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Biorefineries: Relocating Biomass Refineries to the Rural Area

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Abstract

The field for application of biomass is rising. The demand for food and feeding stuff rises while at the same time energy, chemicals and other materials also need to be produced from biomass because of decreasing fossil resources. However, the biorefinery ideas and concepts can help to use the limited renewable raw materials more efficiently than today. With biorefineries, valuable products, such as platform chemicals, can be produced from agricultural feedstock, which can subsequently be further processed into a variety of substances by the chemical industry. Due to the role they play as producers of biomass, rural areas will grow in importance in the decades to come. Parts of the biorefinery process can be relocated to the rural areas to bring a high added value to these regions. By refining biomass at the place of production, new economic opportunities may arise for agriculturists, and the industry gets high-grade pre-products. Additionally, an on-farm refining can increase the quality of the products because of the instant processing. To reduce competition with the food production and to find new possibilities of utilisation for these habitats, the focus for new agricultural biomass should be on grasslands. But also croplands can provide more renewable raw materials without endangering a sustainable agriculture, e.g. by implementing legumes in the crop rotation. To decide if a region can provide adequate amounts of raw material for a biorefinery, new raw material assessment procedures have to be developed. In doing so, involvement of farmers is inevitable to generate a reliable study of the biomass refinery potentials.

Keywords:
rural areas, sustainable development, biorefinery, raw material assessment

1 Introduction

Biomass constitutes a regenerative alternative to fossil resources, which can be used both for energy production and as raw material for further products. By 2020, the share of renewable energies in electricity generation in Germany should rise to 30%. According to the national Biomass Action Plan (Bundesministerium für Ernährung Landwirtschaft und Verbraucherschutz & Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2009), the bulk of the energy is to be supplied by biomass. Although biomass is just one of many possibilities for producing energy from renewable raw materials, these goals induce that political supporting instruments are heavily geared towards the use of biomass for energy production. At the same time, this demand for biomass is competing with other biomass consuming sectors. The chemical industries depend on carbon compounds. Hence, their substitute for fossil resources is biomass. The added value for the use of biomass for materials is five to ten times higher than for the energetic use (nova-Institut, 2010). The chemical industries aim at achieving a 30% share of production from renewable raw materials by 2025; the current rate stands at approximately 13% (European Technology Platform for Sustainable Chemistry, 2005). The "German Action Plan for the material use of renewable raw materials" (Fachagentur Nachwachsende Rohstoffe e.V.,2009), published by the German government in 2009, illustrates that political supporting programmes will in future also embrace the use of biomass for materials, including biorefineries, to advance the efficient use of regenerative raw materials. Biorefinery is the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials, chemicals) and energy (fuels, power, heat) (International Energy Agency, 2009). Important chemicals from biomass, produced by biorefineries, are e.g. lactic acid, succinic acid or fumaric acid, building the base for bioplastics and polyester (Kamm & Kamm, 2007). The biorefinery concept ensures that as much of the feedstock as possible is exploited (van Ree et al., 2007).

The rising demand for biomass results in a shortage of resources. Statistics on cultivation and numbers of livestock on the farms cannot give reliable information on the resource potential of a region. As long as the quality and the current use of the agricultural area are not known, the assessment of potentials is doubtful. New ideas and concepts are required to handle the diversified biomass use, and new methods are needed to compare all potential uses of biomass in a region in order to find the most suitable type of use.

2 The rural areas

In recent decades, the rural regions of Germany have undergone major changes. The farms situated in these regions dominate the landscape. Reforms of agricultural policy (Bundesministerium für Ernährung Landwirtschaft und Verbraucherschutz, 2006), like the abandonment of set-aside land, lead to structural changes in agriculture and hence in the landscape.

The rising demand for renewable raw materials induces that rural areas will increasingly play a major economic as well as societal role in the future. New structures should be developed to enable agriculturists to benefit from this potential and to ensure their future existence, preferably without having subsidised production on their farms. Refining raw materials at the place of production, based on the concept of biorefinery, is one opportunity. Within the discussion about the so called "ecosystem services" this may turn out for agriculturists to supply specific "agrosystem services" to operationalize this approach and to add another component to this discussion.

