processing capacity according to the study of Ecofys</i>
Domsjö	340	

Biowert	7-9 (3-shifts)	
Greenmills	200	

3.2.5 Raw material origin

Our survey showed that utilization of local biomass depends on biorefinery localization (sea access or not). For example: in BioMCN – with nearby port, mostly imported feedstock is preferred. The explanation to this is clear: cost of transporting 1 tone of biomass from Vienna to Groningen is the same as from Singapore to Groningen with sea vessel. The classification of biorefineries according to origin of raw materials is presented in the Table 7.

Table 7

Biorefinery	Local biomass (yes / no)	Type of biomass
BioMCN	No	Glycerin from biodiesel plants
Domsjö	Yes: (70%)	Wood from forests
Biowert	Yes	Grass and municipal wastes
Nedalco	No: Yes:	Waste from wheat processing, Straw/wood remains
Chemrec	Yes:	Wood from forests
BritishSugar	Yes:	Sugar beet (UK's entire crop).
Greenmills	No	Waste oils
Cargill/ Cerestar	Yes:	Wheat

3.2.6 Indirect impacts on rural areas

Indirect impacts of biorefineries on rural areas can be observed in cases when they manufacture sustainable resources for agriculture. These materials and their possible impacts are summarized in the Table 8 below.

Table 8

Biorefinery	Examples of biobased products for agriculture	Potential effects of their usage
Domsjö	Lignosulfonates for feed industry, Soil conditioners	reduction of impacts of livestock husbandry on the environment less nitrate in drinking water

		in rural areas and better health of people living in rural areas.
Biowert	Natural fertilizer – AgriFer BW Protein component – AgriProt BW	reduction of impacts of livestock husbandry on the environment better health for humans due to nature-based food additives
British Sugar	Betaine (separated from the sugar) as aquaculture feed. Residues as high protein animal feed pellets. Lime from purification as natural fertilizer	Less nitrate in drinking water in rural areas and better health of people living in rural areas.

Natural fertilizers are especially important for sustainable production in agriculture. In Europe farmers tend to use intensive methods of crop cultivation. Therefore concentration of pollutants may reach high levels. This is a concern especially in case of groundwater (-> drinking water). Nevertheless, there is still some doubt whether usage of biomass-derived fertilizer can really crowd out the usage of synthetic fertilizer. Also, the intense cultivation of biomass might actually increase the usage of synthetic fertilizer, causing more nitrogen run-off to groundwater.

3.2.7 Waste strains as raw materials

Most of the biorefineries in focus share the same feature – they are using waste materials as their major feedstock. (see Table 9).

Table 9

Biorefinery	Types of waste strains used as feedstock
Chemrec	black liquors from pulping processes
Domsjö	black liquors from pulping processes
BioMCN	unwanted glycerine
Greenmills	waste frying oil
Nedalco:	lignocellulosic waste of wheat, wood & straw
British Sugar	the leftover sugar from betaine production is fermented to bioethanol

Waste strains are becoming the preferred feedstock for biorefineries, because biorefineries are aware of the fact that the “feedstock price” can be one potential for conflicts between the actors of the value chain, since industry needs moderate raw material prices allowing the production of competitive products whereas the agricultural sector wants to realize high farm incomes. Therefore biorefineries tend to rely on waste strains rather than pure agricultural products.

3.2.8 Sustainable water management

Water use minimization is important just when we look at several facts:

- Water scarcity is occurring in at least 17 % of Europe's area
- Chemicals and petroleum industries are responsible for 50% of all water use by manufacturing industry, and paper and food processing for the remaining consumption

Table 10 below highlights the ways in which some biorefineries realize their sustainable water management.

Table 10

Biorefinery	Way of water use minimization
BioMCN	cooling of power plant by sea water
Nedalco	Cargill provides water recycled from its own processes to the Nedalco plant. After use the process water from Nedalco is fed back to Cargill's water recycling plant

3.3 Impact Analysis

When we talk about impacts of biorefinery's operations (or any industrial plant) we tend to think to what extent is a given biorefinery sustainable in its operations or whether it is sustainable at all. A sustainable process does not only mean that its production feedstock base does not compete with food crops. Also the term 'sustainable' does not only mean: acting in the environment friendly manner. Its meaning is much broader because for a process to be sustainable means it has to meet certain social and economical criteria.

Biorefinery to be called sustainable has to fit into the definition of 'sustainable development'. **'Sustainable development'** is taking place when, it "meets the needs of the present without compromising the ability of future generations to meet their own needs" - *Brundtland Commission*. The field of sustainable development can be conceptually broken into three constituent parts: environmental sustainability, economic sustainability and social-political sustainability.



The graphic above shows that a given industrial undertaking i.e. biorefinery theoretically can operate in a non-sustainable manner:

- is only economic (meets only economic standards)
- is only 'equitable' (meets only economic and social standards)

- is only viable (meets only economic and environmental standards)

Economics is a bottom line for operations of any industrial undertaking but as explained above is not enough to operate. Such an undertaking shall first of all be sustainable to the highest possible extent. Our survey was a trial of checking this ‘degree of sustainability’ amongst major biorefineries in Germany, Netherlands, Sweden and United Kingdom.

3.3.1 *Biorefinery impact on regional development*

The operations of the biorefineries in focus in most cases involve ‘white biotechnology’ and in some cases ‘green biotechnology’. One of the reasons is that as mentioned above ‘white biotechnology’ consumes less resources than traditional processes used to produce industrial goods thus adding to sustainability of production. Biotechnology makes it possible to process the biomass materials and achieve significant cost savings. In the opinion of Dr. Alfred Oberholz, Member of the Executive Board of Evonik. “chemistry from the field” has noteworthy advantages since many reaction pathways in nature are exemplary in every respect. For instance, the low energy requirements involved - or the high yields and the avoidance of unwanted by-products.

The utilisation of unwanted by-products and therefore their avoidance by biodiesel refineries was the bottom line for setting up of the BioMCN biorefinery, which buys this waste from very distant markets. Also the ability to utilise the spent cooking liquors from pulping processes was the bottom line in Chemrec biorefinery. Other cost savings brought by the introduction of biorefining can be an improved electricity yield (BLGCC system compared to recovery boilers in Chemrec). For Nedalco the main thing is to convert lignocellulosic waste from wheat processing, straw or even wood remains, using a patented yeast⁵ that they have developed themselves and that can convert xylose into bioethanol.

