Design for Sustainable Development

Crops for Sustainable Enterprise

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Foreword

The move towards sustainable development is one of the main challenges of the European Union. It is an essential principle of the *Fifth Environmental Policy and Action Programme* that environmental concerns are taken fully into account from the outset in the development of other policies and programmes. Because of its structure, the European Foundation for the Improvement of Living and Working Conditions can play a unique role in this area by working with industry and being able to operate at the interface of concerns about environmental and working conditions.

Against this background, sustainable development is one of the six key issues in the Foundation's programme for 1997-2000. The focus of the Foundation's activities on sustainable development is sustainable production and consumption. In order to deal with these issues, the Foundation has launched a project on Design for Sustainable Development with the aim of developing tools, information networks and training for the main actors concerned, such as industry, social partners and designers.

This report, the sixth in the Design for Sustainable Development series, seeks to provide an overview of trends and developments in non-food agriculture crops (NFA) in the European Union and to provide information about the key networks and programmes working in this promising area of sustainable production. Crops such as industrial hemp, corn and maize have many thousands of uses, some recently discovered, some of more ancient provenance. This report identifies productive sectors such as mould-making, textiles and paper production which are coming increasingly to rely on these sustainable fibre crops. One of the main attractions of such crops is that they represent an alternative source of raw material capable of replacing less environmentally benign sources. The authors explore the sort of SMEs that might emerge from the development of these renewables and their potential benefits both in employment terms - new agriculture / land uses - and in ecological terms - less reliance on fossil-based and synthetic resources.

Further publications are in the pipeline on support systems for SMEs and health aspects of workers dealing with sustainable production and services.

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Preface

This report attempts to provide an overview of the potential of non-food agriculture crops (NFA) for sustainable production in the European Union. To help identify the underlying trends, concerns and opportunities in the non-food agriculture sector, fibre crops are the main focus. The reader will find information on the key European networks on NFA and linkages with the European Union 5th Framework Programme.

This report is a timely intervention at a moment when an encouraging and positive shift is taking place in industry from continuing to exploit fossil based resources to developing renewable resources as feed stock for production purposes. However these developments need to be monitored as the agricultural production methods they employ, such as mono-crop culture, genetic modification and the over use of pesticides and fertilisers, are the cause for some concern.

To counter such worrying developments, the report presents a model of a Bioregion that supports 'Bionetic SMEs' - the term given by this report to a new generation of micro-, small and medium sized companies based in that Bioregion. The term derives from the idea that such companies would place care for biodiversity and ecology at the core of their economic activity. They would be engaged in constant networking with each other and exploit information and communication technology to monitor economic, and employment activity in relation to Bioregional carrying capacity.

The Bionetic SME concept borrows from other sympathetic sustainable development ideas, such as Bioregionalism, full resource potential, Permaculture, Biorefining and industrial ecology. The report presents these ideas in an integrated way within the framework of the Bioregion.

A central argument of the report is that we need to change our view of how we exploit plants for material purposes and move towards more sustainable production systems. Instead of focussing on singular characteristics of a plant - for example its oil or fibre - we need to maximise profit and resource use by exploiting the whole plant. The potential of this approach is exemplified by crops such as industrial hemp, which has 25,000 known uses, and corn (maize) which has 3,500. NFA products range from chemicals to textiles, and from biopolymers to building insulation material. Forgotten plants, such as the stinging nettle, which was used to produce fine of textiles several hundred years ago, are also investigated.

A main objective of the report is to highlight how we can develop sustainable systems of agriculture, crop use and sustainable production to realise products based upon renewable material resources. In this respect this report should be viewed as a starting point to stimulate discussion and debate.

Introduction

This report aims to explore the recent upsurge in traditional manufacturing industry in the use of renewable resources for materials purposes. The current situation, the main players, the resources being used and the issues currently engaging attention in non-food agriculture are discussed broadly. However, the main focus is on fibre crops suitable for the European Union and especially on how they can be used to evolve a new model SME based upon principles of sustainable production. In this report the sort of small and medium sized enterprise (SME) suitable for this purpose is referred to as a 'Bionetic SME' and a model is presented as to how such an enterprise might work and contribute to the concept of sustainable production. The model does not pretend to represent 'the' solution - it is far too generic for that - but is intended rather to stimulate the debate on how sustainable production might be realised in the local and regional context based upon renewable resources and the resource potential concept.