2.1 Consequences of structural change

Decreasing numbers of livestock and the rapid increase of monocultures of rape and maize are recent examples that have led to major changes in rural areas and the landscape (Amt für Statistik Berlin-Brandenburg, 2010 (a) and (b)). Some of these changes have had serious consequences. The number of livestock using grassland areas has decreased dramatically. In Brandenburg, the number of cattle has declined by 50% since 1990 (Amt für Statistik Berlin-Brandenburg, 2010 (a)). By contrast, agriculturally used areas decreased only slightly in the same period (Amt für Statistik Berlin-Brandenburg, 2010 (b)). This has led to a considerable abatement of grassland utilisation. In order to retain this important part of the cultural

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landscape, support programmes for the preservation of these areas were initiated by the Brandenburg state government (Ministerium für Umwelt, Gesundheit und Verbraucherschutz, 2010). The biomass yielded from these preserved grasslands remains unused. However, several projects (PROGRASS, GNUT) analyse if an increasing utilisation of these habitats for energy production in biogas or incineration plants would be marketable (Life, 2011; Thüringer Landesanstalt für Landwirtschaft, 2009). Biomass from these grasslands also could be a suitable resource for biorefineries. Thus, before an energetic use, the biomass could be used for material production to reach a higher added value.

In 2004, the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG) (Deutscher Bundestag, 2004) was amended and the support of power generation from renewables was pushed. Whilst the quantity of agriculturally used areas in Germany remained more or less constant, from 2004 the cultivation of energy crops skyrocketed, leading to a major reduction of the area cultivated for industrial crops and feeding stuff, but also for food (Fachagentur Nachwachsender Rohstoffe e.V., 2011).

The "National Strategy on Biological Diversity" aspires to prevent further impairments to the landscape in Germany (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, 2007). The landscape in Germany, however, has changed drastically in places, owing to the supporting programmes in the Renewable Energy Sources Act. Monocultures of energy crops, such as rape and maize, were created to supply the bioethanol and biogas plants with adequate quantities of feedstock.

An increasing number of utilisation options must be supplied by the existing agricultural areas in Germany. Agriculturists often base their crop rotation planning on perspectives for the highest profit. Since the mentioned Renewable Energy Sources Act supports the use of biomass for energy production, there is a distorted tendency towards such use to the detriment of other uses, such as for materials, which may be outcompeted.

3 Potential of the biorefinery concept

The multiple use of raw materials, as envisaged for biorefineries, leads to a higher product yield than in other biomass processing plants, enhancing the plants' efficiency. An advancement of this concept is to locate parts of the biorefinery in rural areas and to refine the raw materials on the farm. This advanced concept aims to make optimum use of all exploitable parts of the raw materials cultivated on farms to ensure sustainability and cost effectiveness of their use.

The most difficult problem with biomass is its large volume and heavy weight in relation to the quantity of usable contents. By producing extracted juice from green biomass on the farm (see chap. 3.2.1), the quantity to be transported to the processing plant is reduced by more than 50% (Venus, 2006). Transportation costs for the raw materials are reduced and the delivery of pre-products, in form of e.g. press juices, starch or molasses reduces the number of feedstocks for the biorefinery plant and therewith the storage and processing expenditure.

Building small processing plants in the rural areas which process the pre-products from the regional farms can reduce the transportation costs of the raw materials and intermediate products even more and can enable the quality of the industrial feedstock to be enhanced. Locating parts of the biorefinery to the heart of rural areas can be achieved if an all-year supply of plant raw material can be supplied within a suitable radius around the farm. Due to the decentralised location, the industrial plants buy products created by the regional farms. By this, a stable regional sales market would develop for the preliminary products generated by farmers. Industry and agriculture may become linked, opening up new entrepreneurial structures for agriculturists. By investing in the refining of biomass feedstock, agriculturists could evolve into suppliers of high-grade products to industry, enabling them to tap completely new markets.

3.1 Pre-products for the chemical industry

The chemical industry tries to turn "green". If the production is more and more based on renewable raw materials, the processing is configured to be more efficient and eco-friendly while the products are preferably biodegradable and intoxic. With the biorefinery concept the chemical industry can produce a variety of chemicals and materials, as well as energy with lowest consumption of resources possible. The industrial plants require a sufficient quantity of high-grade raw materials to manufacture the products. The increasing orientation of the industry towards renewable raw materials presents new challenges to farms as the main producers with regard to altered product requirements. The quality standards for food, energy sources and industrial feedstock differ considerably. Consequently, the raw materials produced must be adapted to the requirements of the respective buyers.