Another example (although not covered by interview) is in the field of skin care and cosmetics and the case of German industrial giant - Evonik. A team led by Dr. Tim Köhler is working on an improved production method for the sphingosine molecule, an important building block of the so-called ceramides, for which Evonik is already the world market leader. Until now, producing sphingo-sine-based ceramides has been extremely difficult, since a chemical process involving many stages was required. Now, a joint project from S2B Bio and the Consumer Specialties Business Unit has succeeded in decisively shortening this complicated path by employing the well-established yeast strains and, using modern biotechnological methods. The new manufacturing process not only offers significant cost advantages, but is also based on renewable raw materials.

The phenomenon we tried to analyze is the **net economic impact of the biorefinery**. The term ‘net’ refers to the difference between two possible scenarios for the economy:

- without biorefinery – this is the ‘do nothing’ scenario and
- with biorefinery – this is the proposed development scenario.

The most widely accepted methodology for determining the direct and indirect economic impacts of biorefinery diffusion is through the use of general equilibrium modeling (GEM).

⁵ *The modified Saccharomyces cerevisiae yeast is able to anaerobically ferment xylose as well as glucose.*

This includes positive flow-on (or ‘multiplier’) effects created by the additional investment and production following the expansion, as well as any offsetting impacts through ‘crowding out’ (or ‘displacement’) effects arising from increased competition for resources. Displacement effects can be particularly important, for example, if the economy is facing shortages and in locations where unemployment is very low.

In general, biorefineries have positive impact on other industries, however the remark from Nedalco that *not all jobs at Cargill were filled in from the pool of jobless people*, indicates that there might be some ‘displacement’ effect. To address this issue completely one would have to interview the representatives of other industries that look for the same resources as biorefineries (i.e. highly qualified staff for their labs etc.). The question would be then, whether biorefineries generate jobs for their target group at the expense of other companies (industries) ?

Nevertheless, for the economy it is always good that labour resources are shifted to sectors with highest innovation degree just as the biorefinery sector is.

Our survey showed that biorefineries are strengthening market position and job creation or their maintenance in companies which collaborate with them, i.e. injection moulding companies, which cooperate in development of bioplastic with Biowert. Another example is Chemrec biorefining technology which supports the pulp and paper industry, as the biorefinery technology is directly connected with this industry and therefore helping pulp and paper mills transform into biorefineries with a unique, proprietary black liquor gasification technology. Opening up new markets in sustainable, low-carbon chemicals and fuels will be a step-change in the industry.

In case of British Sugar’ plant in Wissington, the innovative approach has taken the factory beyond just sugar. The factory is now a major exporter of electricity and can extract other plant materials from the sugar beet. It operates the UK’s first fuel bioethanol plant and has the largest single salad tomato business alongside the main factory. The site has developed a strategy of continuous operation, using efficient and innovative processes which integrate to create a unique facility. Since British Sugar is a major local employer then the local workforce and local economy will benefit if British Sugar can stay competitive with international sugar producers by applying biorefining processes. Besides, the new renewable energy industry will benefit from the learning experience.

The operations of Greenmills’ biorefinery provides benefits to several other companies with whom it cooperates⁶

In case of Nedalco, there are a lot of synergies with neighbouring plants. By having industries located in the same geographic area and using each other’s by-products as feedstock, the use of resources can be optimized, costs can be lowered and the volume of materials entering the waste stream can be reduced. Cargill plant supplies Nedalco with around 10,000 metric tons of steam and a few hundred cubic meters of purified water per year for its processing needs.

In cases where feedstock is **completely or mostly sourced from the surrounding region** - biorefineries strengthen region by taxes and establishing market for agricultural production. Farmers have greater diversity and more resilience for their production. In the opinion of Dr.

⁶ Rotie, Noba, Tankstorage Amsterdam, Biodiesel Amsterdam, Tank and truck cleaning Amsterdam and Orgaworld

Arend Oetker, President of the Stifterverband für die Deutsche Wissenschaft industrial nations are facing a revolution in the fields that will **propel agriculture from its current peripheral existence to the forefront of innovation**. As producers of energy sources and raw materials, biomass and agricultural products farmers are thus becoming key pillars of technology for the 21st century

In case of such companies as BioMCN and Cargill who get their raw materials mostly by boat situation is different. But imports do not necessarily displace local production. In case of biorefineries which import their raw materials, there is question on how to distinguish or disaggregate the total value of annual imports in order to identify those "specific" imports that may displace local (national) production, or the extent to which this production is displaced. Certainly, some imports may have a marginal, short-term job-displacement effect by shifting domestic production labour to higher productivity, knowledge-based sectors of the economy where a given biorefinery country has a competitive advantage. In case of BioMCN most of the raw materials are sourced abroad and is assumed to be within the radius of 20.000 km which means also North and South America. Does this import actually displace domestic production and/or jobs in the Netherlands ?

Firstly, imports like this, namely BioMCN's feedstock – glycerin as a by-product - are "goods" that are in short supply in the Netherlands compared to the plant's capacity, which means they do not have a one-for-one job displacement effect.

Secondly, it should be noted that increased imports in this case:

- displace imports (of natural gas) from other countries and
- revive the profitability of production (production of methanol from natural gas became too expensive in the existing facility and could not compete with cheaper production based on flare gas from oil exploration sites, mainly outside of Europe).

These two arguments discount the claim that these imports cause any job loss in the methanol production facility in Delfzijl. In fact, many intermediate imports provide competitive inputs for local production, which may actually support rather than displace local production and local jobs⁷.

⁷ *The automotive industry is an excellent example of this phenomenon, i.e. U.S. imports Mexican automotive vehicles and parts, however those imported vehicles include a high percentage of components made in the United States. Of course in case of biorefinery such a two-way trade would exist only if the Netherlands exported 'biodiesel plants' to Brasil or Argentina and then sourced by-products of their manufacturing for its biorefinery. This would be an ideal scenario for enhancing of the efficiency and competitiveness of the Dutch industry.*

3.3.2 Biorefinery impact on employment issues

Firstly, in order to analyse the particular impacts, the biorefinery sector can not be viewed without taking into account of the current situation of particular economies in the countries where researched biorefineries are located, namely: UK, the Netherlands, Germany and Sweden. It is important to realize that, for example, **the net job creation effect** depends highly on the economic situation of the given country where a biorefinery is located. As demand for a company's product increases at home or abroad, the firm "creates" jobs by hiring more workers. However, if overall demand in the economy does not also increase, these new jobs will simply be shifted from other sectors of the economy, with no net gain in total employment.