In a general way the report raises issues connected to the impact a 'Bionetic SME' might have on jobs, the health of the worker and the environment in the immediate future. To give meaning to these issues the report contains concise references to industries that have made a move to, or recognise the importance of, renewable resources in terms of material performance and or sustainable development.

Many programmes currently support the reintroduction of previously discarded renewable resource based materials, while at the same time innovative new technologies and approaches are being encouraged. The European Union Fifth Framework Programme (FP5, 1999 - 2002), launched in February 1999, supports research relating to non-food use of crops. Within the Thematic Programme 1 - Quality of Life and Management of Living Resources, Sustainable Agriculture is identified as one of six key actions.

An overriding strategic consideration that drives these key actions is the recognition that non-renewable fossil fuel based materials contribute significantly to global warming and to air, land and water contamination. A move to sustainably developed renewable resources can reduce CO2 emissions. It can also reduce the complex mix of synthetic compounds that enter the eco-system via human manufacturing systems and non-sustainable consumption patterns. To produce a greater supply of renewable resources for material processes the agriculture industry will increasingly need to grow crops for industrial materials purposes rather than for food. This will be likely to result in:

- New jobs in agriculture and industry
- New product opportunities and markets
- An improved ecological balance between fabricated products and the environment
- The replacement of existing chemicals and materials, raising new issues in relation to workers' health and safety

Recognising the importance of renewable resources

It can be argued that since the industrial revolution there has been a move away from renewable resources to fossil fuel use and synthetic material development. However, the use of renewable resources by main stream industry may be more widespread than hitherto thought.

Unusual links between the different participants are emerging as the non-food agriculture sector moves from being an exotic experiment to becoming a main supply stream for renewable materials for manufacturers. In this way, the market increasingly appears to be integrating the agriculture sector and the manufacturing industries. They are carrying out joint research and market studies and even mainstream multinationals have become aware that they are a part of a closely linked supply chain that also requires sustainable care. For example, UNILEVER (which employees 300,000 people worldwide) carried out a 'broad-brush' survey in 1997 aimed at identifying the core sustainable development concerns of the company. To their surprise, 70% of the business is based exclusively on renewable resources. In recognition of this fact, they have implemented many initiatives aimed at supporting sustainable development and at the same time strengthening the area of their business based upon renewable resources. To do this they have joined forces with the World Wild Life Fund (WWF), an alliance which would have previously seemed very unlikely, but from which both have much to gain. The WWF looks at sustainable development from an environmental perspective whilst UNILEVER views it from a business perspective. This type of partnership prefigures a new type of business that may change the nature of traditional industries, increasingly utilising renewables as essential raw materials and stimulating the growth of non-food agriculture.

Such a benign partnership involving a very large company and an NGO is very welcome and is mentioned to demonstrate the importance of renewable resources even to a transnational company such as UNILEVER and to highlight that the importance of non-food agriculture cannot be overestimated in the future.

However, this report is concerned with smaller organisations - the SMEs - and their potential to become economically viable whilst pioneering sustainable production methods based upon a crop suitable for the E.U. by employing the 'resource potential' concept. In exploring the resource potential concept, this report highlights the diversity and potential of renewable resources for product development.

New product opportunities and markets

Renewable resources can be exploited in a vast range of known applications, from the farm gate to the end user, such as liquid fuels, bulk chemicals, fertilisers, bio-polymers, lubricants, coatings, detergents, fine chemicals, composites, fibre, pharmacy, fabrics, paper and card.

The extensive new farming and processing technologies involved in these developments will obviously have an influence on the ecological balance between man-made products and the environment. This report broadly explores the sort of SMEs that might emerge from the development of renewables and their potential. It suggests a positive approach towards expanding the renewables market but concludes that the increased exploitation of renewables will only be sustainable if wisely developed. Emphasis is given to the future opportunities that a 'Bionetic SME' might realise without overlooking possible risks to health, employment and the environment related to the increased exploitation of renewables in the EU.