The chemical industry primarily requires an all-year supply of agricultural products of consistently high quality at reasonable prices (Peters, D.,2004). Ensuring the year-round availability of domestic renewable raw materials constitutes a problem. For Central Europe the usual harvest period is from May to October. Sufficient quantities of raw material must be produced within these six months to be able to provide the chemical industry with an all-year supply. The demands for a consistently high quality can be met by adjusting the sowing, maintenance, harvest and processing of the raw materials to the use for materials. Above all, it is vital to preserve biomass rapidly to prevent the onset of uncontrolled fermentation processes (Thomsen et al., 2003). Degradation of the valuable contents can be virtually prevented altogether if the plant material was preserved within a period of 24 hours. This is crucial not only for the quality required by the industry, but also for the consistency of this quality. For the finished product, it must be irrelevant when and where the feedstock was produced and processed. The refining on the farm allows a very fast processing and can therewith deliver high quality pre-products to the decentral biorefinery plants, which produce the basic materials for the chemical industries.

3.2 Biomass refining on the farm

Since the demand for food and feeding stuff will continue to rise in future and the provision of these goods should take priority over the use of biomass for materials and energy production, it is necessary to exploit new raw material potential in addition to making the exploitation of existing agricultural feedstock more efficient. In the best case, the use of raw materials does not compete with food production. For this reason, in the area of agriculture, the use of biomass for materials and energy production should concentrate on the incrementally unused grassland locations. Nevertheless, green biomass from cropland also can be used for an on-farm refining. The examples presented below show possibilities to step into refining. The market potential for the products yielded from refining is high; hence the intermediate products also have a suitable profit potential. In these examples, part of the refining process can be relocated to the farm at relatively low cost from the investor's perspective and with regard to acquiring the technical expertise.

3.2.1 Extracted juice from green biomass

A culture medium for lactic acid bacteria is required to produce highly concentrated lactic acids from raw materials containing starch. A juice extracted from legumes has proven to be highly suitable for this (Leiß et al., 2010). Lactic acid is a primary platform chemical used not only in the food industry, but also as a parent substance for the synthesis of chemicals (for instance lactic acid ester) and in the production of polylactic acid (PLA). Plastic made from polylactic acid (polylactate) is a plastic for the future because it is biobased, biodegradable, or both (European Bioplastics 2011 (a)). Scenarios figured out that the market for PLA will grow further; the global bioplastics production capacity will more than double from 2010 to 2015 (European Bioplastics 2011 (b)). A culture medium for the production of lactic acid can be created on the farm by squeezing fresh green biomass. Nitrogen and inorganic salts, contained especially in legumes, foster cell growth in lactic acid bacteria, and are essential for the optimum exploitation of lactic acids (Venus, 2010). The juice yielded can either be used fresh, i.e. within 24 hours, as a culture medium or be preserved by adding lactic acid bacteria which create lactic acid (Thomsen et al., 2003). This process shows that lactic acid can also be produced directly from green biomass. For high lactic acid production in this case, the green biomass must be ensilaged immediately after harvesting. A wide

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range of green biomass types other than legumes can also be used in this method of processing (Krotscheck et al., 2004). The dry matter of the silage juice extracted consists to an average of 30% of lactic acid (Krotscheck et al., 2004). However, lactic acid produced in this way is not suitable for the manufacturing of bioplastics (Venus, 2010). Nevertheless, there are extensive areas of application: The market for biologically degradable solvents and cleaning agents is steadily growing; these products are easy to be manufactured by reacting lactic acid with ethanol (Krotscheck et al., 2004). It is also possible to use the substance as preservative and to produce food and feeding stuff after ensilaging.

The production and preservation of such extracted juices can enable farms to make additional gains if grassland locations and cultivated legumes have so far been used inadequately or not at all. The price for the screw press to produce a press juice highly depends on the possible throughput rate. So farmers can choose the optimal size of the press for their accruing amount of green biomass for the biorefinery process. The lactic acid bacteria the farmers need for the conservation can be equated with those used for the ensilage process and are available at reasonable prices.