Secondly, biorefineries' operations have potential to generate significant long-run increases in employment but at the same time can generate some (mostly short-term) displacement effects in the labour market i.e. the case of Cargill/Cerestar. The question is to what extent the overall boost in indirect employment: supply chain and clients (ultimately amounting to 4 to 5 thousand jobs in case of BioMCN) can be called the net job creation effect rather for the local economy than global economy .

The case studies of BioMCN and Cargill/Nedlco prompts us to take into account the differentiation between impacts on local (regional) labour market and global market. One can conclude that although it is true (after the study of Ecofys) that 1 job is created per each 1000 ton of newly installed biomass processing capacity, not all these jobs will be created locally and therefore job creation effect in a given region can be suppressed.

The different case than that of BioMCN is the supply chain of British Sugar. Three million tonnes of beet are produced within a 50 mile radius of the factory, which means that exactly 1,500 growers (the whole population of growers in UK) maintain their jobs thanks to continued operation of the biorefinery.

Another observation is that the term 'biorefinery' does not necessary mean a new plant (industrial object) but a biorefinery can also be when the well-established factory applies a new manufacturing process based on renewable raw materials. Therefore biorefinery does not have to be a completely new facility (new building etc.) but it can be a part of the existing facility. In such case socio-economic impacts are less visible than in case of the setup of a new industrial facility. For example less construction work is needed to establish such a biorefinery and therefore the impact on employment as regards construction workers in the preparation phase is almost negligible.

The example (*not covered by interview*) here can be the German industrial giant, Evonik which has been using biotechnological methods to produce amino acids for use as food additives or to manufacture cosmetics and pharmaceuticals. The company's extensive expertise has contributed to several successful Project Houses and even led to the founding of the S2B Bio, which was officially opened in March 2007 in Marl and is supported by both the European Union and the Federal State of North Rhine-Westphalia. The center currently employs 40 staff but this number is soon to increase to 50 or 60.

Our case survey showed that the job creation effects of biorefineries take place in the research & development area. In case of Biowert, the injection moulding companies are willing to run research work on bioplastics based on Biowert's Agriplast, which potentially will lead to

more jobs. Also the involvement of Hessen laboratory in the initial product development phase meant that the job places in the laboratory has been filled in thanks to the orders from biorefinery.

Biorefineries usually outsource research work in collaborations, e.g. they co-operate with universities and research institutions. In many cases however it does not mean the job is done locally because the technologies can be purchased from abroad i.e. from India, where R&D work has been undertaken beforehand and local staff has been employed (Cargill/Cerestar case).

Our survey showed that the transition to biorefining primarily secures jobs in the long-term perspective. The example is bio-methanol plant of BioMCN which guarantees the maintenance of 100 jobs that are direct employees of the former natural gas-to-methanol plant, otherwise those people would be dismissed. Also, the transportation sector benefits from biorefinery operations: for instance in Nedalco biorefinery, 6 to 7 truckloads of ethanol per day need to be transported throughout Europe, some of these truckers might live in the region. Sometimes the launch of biorefinery operations can lead to loss of jobs like in the case of Cargill/Cerestar.

Apart from biorefineries' effects on job creation in the R&D sector, there are indirect effects on employment in different sectors, e.g. in agriculture. This is happening in cases where feedstock is sourced from the surrounding region - biorefineries strengthen farmers' jobs through contracting of raw materials. Farmers have greater diversity and more resilience for their production.

Table 11 Direct and indirect employment effect in 8 case studies

Biorefinery	Direct employment	Indirect effects on employment		
		Agriculture	Industry	R & D
Chemrec	n.d.	Feedstock from the region - forests	It supports the pulp and paper industry, as the biorefinery technology is directly connected with this industry.	
British Sugar	330 in the season	It has kept farmers able to grow sugar beet in the region and the plant employs over 300 people in the high season. 35000 fort the whole group Three million tonnes of beet are produced within a 50 mile radius of the factory by some 1,500 growers. Up to 1,000 deliveries arrive at the factory six days a week, from mid September to March. Farmers will have greater diversity and more resilience for their produce. The local workforce and local economy will benefit if British Sugar can stay competitive with	The main advantage has been to learn about how the fuel market operates and to become a serious player in biofuels. This has meant that BP sees British Sugar as a serious partner with lots of knowledge of an industry outside its traditional base.	The research team is fairly small and the design and construction was undertaken in Glasgow, Coventry and India, not locally. Research Mostly outsourced in collaborations. The bioethanol plant technology was bought from India. The company has internal expertise in chemical engineering and food research. Some research in UK. Collaboration with UK universities.

Biopol - Deliverable 2.2.3

		international sugar producers; it is a major local employer. The new renewable energy industry will benefit from the learning experience.		
Greenmills		No contracts with farmers	5 new enterprises co-operating - Greenmills is a cooperation of Rotie, Noba, Tankstorage Amsterdam, Biodiesel Amsterdam, Tank and truck cleaning Amsterdam and Orgaworld. All of these benefit from the existence of the plant.	
BioMCN	100 Establishment of bio-methanol plant guaranteed the maintenance of 100 jobs (direct employees of the former natural gas-to-methanol plant), otherwise those people would be dismissed.	The overall boost in indirect employment (supply chain and clients) shall ultimately amount to 4 to 5 thousand jobs.	The overall boost in indirect employment (supply chain and clients) shall ultimately amount to 4 to 5 thousand jobs. Baseline indicator: the study of Ecofys contains data that 1 job is created per each 1000 ton of newly installed biomass processing capacity.	
Domsjö	340	feedstock base: 70% local forests and 30% import	Gradual change to more employment, has influence on business investment and location decisions of other companies/industries	10 for their entire business.
Biowert	4 people (2 shifts), 7-9 people (3-shifts)	No major change in the structure of labour market however, there is some impact on indirect employment Strengthens farmers' jobs through contracting of raw materials from 7 farmers within radius of 13 km. Also second income option for farmers' family: they can get second job in winter working on mounting of Agricell insulation material	Strengthens job creation in injection moulding companies, which buy bio-granulate / bioplastics 1 local co-operation with Injection moulding plant 3 km from Biowert other 6 companies – potential joint-ventures and offer development of bioplastics based on Biowert's AgriPlast Unemployed can get a job working on mounting of Agricell insulation	Injection moulding companies willing to run research work on bioplastics based on Biowert's Agriplast, Landeslabor Hessen – involvement in the initial product development phase