In developing a more holistic approach to renewables, other interesting factors come to light that have an influence on how we might best exploit renewable resource materials in the future. Traditional European dependence on the 'technology fix' to optimise material supply chains must now be balanced against social considerations such as the way it affects health, jobs and the environment. One such non-technical concern is that a new generation of renewable materials will have different qualities which consumers will perceive differently from existing fossil based materials. This means that the potential use of renewable materials will depend as much on the way consumers perceive them and on the consequent consumer demand as on any technical hurdles.

Below is a tentative check list of the strengths and weaknesses of renewable resources and non-food agriculture (Green Chemistry, 1999):

Strengths

- Low environmental impact
- New opportunities
- New functionality

Weaknesses and challenges

- Natural variability
- Cost
- Complexity
- Unknown technology

While taking these considerations into account this report aims to be forward looking and to stimulate discussion and debate on the potential of 'Bionetic SMEs' for realising sustainable production.

Chapter 1

Non-food agriculture (NFA)

Historically, the agriculture industry has always produced crops that are used as raw materials for manufacturing purposes. Currently, the interest in the use of renewable material resources is growing internationally. This trend goes against the domination of fossil-based materials and products that have been produced by the industrial world during the 20th Century.

Although many fossil-based products have tremendous engineering characteristics, enhance our lives and are economically sound, they also tend to have many negative ecological impacts. The issue of global warming brought about by the volume, character and pace of the use of products based on fossil resources such as oil, coal and gas is central to the debate. The extraction of fossil resources that are stored in the earth's lithosphere results in CO2 emissions as the resources are distributed and transformed into fuels, materials and products. This process represents a net addition to the natural levels of CO2 in the atmosphere that leads to global warming.

Fossil-based resources are mainly used for energy and transport purposes. Mineral oil is not only the basic resource for the production of different types of fuel, but also for a number of other commodities such as polymers and an enormous variety of chemical substances. Mineral oil based fuels, substances and materials are largely carbon and hydrogen based and generally contribute to CO2 emissions to the atmosphere when used.

In contrast, the use of plants and trees as alternative sources of fuels, substances and materials is fundamentally different. Although also largely carbon- and hydrogen-based, because the material is 'borrowed' from the natural carbon cycle and managed through agriculture and forestry, the use of these renewable resources results in emissions of 'natural' CO_2. The use of renewable material resources therefore is CO_2 neutral.

Although this clearly is an improvement, great care is necessary in exploiting renewables as there are still risks. For example, if too much of a particular resource is taken from the natural environment, (such as a certain species of plant) it may become extinct. If a natural or a human-made ecosystem is not utilised carefully, it may cease to be renewable. Thus, although renewable resources provide an attractive alternative from a global warming point of view, they must be sustainably extracted, applied and used. The mere substitution of renewable resources for the fossil resources that currently dominate production and consumption will not do. The level of resource use, the character and location of production, consumption and disposal must also be properly recognised and addressed.

However, interest in the production and use of renewable resources for fuel purposes has increased tremendously in the last decade. The production of rapeseed, based alcohol (ethanol) as 'bio-fuel' for transport is one such example. This has put a pressure upon agriculture, especially in some developing countries where the production of bio-fuel is conflicting with the production of food. In countries with an overproduction of food, such as those in the European Union, the use of agricultural land for non-food production provides an attractive alternative to many farmers, as a means for supplemental income. Many debates have been devoted to the environmental effects of fossil fuel use as compared to those of bio-fuel use. Clearly, although the use of bio-fuel has benefits, its production can involve undesirable side effects such as the use of fertiliser and pesticides on agricultural land, and of energy for mechanically transforming the top layer of the soil and for harvesting.