3.2.2 Proteins from legumes

Plant proteins can be used for many applications. As food, they are a good alternative to animal proteins. Amongst other things, they are used in industry to manufacture adhesives, emulsifiers and cosmetics. A large proportion of the plant proteins produced, however, is used in the animal feed industry. They are mainly produced from legumes because they are not only rich in nitrogen, but their protein content also exceeds that of many other types of plants (Aufhammer, 1998).

The green food proteins can be produced on the farm completely. The proteins are separated by either heating the previously produced press juice or by varying the pH value in the proteinaceous solution (Bonk, 1999). Once the proteins manufacturing the feed have been separated, the deproteinised juice extracted from the legumes can be used as culture medium for bacteria (Leiß et al. 2010). Both grain and feed legumes are equally suitable for recovering proteins. Drying the proteins yielded is a very energy-intensive work step involving high investment costs by the farm (Edwards et al., 1975). These costs can be cut if the protein sludge is supplied directly to fattening plants in the vicinity in a moist state (Schönicke, 2010). Although it only remains usable for a few days, both parties will benefit from the lower production costs and the resulting lower price. Even if the farmers don't have to buy a dryer for the protein production, the investment is much higher than for the production of press juices and only pays off, if on a farm or by a cooperation of farms high amounts of legumes can be produced and processed.

4 Raw material assessment

Usually, all the different users of biomass create individual raw material assessments to see if a region has the potential to supply suitable biomass for their use option. Often it is not considered that the various biomass potentials overlap reducing the single use options or even make some of them unavailable. First studies showed that analysing statistics on cultivation and livestock in agriculture, which is common for the raw material assessment, cannot give reliable information on biomass potentials (Papendiek, 2011; Papendiek et al. 2011). Participation of farmers is essential to get this information from agriculture. From the actual point of view farmers use their raw materials already quite efficiently (Papendiek et al., 2011). It is to clarify if different cultivation systems, e.g. a catch-crop cultivation (see chapter 5), can produce additional amounts of biomass for the energetic and material use. Studies have to follow to see if an integration of legumes in crop rotations of the conventional agriculture can produce high quality biomass for the biorefinery. This can diversify the crop rotation to valorize the soil quality and reduce the amount of fertilisers needed. On grasslands it has to be clarified if areas under nature conservation can provide suitable biomass for the biorefinery when the maintenance of these areas is intensified. Sowing of about 50% legumes on the grassland locations could optimize the quality of the biomass for an industrial use. Adequate analyses have to show if this and an extensive use can preserve or even increase the spectrum of species on

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grasslands. The impact of political parameters should also be included in a raw material assessment to take prospective developments into account. An impact assessment tool can be used to create political scenarios and compare the development of biomass use under the different conditions (Helming et al., 2008).

5 Discussion

The rising demand for raw materials can only be met by using previously untapped raw material sources and by implementing a cascade use of the raw materials. According to the definition of biorefinery (International Energy Agency, 2009), this means to use the biomass for food and feeding stuff in the first instance, and then for materials or chemicals and, finally, as an energy source. Under-utilised grassland locations are ideal as a raw material source for the use of biomass for materials and energy production, since there is no competition with the production of food and feeding stuff on these sites. Due to the measures introduced, many of the grassland areas have been set aside for nature conservation. Today, therefore, economic use of such areas is only possible to a limited extent (Hertwig & Pickert, 2004). The PROGRASS project examines whether biomass from designated FFH habitats can be used for energy production and at the same time biodiversity in those areas can be preserved or even increased (Life, 2011). The use for materials and chemicals should also be examined because of the higher added value.

The rising demand for raw materials must not lead to the exploitation of resources. Agricultural areas should still be managed sustainably. For example, it should be assumed that up to 80% of straw has to remain on the field on some sites to protect the soil (Boelcke, 2003). Carbon can only partly be fed back into the soil via biogas substrates, but primarily via manure and straw (Arthurson, 2009 cf. Wragge et al., 2010). Even if the prices for the raw material increase, this must not lead to a reduced amount of straw being left on the fields. One option to remain higher yields and therewith more biomass from a constant area, is to integrate catch crops in the crop rotation. Catch crops here are meant as fast growing plants, e.g. legumes cultivated in between of two main crops. This cultivation system approach is to reduce risks of erosion and nutrient losses (Freyer, 2003). The yielded legumes provide important raw materials for the biorefinery and can support a sustainable management of the agricultural areas, optimizing the water availability and nutrient supply in soils (Kahnt, 2008). Therewith, several services are facilitated, offering a multiple dividend. According to the discussion on ecosystem services within agricultural landscapes these may be called "agrosystem services", just to point out the coupled product of agricultural production.