Biopol - Deliverable 2.2.3

			material in house.	
Nedalco	12	No significant local impact - Cargill gets materials mostly by boat and probably also from surrounding agricultural land.	No significant local impact 55000 people are living in Terneuzen of which 3800 in Sas van Gent. Around 888 people in Terneuzen are jobless, so 12 jobs could make a significant difference (though not all jobs at Cargill were filled in from the pool of jobless people). Compared to the total working force in the municipality of more than 14000 workers (=1/4 times 55000) it is not so much.	
Cargill/ Cerestar	300	Supports wheat growing and the wheat price in the UK. Agriculture and food industry benefit the most from it. .	It has contributed to the continuing regeneration of an old industrial site. <u>The move to wheat from corn caused a loss of jobs at a plant that was shut near London.</u>	Cargill is a multinational with major research facilities worldwide, but not at Trafford Park.

When a company or industry experiences large increases in productivity from increased automation, this labor-saving technology often results in a reduction of jobs in this company or sector as production becomes more efficient and capital shifts to more productive sectors of the economy. Nevertheless the growth in manufacturing output, however, contributes to strong overall job growth in non-manufacturing sectors because of the increased demand generated by the manufacturing sector for inputs from other sectors of the economy, such as business services. In all biorefineries innovative patented technologies were introduced (Table 12). Apart from the case of Cargill/Cerestar, the interviewees did not report any reduction of jobs resulting from this.

Table 12 Impact of innovative technologies introduction

Biorefinery	Innovative technologies introduced and effect	New markets opened
Chemrec	unique black liquor gasification technology - helps pulp and paper mills transform into biorefineries to minimize present risks in the manufacturing: no risk of smelt-water explosion	sustainable, low-carbon chemicals and fuels
British Sugar	efficient and innovative processes to extract other plant materials from the sugar beet, which are integrated to create a unique facility.	now major exporter of electricity can extract other plant materials from the sugar beet. UK's first fuel bioethanol plant the largest single salad tomato business alongside the main factory.
Greenmills	Technology for upgrading waste streams to biofuels	biodiesel and bioethanol markets
BioMCN	Between the bio-methanol plant and two energy generating biomass plants a torrefaction plant will be constructed, which will produce dry fuel pellets (gasifier for solid biomass to produce syngas)	biomethanol, biodiesel, bio-DME, biogas, biopower and heat, bio"LPG", bio-"coal"

Biopol - Deliverable 2.2.3

Domsjö	The investment in technology for production of products ancillary to specialty cellulose such as lignosulfonate. In doing this, Domsjö took the first step in developing into a complete biorefinery.	markets of special cellulose, lignosulfonates, bioethanol, carbon dioxide, methane
Biowert	Technology for conversion grass fibres into multiple products Further innovations on agenda are to select sugars in such a way as to be able to create bases for glue manufacturers	Insulation/Isolation material – AgriCell BW Bioplastics – AgriPlast BW Protein component – AgriProt BW Natural fertilizer – AgriFer BW Biogas for electricity and heat
Nedalco	Converting lignocellulosic waste from wheat processing, straw or even wood remains, using a patented yeast that they have developed themselves and that can convert xylose into bioethanol. The modified <i>Saccharomyces cerevisiae</i> yeast is able to anaerobically ferment xylose as well as glucose. The construction will start at the end of 2008 near the 1st plant of ROYAL NEDALCO. Additionally no explosion/fire risk exists anymore.	bioethanol market
Cargill/Cerestar	Conversion of an old plant: thermal insulation, fabricated cladding and structural cladding to several installations including 10,000m of pipe work, new acid conversion plant, fermentator plant, carbon treatment plant, vital wheat gluten drier, tank farms and a pipe work gantry.	Glucose syrup, Bran (cattle feed), Wheat gluten (vita wheat), Fermentables that cannot be turned into sugars are sold to Nedalco, who ferment them to drink-quality alcohol and return the silage to Cargill.

3.3.3 Biorefinery impact on environment

In case of **‘green biotechnology’** there is a great probability that its application will result in creation of sustainable production in agriculture i.e. by reducing the need for external application of pesticides or usage of natural fertilizers. This is specifically important in biorefineries in which agricultural products are the only resource i.e.:

- the case of British Sugar with its 7 million tonnes per year of sugar beet, constituting the UK’s entire crop.
- The case of Biowert where wet biomass, grass in particular is a main feedstock. Farmers who supply grass receive NPK bio-fertilizer in return. This circulation adds to sustainability of the whole production at Biowert.

3.3.3.1 Land Use Change (the iLUC factor)⁸

Land use change (LUC) may cause large GHG emissions. These impacts are associated with switching from one crop to another. For example corn farmers switches from corn/soy to corn/corn (direct process emissions). This results in less soy being delivered to the market and a rise of world soy prices. The environmental impacts could be that:

- Other soy farmers start using more inputs (fertilizers etc.) to increase yields (indirect process emissions)
- Additional land i.e. in Brazil is put into soy production which can result in indirect LUC emissions⁹

Therefore it is reasonable to check in which of the analyzed biorefineries the start of production incurred the farmers' switching from one crop to another (Table 5). For ecosystems with large carbon inventory e.g. forests, land conversion may be accompanied by a large carbon debt unless:

1. New biomass is used to displace GHG emissions and/or
2. Forest land is managed after conversion to minimize GHG emissions

It should be noted that in general grassland conversion does not generate any significant carbon debt. So grassland conversion 'debt' is zero. And actually if grass is put to the purpose of displacing GHGs (the case of Biowert) then the 'carbon debt' is even negative. Sometimes when biomass after land use change is put to displace GHG emissions and before this biomass was just being burned, then land use change can make the 'carbon debt' even negative.

Researchers have studied various scenarios and worked out a set of indicators as regards the payback time of carbon debt, for example:

- Baseline: Land use change (forest) and no mitigation of GHGs – 50 years of carbon debt payback time
- Harvesting biomass for biofuel production reduces payback time by 20 years (from about 50 to about 30 years)
- Harvesting biomass for paper production reduces payback time by 40 years (from about 50 to about 10 years)
- Applying best land management practices reduces the payback time by 25 years
- These approaches can be added to each other: thus the total savings could be as large as 40 + 25 years = 65 years, therefore giving a negative payback period.
- In real scenarios land use conversion will involve a mix of forest and grassland, therefore the "carbon debt" may in fact be zero or even negative.