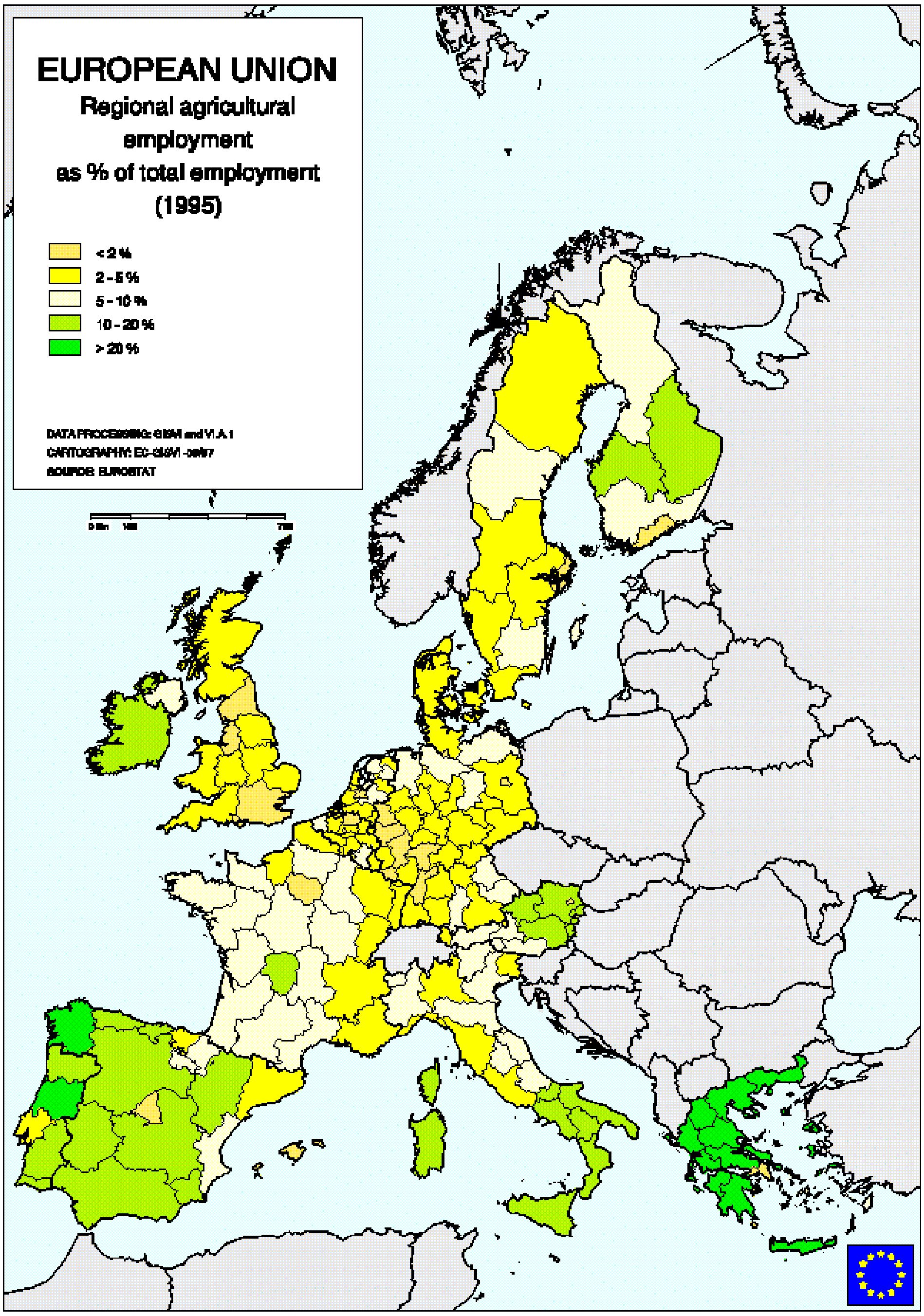
Other recent developments in non-food agriculture are also controversial. These include the bio-genetic manipulation of plants to adjust their properties to agricultural and industrial objectives such as less susceptibility to pests, less need for pesticides, achieving a higher yield, a higher content of oil, or obtaining more of a particular type of starch. Plants, plant cells, micro-organisms and enzymes are being further developed for the industrial production of substances such as oils, fats, natural pesticides, sugars and starch.

However, this report does not deal with the issues involved in agricultural production of fuels, biogenetic manipulation, or the production of substances as raw materials for the chemical industry. Rather, it concentrates on non-food agriculture 'fibre crops' for the production of raw materials for structural material purposes.