When the biomass refining starts on the farm, the residual materials (press cake) left over after refining can be used as animal feed or a source of energy, and subsequently as fertiliser. In other words, nutrients and carbon are directly used on the farm and returned to the soil, which is a vital aspect in the sustainable management of agricultural areas (Kahnt, 2008).

Since in the biorefinery concept the use of biomass for energy production is placed at the end of the value-added chain, the substances contained in the plants are the key criterion for cultivation rather than their energy density. The cultivation of maize and rape in monocultures for use in energy production can therefore be reduced, and the diversity of the landscape due to production schemes can grow again. Biomass used as renewable raw material is generally produced in rural regions. For this reason, the added value should also commence there. Since the numbers of livestock have declined dramatically, farms have evolved into exclusive suppliers of primary raw materials. In the future, biorefineries bring new methods of refining raw materials to farms, which would promote the development of the rural areas. These first refineries would contribute to meeting the industry's demands on regenerative raw materials to the greatest extent possible. By working together, industry and agriculture can prevent errors in the cultivation, processing and transportation of renewable raw materials or the products gained from them, ensuring there are no fluctuations or reductions in quality, endangering the cost effectiveness of processing. The prices realised for the products yielded are expected to be higher and more stable than for primary raw materials. Regional and supraregional economic cycles can be established between agriculture and industry (e.g. discussion about "innovation partnerships" within the EU agriculture policy), leading to the promotion of investments in the

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regions and an increase in their economic strength.

A similar approach to the on-farm refining is the development of regional biomass processing centres (RBPC). The problem of large biorefinery plants is that they also entail increased costs of biomass transportation and storage, high transaction costs of contracting with large numbers of farmers for biomass supply, potential market power issues and local environmental impacts (Carolan et al., 2007). The RBPC is conceptualized as a flexible processing facility capable of pre-treating and converting biomass into appropriate feedstocks for a variety of final products such as fuels, chemicals, electricity and animal feeds (Carolan et al., 2007). They reduce the conflict between plant size and transportation costs. These centres are concepted for lignocellulosic resources and are proven to be economic for this kind of biomass. For dry biomass, these centres are more capable than an on-farm refining. The only possible refining on farms would be the comminution, but the transport costs wouldn't decrease noticeable because of this process, and the quality for upcoming products wouldn't rise. Then again, for fresh biomass this quick and local refining is very important for these aspects and increases the profitability of green biomass use.

6 Conclusions

Biorefineries allow more efficient use of biomass to save resources. The opportunities of an implementation in the rural area are diverse. The cost effectiveness of the biorefinery concept depends to a great extent on the costs involved in transporting the biomass. If a high part of the biorefinery process is implemented decentrally, transport distances are minimal, making biomass processing even more efficient. The highly concentrated chemicals produced in the decentral plants can be transported over longer distances to the central industry sites. The production of pre-products on the farm and in decentral plants results in a better quality of the industrial products and supports the sustainable development of rural areas. Refining biomass can constitute additional income for agriculturists, as is already the case in the use of biomass for energy production. The potential for establishing biorefineries should accordingly be linked directly to agriculturists' production-related decisions. All considerations of the potential availability of space for the cultivation of the relevant biomass are misleading. The refining of previously unused or only partially used raw materials can facilitate stable income on a promising market through the close link to biorefineries, and hence to industry. After the refining of raw materials, substances are left that can be used to close material cycles on the farm. However, the potential of relocating biomass refineries to the rural areas is not yet sufficiently studied. It is not clarified whether the participation of agriculturists will help evolve a new method to describe raw material potentials more reliably. It still has to be investigated if on-farm refining can really pay off for the agriculturists, and if it is possible to cultivate and refine enough high-grade biomass for the future demand of the various industries. One critical aspect is the fact that in legumes breeding towards higher and more stable yields only little progress has been made in recent decades. Moreover, it is still an open question whether grassland sites that are under nature conservation can be used for the production of biorefinery raw material while keeping or increasing biodiversity on these sites.

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