⁸ The approach of the Oeko-Institut considers that *all* arable land used for *additional* (incremental) biomass feedstock production will induce indirect land use change risks due to displacement, but that the risk is small and can be ignored for feedstock produced from wastes and on degraded land and also on set-aside and idle land, as well as biomass feedstocks derived from intensified land use (higher yields). This is entirely consistent with approaches proposed in this review. The iLUC factor is derived by considering the *potential* release of GHG from land-use change caused by displacement to be a function of the land used to produce agro products *for export purpose* on the basis that only trade floks will be affected by displacement. The approach assumes countries increase feedstock production in response to global supply and demand. The additional land demand is estimated in a *deterministic* approach. Assumptions are made about the likely type of land-use change and emissions calculated using the regional land-use shares for agro commodities. From this, an average CO₂ emission factor per hectare of displaced land can be derived, and discounted over a time horizon of 20 years. A "full" iLUC factor would have to be applied if the risk of displacement is 100%. The authors suggest that in practice the risk will be lower for feedstock produced on idle land, through intensification of existing cultivation schemes and use of marginal land, etc. An *indicative* order of magnitude for the iLUC factor is given below, with a "minimum" assuming 25% of all non-zero risk biofuels are subject to the iLUC factor, "medium" meaning a 50% share of non-zero risk feedstocks, and "maximum" for the 75% level of the iLUC factor. Source: Fritsche (2008)

⁹ Source: O'Hare, M. Jan, 17, 2008, CARB LFCS Working Group 3. Greenhouse Gas Emissions from Indirect Land Use Change

Table 13 Impact of case studies on land use change

Biorefinery	land use change (yes/no)	Land use before	Land use now	Potential carbon debt	Other
Chemrec	No: feedstock is waste stream black liquor gasification, from pulp and paper mill Indirectly Possibly Yes: Wood from forests	Forest	Forest	negligible	
British Sugar	No: feedstock is sugar beet 7 million tonnes per year, the UK's entire crop.	Sugar beet	Sugar beet	negligible	
Greenmills	No: feedstock is food waste	not applicable	not applicable	none	
BioMCN	the feedstock is waste but in future also solid biomass.	not applicable	not applicable	none	
Domsjö	No: feedstock is waste stream black liquor gasification, from pulp and paper mill Indirectly Possibly Yes: Wood 1,5 Mm ³ converted to black liquor With gradual increase in volume 70% locally and 30% by import	Forest	Forest	negligible	Price increase of forest land due to high demand of wood
Biowert	Moderate or negligible: Feedstock is grass and agro-food industrial waste, Animals manure/sludge and other biodegradable substrates	grassland	grassland	negligible	
Nedalco	No: Feedstock is lignocellulosic waste from wheat processing, straw or even wood remains	not applicable	not applicable		
Cargill/Cerestar	Possibly yes: recently changed from corn (maize) to wheat	corn (maize) from France	wheat grown locally	to be analyzed	

3.3.3.2 Direct impacts on environment (other than LUC effects)

All interviewees reported that total **GHG emissions** compared to conventional production are lower. For example:

- full implementation of Chemrec technology in all Swedish pulp mills would yield about 6 000 000 tons of CO₂ reduction per year or roughly 10 % of current Swedish CO₂ emissions while supplying 25 % of current Swedish automotive fuel consumption. The technology has potential to globally provide motor fuels equivalent to over 45 billion litres/year of gasoline (12 billion gallons/year).

- British Sugar’s bioethanol is certified at 71% less greenhouse gas emissions than gasoline.

Operation of biorefineries does not require more **water**, in most cases process water requirements are met 100% internally either from the feedstock (Biowert, British Sugar) or necessary water is sourced from the sea (for cooling of power plant at BioMCN). A good example of synergy effects in the water management is Nedalco and Cargill: Cargill provides water that is recycled from its own processes to the Nedalco plant. After use the process water from Nedalco is fed back to Cargill’s water recycling plant for purification and re-use.

The appropriate **handling of residues** is a bottom line for any biorefinery, only methods and applications are different. For example in Wissington (BS) betaine is separated from the sugar and sold as aquaculture feed. Other residues from sugar beet processing are sold as high protein animal feed pellets, whereas lime from purification of sugar is sold to farmers. Additionally the leftover sugar from betaine production is fermented to bioethanol and CO₂ and waste heat is used to grow tomatoes. Milk of lime and CO₂ are used to make calcium carbonate or chalk for farming. CO₂, which is sent through a cleaning installation and for the moment released into the open air by a pipeline. For the future it is planned to store the CO₂ and supply it to customers, e.g. the planned greenhouse area near the plant. The Greenmills biorefinery upgrades waste streams to biofuels, whereas the rest material of the Royal Nedalco process is supplied to Cargill again by pipeline. Also Cargill supplies several hundred metric tons of ‘B’ quality starch - a by-product of its production process – per year to Nedalco for the production of potable alcohol.

Some biorefineries also use their residues for energy purposes. In Biowert, grass juice is fed to the biogas plant as a valuable substrate which enhances biogas yields. Residues after biogas fermentation are used as liquid fertilizer by farmers and scattered over crop fields. In Chemrec the system utilizes the syngas from the black liquor gasifier as feedstock for green electricity generation through combined CHP system with both gas and steam turbines.

Table 14 Direct impacts of 8 case studies on the environment

Biorefinery	Direct impacts on environment		
	GHG emissions (plant and/or product)	Water use	Handling residues
Chemrec	Lower: Full implementation of the technology in all Swedish pulp mills would yield about 6 000 000 tons of CO ₂ reduction per year or roughly 10 % of current Swedish CO ₂ emissions while supplying 25 % of current Swedish automotive fuel consumption.		
British Sugar	British Sugar’s bioethanol is certified at 71% less greenhouse gas emissions than gasoline. LCA impact is measured only for bioethanol. Use the RTFO reporting procedure (RFA methodology) http://www.lowcvp.org.uk/assets/reports/Summary%20of%20RTFO%20C&S%20reporting%20requirements.pdf Measures had be done with the	“Sugar beet is 70% water, so we’ve actually got about a million and a half tonnes of water being produced by Wissington a year, which keeps the local river going quite nicely.”	Betaine is separated from the sugar and sold as aquaculture feed. Residues from sugar beet processing are sold as high protein animal feed pellets. Lime from purification of sugar is sold to farmers.