Decline of rural economies

As well as having the potential to address some of the causes of global warming non-food agriculture can also revitalise the rural economy. Traditional agriculture and forestry no longer form the backbone of rural economies throughout the EU. Employment in agriculture is declining in both relative and absolute terms. Figure 1 shows the scale of rural employment against total employment in the European Union (European Commission, 1995).

Figure 1: *Agricultural employment in the regions of the European Union*



It now represents on average only some 5.5% of total E.U. employment and, even in the most rural regions, its share is rarely higher than 20%. Much of the agricultural work force is employed only part-time in agriculture.

The European Union 5th Framework Programme contains initiatives that aim to address this decline in rural economies.

Links to the European Union 5th Framework Programme

The 5th Framework Programme (1999 - 2002) (FP5) launched in February 1999 supports research relating to non-food use of crops. Previous main European Commission programmes supporting this research are FAIR (FP4), AIR (FP3), and ECLAIR (FP2). In addition, the European Commission has funded bio-mass and bio-energy projects through its JOULE/THERMIE Programme (Fourth Framework Programme (FP4). The FAIR programme also concerned green chemical and polymer projects, and forestry-wood.

The FP5 - Work Programme contains a Thematic Programme 1 - Quality of Life and Management of Living Resources, which is built around six specific 'key action' areas:

- Food, Nutrition and Health
- Control of Infectious Diseases
- The 'Cell Factory'
- Environment and Health
- Sustainable Agriculture
- The Ageing Population and Disabilities

Key actions are mission orientated and targeted towards immediate policy objectives of improving the competitiveness of European Industry and enhancing the life of the E.U. citizen. A unique characteristic of key actions is an ability to respond to the common needs of cross-linked community policy objectives such as those in agriculture and fisheries, industry, environment and health.

The theme also includes generic activities that aim to build up the knowledge base in the identified areas of strategic importance for the future in relation to 'genomes', the science of the brain, public health, chronic diseases, and socio-economic and ethical issues surrounding bio-sciences. Further activities with an increased role for the involvement of small and medium sized enterprises and entrepreneurs, relating to infrastructures, dissemination and exploitation of results and training, will support these key actions and are intrinsic to the programme.

The European Union 5th Framework Programme takes a positive stance on the realisation of sustainable production within its 'key action' of sustainable agriculture.

Sustainable agriculture

The EC defined the objectives and deliverables for the 5th key action of 'Sustainable Agriculture', as follows:

> "The aim is to improve the quality of life through the sustainable production and rational utilisation of natural resources, with a special emphasis on new technologies, including biotechnology. Research applicants should consider the European Challenges in their area and how their proposals directly address them and are capable of meeting them. A multidisciplinary approach is encouraged where possible, with the environmental, social and economic affects considered. The end users should as far as possible be involved and consideration given to the dissemination of results and information (NF-2000, 1999).

When investigating the sustainable management and utilisation of biological resources, research should bring together current and future market requirements and processes and production practices in order to realise to the full the possible economic, social and environmental benefits. The anticipated deliverables of this section are:

- Provision of integrated systems of sustainable production and clean and efficient process technologies, which will lead to the delivery of new or improved products with high-value.
- Lower impact on the environment.
- Expansion of the production and use base of biological raw materials which, integrated with industrial and market needs, will contribute to the creation and realisation of diverse and versatile markets.

Farm based products and renewable materials complying with consumer well-being and quality requirements form another key topic. Research will focus on factors affecting the delivery of high quality products and consider all aspects of production and processing. Final product characteristics, safety aspects and marker requirements will also be addressed. The anticipated deliverables are:

- A better scientific and technological basis for the development of new or improved products
- Detailed data on life cycle and recyclability
- Cost analysis
- Safety and product performance

When considering non-food uses of biological materials, the Framework Programme concentrates on the market, the factory and raw materials.

Market

The production and sustainable use of biomaterials such as bio-plastics and composites, or bulk and fine chemicals, with enhanced raw material quality and end-use performance, will be demonstrated and supported by market and life cycle analysis studies. The results will be applied in the promotion of standards, codes, guidelines and databases for the consumer and end-user.

Factory

Biological, physical, and chemical processing and modification of biological raw materials producing large volume or higher added value chemicals polymers, composites and biofuels will be developed. At the same time, improved processing technologies that enhance the recovery of purer products for recycling and allow the recovery of potentially valuable components for reuse, will be sought. Both these activities must address the problems associated with scale-up processes, with the adaptation of conventional material processing technologies, and with the modification of functional groups, along with the processing of wastes.

Raw materials

Biological materials matching industrial requirements with respect to quality and security of supply need to be developed. Yields of valuable molecules will be maximised with an emphasis on molecular farming and storage systems that preserve and increase the recovery of valuable components. This initiative includes concern for 'near point' production processing technologies, which add value, reduce transport costs, and improve resource potential utilisation.

Paving the way for renewable raw material resources

Beyond the Fifth Action Programme, some national governments are also engaged in enlightened research in support of non-food agriculture and sustainable production. The Austrian Federal Ministry for Science and Transport, for example, has commissioned two studies which demonstrate that the burden upon the environment is relieved by the use of renewable raw materials as basic substances, although this is highly dependent on the type of technology and raw material used.

The first study ALCHEMIA-NAWARO reports on research and production methods aimed at stimulating a new political platform for discussing the use of renewable substances and soft chemistry (Machwitz, 1997). The study asks how to make renewable resources last whilst exploiting them and explores new production and exploitation methods that would enable us to fulfil our material needs even after fossil resources are exhausted. It also examines basic principles, future perspectives and limits regarding undesirable trends in bio-genetics and soft chemistry.

The other study concerns renewable raw Materials used as basic substances in Austria' (Krotschek, 1997). It sets out to demonstrate that non-invasive technologies for the production of recyclable materials and highly specialised structures such as those present in renewable raw materials, represent a key-technology of the future. The study explores the idea of 'hyper tech', which involves the integration of high tech measures (such as biotechnology and complex controls), as well as nature itself, into a highly effective synthesis factory. The study also argues that a recycling economy based upon renewable raw materials is more complex than today's economy based on fossil fuels. The research identifies a great variety of applications for the 'cascade of materials' concept that demand improved organisation of supply and disposal channels. It recommends that this approach should fully exploit existing ecological opportunities in a sustainable manner. This area, the study says, will be of high importance for future technology policies. However, in addition to ecological opportunities, there is the opportunity to initiate new organisational networking structures for the promotion of technology to improve product line development and regional co-operation. Such networks are considered to provide a fundamental platform for the lasting development of renewables. The study suggests a number of measures in order to reinforce the use of renewable materials in Austria such as co-ordinating in technology clusters and implementing new financing systems.

The plant as a prototype of soft technology

Austrian researchers involved with renewable resources are also exploring the idea of the plant as a prototype of soft technology. They propose that only raw materials managed from renewable resources can supply the organic resources needed globally in a medium and long-term period. This supply will serve as the input for soft chemistry by using safe and readily available substances and structures of primary and secondary metabolisms, such as cellulose, starch, lignin and chitin.

Natural fibres, such as flax and hemp also play an important role if cultivated and processed as considerately as possible. In this respect it is not only essential to have bio-genetic raw materials continually available, but also to produce products from raw materials organically so that they can be entirely returned into the natural cycle after their use. The starting point of the soft chemistry approach is that before developing a new material it is essential to look for a bio-genetic substance which by itself already has the structural, physical and chemical properties required.

Oil plants are especially suitable in this respect. The oils from the seeds of these plants contain fatty acid structures and other valuable substances that can be used as a basis for the production of a variety of products. After the extraction of the oil, the seeds may be used as animal food.

In addition, biologically active substances exist which result from secondary metabolisms in plants and can be used for specific purposes according to their natural properties. These substances include: colouring substances, resins, tanning agents, waxing agents, essential oils, repellents plant hormones and pharmaceutical substances.

The Austrian studies emphasise the need for basic political and economic conditions to be in place for the development of new product lines based upon renewables. With the right conditions in place, the Austrians envision a cyclic renewables based economy in which the recycling of biomass has a central role. If implemented such a system will demand new and innovative technologies.

Environment, health and safety

In developing a renewable resource based economy and its supportive technology it is essential that attention is given to their impact on the internal and external environment, the health of workers and consumers, and that safety is ensured.