Biopol - Deliverable 2.2.3

	help of an external organisation: North East Energy as consultants		
Greenmills		The usage of water is minimized.	The facility upgrades waste streams to biofuels .
BioMCN	Lower, reducing carbon footprint of biofuels	actually no significant water amounts are sourced from external network for the process, only water is needed for cooling of power plant, but this water is sourced from the sea.	
Domsjö	Lower		
Biowert	Lower: The plant is to undergo certification to prove the neutrality to environment and high degree of sustainability	process water requirements are met 100% internally	Residues (NPK bio-fertilizer) after biogas fermentation as liquid fertilizer is being picked up by farmers in return for grass and then scattered over crop fields
Nedalco	Lower: it is far more efficient to produce ethanol from this stream than to treat this stream as a waste stream	Yes, Cargill provides water that is recycled from its own processes to the Nedalco plant. After use the process water from Nedalco is fed back to Cargill's water recycling plant for purification and re-use. Moreover, the rest material of the Royal Nedalco process is supplied to Cargill again by pipeline. The material that is pumped back is very thick. To prevent the material from sticking on the wall of the pipeline they send a 'pig' (prop) through the pipeline each day.	The rest material of the Royal Nedalco process is supplied to Cargill again by pipeline. The material that is pumped back is very thick. To prevent the material from sticking on the wall of the pipeline they send a 'pig' (prop) through the pipeline each day
Cargill/Cerestar	involved in the EU ETS now, regularly audited by the regulator.	A wastewater treatment plant is currently being evaluated and may be installed.	If any co-products become available we will try to turn them into products.

3.3.3.3 Indirect impacts on environment

The indirect impact on environment can be observed when we look at improvements in material processing or maximization of electricity yields (minimization of heat losses). The most vivid examples are:

- 1. Chemrec** - dramatically improved electricity yield /BLGCC system compared to recovery boilers/ (at full scale unit)

2. **BioMCN** - downstream process (syngas to methanol) made more effective now due to the new technological feature: the process is performed without polluting of the reformer catalyst.
3. **Biowert** - Waste heat (warm water) from cooling of the aggregate is channeled to the central buffer for warm water which is for the common use both by the biogas facility and grass processing plant. The production process is energetically neutral thanks to integration with with biogas plant
4. **British Sugar:** the Wissington plant is >80% efficient in terms of energy production.

Our research indicated **that in plants where two or more technological processes has been combined, the increased yields, efficiency and lower costs could be achieved.** For example: (1) Chemrec: combining of black liquor gasification with a chemical synthesis plant for production of green automotive fuels, (2) Biowert: grass fibre processing & biogas production: grass juice fed to the biogas plant gives better yields than slurry and because it is easily available on site this feedstock stream generates no logistical costs.

Table 15 Indirect impacts of 8 case studies on the environment

Biorefinery	Indirect impacts on environment	
	Use of co-products from the process as a feedstock/energy carrier	Energy efficiency – process improvements
Chemrec	The system utilizes the syngas from the black liquor gasifier as feedstock for green electricity generation through combined cycle power generation incorporating both gas and steam turbines.	improved electricity yield /BLGCC system compared to recovery boilers/ (at full scale unit)
British Sugar	Yes, the leftover sugar from betaine production is fermented to bioethanol, CO ₂ is used to grow tomatoes, Waste heat is used to grow tomatoes, Milk of lime and CO ₂ are used to make calcium carbonate or chalk for farming	The Wissington plant is >80% efficient in terms of energy production.
Greenmills		
BioMCN		downstream process (syngas to methanol) made more effective now due to the new technological feature: the process is performed without polluting of the reformer catalyst. Tankers delivering the raw glycerin collect a return load of methanol, thus optimising the logistics in the chain.
Domsjö		Purchase of electricity.
Biowert	combining grass fiber processing & biogas production: grass juice fed to the biogas plant gives better yields than slurry & easily available on site – means no logistical costs	Waste heat (hot water) from cooling of the aggregate is channeled to the central buffer for warm water for the use by both: the biogas facility and grass processing plant. Energy neutral process thanks to integration with biogas plant Combining of black liquor gasification with a chemical synthesis plant for the sake of increased yields, efficiency and lower costs.
Nedalco	Waste stream from Cargill (which produces starch and starch derivatives) The plant of Sas	

	<p>van Gent produces alcohols (400.000 HI/y) from wheat liquefied at CARGILL plant Cargill supplies several hundred metric tons of 'B' quality starch - a by-product of its production process – per year to Nedalco for the production of alcohol. The product is provided through a pipeline, as such saving on transportation costs. It also supplies Nedalco with around 10,000 metric tons of steam and a few hundred cubic meters of purified water per year for its processing needs.</p>	
Cargill/Cerestar	<p>In future they may digest a waste water sludge if they have a waste water treatment plant, but it will not provide a huge amount of biogas.</p>	<p>4 CHP units. The heat is used mainly for glucose evaporation. The power is used for milling. Excess power is exported to the grid. Cargill have a European team that looks at all the plants and conducts pinch analyses to see where they can reduce energy consumption. They are now looking to incorporate heat recovery as the next step. They measure the <u>energy requirement for one tonne of glucose</u> syrup because it is difficult to allocate energy demand to all the different co-products. This will allow them to introduce improvement. Between 2000 and 2007, under the UK Climate Change Levy, they <u>reduced this figure by 33%</u>. It has now risen slightly as wheat requires more power for dry (instead of wet) grinding and milling. Possibly negative effect on environment: previously the corn was easier to bring in logistically 3 times per week, and the wheat requires <u>a lot of lorries daily</u>, but it is more cost-effective.</p>

4 Biorefinery concept diffusion factors

Diffusion of biorefinery concepts to a great extent depends on the marketability of the biobased products, feedstock price, crude oil price and available funding for pilot plants as to verify the technology before scaling-up. This funding may come from the state i.e. the case of Chemrec (100 MSEK Swedish national Black Liquor Gasification BLG-Program¹⁰ intended to remove hesitation from industry to adopt the new technology) or from private investment (the case of Biowert).

For private investors the economic indicators count the most, in particular the investment payback time (ROI) which heavily depends on the capacity utilisation. For example for Biowert plant, at capacity utilisation of 70%, – ROI is 6-8%, but with 90% - shall reach 8-

¹⁰ The BLG-Program was carried out in cooperation between industry, authorities, universities and institutions during the period 2004-2006. The BLG-Program comprised two parts, the erection and operation of the DP-1 plant and the carrying out of a dedicated R&D program with 8 subprojects.

12%. Our survey indicated also that usually in the pilot phase, some costs turn out to be unnecessary – but this is attributed to the learning curve

4.1 Future developments

In biorefineries which produce biomethanol even more focus will be on developing pathways to convert biomethanol as effectively as possible. Biomethanol has a lot of potential because:

- its molecule can be obtained from abundant feedstocks such as wood or straw using specialist microbes and on the other hand
- many microorganisms can metabolize this molecule with ease and thus manufacture a range of chemical compounds that are of interest to industry, for example, for the production of animal feed.

Judging from above, the biorefineries such as BioMCN have great perspectives. Although they usually produce biofuels (i.e. BioETBE) this can become the starting point for renewable chemistry.

Additionally, for many industries the application of bioethanol or biomethanol means ‘greening’ of their processes i.e. production of formaldehyde, acetic acid, and many others. In all cases, the methanol molecule serves as an easily-accessible source of carbon. Besides, the yields from renewable chemistry contribute several times more added value to the process than as fuel. The chemical industry is already aware of this fact. In Germany alone, the chemical industry already uses more than 2.5 million tons of methanol per year. This constitutes 12 percent of the raw materials used, which is considerably more than those used for heat generation (5.5%), biofuels (4.7%) or electricity generation (3%).

Another market with huge perspectives are **biopolymers**. The production capacity for biopolymers is growing rapidly. While the capacity stood at 315,000 tons in 2007, this figure is set to rise to 1.4 million tons by 2010. This means an explosive growth rate of more than 100% annually. Looking at this forecast the seemingly high expectations of market growth rate of biorefinery products in the 5-year period as expressed by Biowert’s owner (Dr. Gass) to be around 50% per annum, seem to be quite moderate. It is way above forecasts for biofuels: Research&Markets forecasts biofuel market growth at 12,3% per annum in the period 2007 -2017.

The technology of Chemrec has potential to globally provide motor fuels equivalent to over 45 billion litres/year of gasoline (12 billion gallons/year). For Domsjo refinery the forecasted market growth is 7% for special cellulose, lignosulfonates, bioethanol, carbon dioxide, methane.

Biotechnology in future will have two roles:

1. On the one hand, it will expand the raw materials base with wood, biogas or biogenic residues.
2. On the other hand, it will create new pathways to key chemical substances such as biopolymers for instance polyhydroxybutyric acid or specialty chemicals.

Currently a lot is said about the energy-related benefits of biomass. Nevertheless, the owners of biorefineries – in the long term - rather pursue its use in materials, which can always be converted to energy in a second stage.

4.2 Main findings - summary

The conducted interviews, desk research and the analysis of particular impacts of biorefineries on environment, regional development and employment resulted in following conclusions (sometimes open questions):

- Transition of existing plants to biorefineries usually helps in the maintenance of current jobs.
- New labor-saving technologies in biorefineries change the manufacturing processes and may cause job redundancies. Can those be offset by the more jobs in the non-manufacturing sectors i.e. supply-chain or business services ?
- Effects on employment in agriculture are mostly positive but also depend on the geographic supply chain structure.
- Is the net economic impact of the biorefinery on the local economy always positive ? (the term 'net' refers to the difference between two possible scenarios: (without biorefinery and with biorefinery)
- Is biorefineries' development likely to result in the net gain in total employment ?
- What happens if demand for a biorefinery's product increases, but the overall demand in the local economy does not also increase? Will there be a net gain in the total employment ?
- Biorefineries are catalyst for innovation in the economy: they strengthen job creation effects in the industry and especially R& D area.
- Biorefineries constitute a more environment friendly proposition for various industries: because of their lower carbon footprint, enhanced energy efficiency and mostly zero-waste production processes
- In cases where biorefinery is at the existing facility – the impacts are less visible, but on the other hand – the impacts are heavily dependent on the scale of production.
- Product-derived positive impacts on environment (i.e. due to the low carbon footprint of new fuels) are usually seen in places where those products are mostly applied and not necessarily in the region
- Biorefineries help in the economic utilization of previously unwanted or low-value feedstocks
- The existing biorefineries apply the most advanced technologies in terms of energy efficiency and waste processing because the technology providers/project developers want them to showcase their inventions with the purpose of further commercial deployment worldwide.
- Sometimes the biorefineries are not invested optimally because of the learning-curve.

5 Acknowledgements

The authors would like to thank all the individuals who made the production of this report possible, above all our interviewees. We are especially grateful to Dr.-Ing MBA Michael L. Gass, CEO of Biowert Industrie GmbH in Brensbach, Germany for enabling Adrian Karbowski to visit his biorefinery facility. Dr. Gass provided us with valuable insight in the biorefinery operations.

Thanks also to Dr. Richard van den Broek, member of the Board (CEO) of Bioholding, who generously devoted his time for telephone interview. His comments on BioMCN biorefinery operations as well as environmental and social impacts were very helpful.

6 References

The Gallagher Review of the indirect effects of biofuels production, July 2008

http://www.renewablefuelsagency.org/db/documents/Report_of_the_Gallagher_review.pdf

Renewable Fuels Agency, Ashdown House, Sedlescombe Road North, St Leonards-on-Sea East Sussex, TN37 7GA, Tel: 0207 944 8229, E-mail: rfa.info@dft.gsi.gov.uk, www.renewablefuelsagency.org

Position Paper: Life Cycle Analysis of Bioplastics by European Bioplastics e.V., Germany

Annex to the COMMUNICATION FROM THE COMMISSION An EU Strategy for Biofuels IMPACT ASSESSMENT {COM(2006) 34 final}

Industrielle stoffliche Nutzung nachwachsender Rohstoffe, Dagmar Oertel, Das Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag (TAB)

Dieter Bockey, UFOP 'Biodiesel at a dead end!? Current bio fuel politics in Germany and the EU – a critical appraisal'

Evonik Magazine 4/2008 by Evonik Industries, page 18, "Growing Technology" by Harald Carl,

Logistic function - Wikipedia, the free encyclopedia

http://en.wikipedia.org/wiki/Logistic_function

Gompertz function - Wikipedia, the free encyclopedia

http://en.wikipedia.org/wiki/Gompertz_curve#Uses

O'Hare, M. Jan,17, 2008, CARB LFCS Working Group 3. Greenhouse Gas Emissions from Indirect Land Use Change

"About Wisington factory"

<http://www.britishsugar.co.uk/IsolatedStorage/94175874-67b5-4c33-9f38-380233f14049/ContentAssets/Documents/About%20BS/Our%20UK%20Operations/About%20Wisington%20Factory.pdf>

Modelling the employment impact of innovation - The Employment Impact of Innovation Evidence and Policy

<http://www.informaworld.com/smpp/content~content=a728256464~db=all~order=page>

biomasse-studie Strom erzeugen statt Autos antreiben « DiePresse.com

<http://diepresse.com/home/wirtschaft/economist/393628/index.do>

Etha+ A green fuel, a green additive Feedstock characteristics

<http://www.etha-plus.ch/index.php?id=4&L=2>

Biopol - Deliverable 2.2.3

GlycosBio - A New Kind of Chemical Company

<http://www.glycosbio.com/about.htm>

Appendix A Questionnaire for assessment of impact of biorefinery on rural development, employment and environment.

Introduction

Definition of biorefineries within that interview

Biorefinery is the sustainable processing of biomass into a spectrum of marketable products and energy. Based on this definition, four different biorefinery concepts are distinguished, i.e.:

- Green Biorefineries
- Whole Crop Biorefineries
- Ligno-cellulosic Feedstock Biorefineries
- Two Platform Concept Biorefineries

The aim of this survey

The purpose of this interview guide is to gather opinions about possible effects of current (and future) biorefineries' operations on employment, rural development and environment.

Questions are marked in green.

I. General questions about the biorefinery in focus:

- 1. Name/Region/Location:**
- 2. When did the production start ?**
- 3. Used feedstock: type and volume per year:**
- 4. Do you plan to change/extend your feedstock base in future ? If yes, in what way ?**
- 5. Product: Please specify type and volume of produced bio-products per year:**
- 6. From where do you source the raw materials (from the surrounding of the biorefinery or from outside of this region)?**
- 7. Is the surrounding area of your biorefinery:**
 - mostly an agricultural land ?
 - a mixture of industrial areas and agricultural areas ?
 - other

II. Impact on job market and community welfare

1. Do you think your project enhances job creation and employment diversity in the region ?
2. How many people work directly in your biorefinery?
3. Will this number change within the next years? If yes, how far and in which period of time?
4. How many full time operators are working on the project?
5. How many researchers are working on the project?
6. What is the influence on indirect employment in the region
 - contracts with farmers
 - new enterprises co-operating
 -
7. Do you think there would be an element of the wages' increase observed in the region due to your plant operations ?
8. Has the biorefinery changed the structure of the labour market in the region?

YES NO
9. If YES in which sense? (e.g. agricultural producer groups were formed, more job for educated and highly trained people, new enterprises)
10. Are people/institutions from the region anyhow partner/shareholder or the like of the biorefinery? How far are they involved?

III. Effects on Land & Property Value

1. Do you plan any acquisitions of property or land or have you purchased land already ?
2. Did you recognize any changes concerning average land & property prices across the region of the biorefinery in the last years ? Do you know any figures?
3. If yes, was it because of the biorefinery or any other developments?

IV. Biodiversity & Environment

1. Was there any loss of habitat due to biorefinery construction ?
2. Have you adopted any water sensitive design to minimise water consumption in the production cycle?
3. If raw material is produced in the region how does it influence regional ecosystems, especially biodiversity and water regime (i.e. increased use of fertilizers, crop monoculture etc.) ?
4. Is the existence of your facility in the region a catalyst for the transformation of former untouched reservoirs to more agricultural land?
5. How do you make use of residues ? Do you upgrade them to value-added products?

V. Energy efficiency

1. Are you already self-sufficient with respect to heat and electricity or do you pursue such goal in the future ?
2. Are the total GHG (Greenhouse gas) emissions from production and upstream processes of the biorefinery. higher or lower compared to the conventional production systems ?
 - neutral
 - higher

VI. Economic drivers & net economic impact of biorefinery

1. How long did it take from first idea to realization of biorefinery facility ?
2. What is the total investment value of your biorefinery project ?
3. What is the fixed capital investment of the plant? (this is the cost of installed equipment)

4. What is the total investment? What is included in this number (labour, capital, off site costs)?
5. What is the expected Return on Investment (ROI) in your project ?
6. What is the minimum ROI of biorefinery project that you could accept ?
7. How strong are following factors with regard to the influence on your ROI ?

This is classified information that we do not share.

If not possible to provide estimation in % please specify between: very important / important / negligible

Name of the factor	Your estimation (%) if the factor changes by 25%	Please choose one that reflects your opinion		
		<i>very important</i>	<i>important</i>	<i>negligible</i>
Utilization of plant's production capacity				
Feedstock price				
Market price of biobased product				
Change in the loan interest rate				
Subsidy to biobased product				
Subsidies for the biorefinery itself				
Other:				

8. What is the % of the project cost that can be covered by government loan guarantees ?
(if project was not eligible for government loan guarantees, please indicate this, too)
9. What is the forecasted market growth (% per annum) for your major biobased product in the 5-year period?

- 10. How strong does your project’s viability depend on crude oil price development ?**
(Please specify between: very important / important / negligible)
- 11. What is an assumed economic life of your biorefinery project ?**
- 12. Does your biorefinery facilitate economic activity and performance of other industries in the region ?** *i.e. has influence on business investment and location decisions of other companies/industries*
- 13. What particular resources (workforce, capital, raw materials etc.) have been taken away from other sectors of the economy to construct and run your biorefinery ?**
- 14. Do you think that your biorefinery activities are negatively influencing food production (at local level, at national level or at global level)?**
- 15. What do you think about the acceptance of biorefineries in the region? Do you have any resistance within the population like it was sometimes the case with some wind power plants or biogas plants?**
- 16. If there are any opponents, what groups oppose biorefinery activities ?**

VII. Other impacts

Do you know about other additional impacts that you consider relevant to the topic of biorefinery? If so, please use the space to fill in the table below.

Impact Name	Description of Impact	
	Description in Words	Significance Criteria (negative, negligible, beneficial)

Your comments:

.....

Thank you very much for participation in this survey.
BIOPOL Team