In dealing with synthetic chemical substances based on fossil resources we have found a real need to develop strategies which deal with the diversity, characteristics and proliferation of these substances and their impact on human health and the environment. Various problems have arisen affecting the food-chain, public health, workers' health and environmental pollution problems. The problems caused by dioxins, phtalates from PVC, allergies, hormone-like substances, volatile organic compounds and CFCs (for example) have underlined the importance of preventative action and, more fundamentally, of the precautionary principle in the design and development of new materials and substances.

Already existing environmental and health consequences will continue to be articulated and new ones will undoubtedly emerge as renewable resource based substances are increasingly used and developed. The transition between the old and the new production systems will lead to the generation of side effects from combinations of their sub-systems. In addition, basic properties of renewable resources and the substances, materials and structures derived from them are likely to pose some problems of their own with respect to environment, health and safety (EHS). Four levels of impact upon EHS can be identified.

First level

The first level of potential EHS-effects has its origin in the natural properties of plants and plant based substances, materials and products. Plants contain all kinds of substances that can cause allergies, are toxic, or may damage human health in other ways. Plants may contain enzymes, moulds, micro-organisms or insects that can affect the health of workers and consumers.

Second level

The second level of EHS side-effects is technology induced and occurs during the processing of plants and substances and the materials and structures derived from them. Typical examples of this are the release of first level substances, the reduction and release of natural fibres, the increase in concentration and exposure to micro-organisms, and the potential accumulation of dust in processing and storage that might cause dust explosions.

Third level

The third level of potential effects has its origin in the design of the technology applied to the renewable resource base. Like the well known global pollution problems caused by pesticides, CFCs and dioxins, the new substances, materials and structural products emerging from technologies such as combinatorial chemistry, advanced materials technology and genetic modification of plants are likely to cause unexpected negative side-effects. These side effects can either be totally avoided or at least minimised if EHS considerations and requirements are incorporated in the very early stages of the design process. This general precaution will remain valid as existing fossil based resources are gradually replaced by renewable resources.

Fourth level

Finally, a level potentially exists in which several components of the preceding levels are combined, either intentionally or unintentionally, reinforcing or increasing the ways in which human health, safety and the behaviour natural systems are negatively affected. This is the level of synergetic, largely unknown, unexpected and unanticipated potential side effects. As these effects tend to be more systemic and serious, attempts must be made to anticipate and avoid them as far as possible

Need for greater understanding

The research for this report discovered that very little information is currently available on the potential EHS effects of natural materials such as plant fibres, whether relating to their natural properties, properties occurring during and after processing, or those of the fibres in the resulting materials, composites and products. If this kind of information does exist it is certainly not widely accessible. Consultation with several Dutch, European and international experts has confirmed the lack of data, information and insight in these matters. Clearly, in the transition to the development of new substances, products and materials from a renewable resource base, this should be an area of increased attention for all products and the fibre based ones highlighted in this report.

The plant as a source of fibres

It is expected that in future fibres produced on agricultural land will contribute significantly to the world fibre supply. Such fibres might come from residues or from dedicated fibre crops harvested annually. Long fibre crops such as flax and hemp have particular promise in the E.U if production costs are competitive with countries producing fibre in the Third World. However the European countries may require a technological edge in processing to realise this competitiveness. The following table shows the most important sources of plant fibre used globally. The list is not exhaustive as it ignores the fact that much of the wood is used as fuel. Also it does not include fibrous residues such as straw which are sometimes used in the same way as the fibre types listed (Bolton, 1995).

Species	Species	World Production	Origin
Wood	(> 10.000 sp.)	1.750.000	Stem
Bamboo	(> 1.250 sp.)	10.000	Stem
Cotton Lint	Gossypium sp.	18.450	Fruit
Jute	Corchorus sp.	2.300	Stem
Kenaf	Hibiscus cannabinus	970	Stem
Flax	Linum usitatissimum	830	Stem
Sisal	Agave sisilana	378	Leaf
Roselle	Hibiscus sabdariffa	250	Stem
Hemp	Cannabis sativa	214	Stem
Coir	Cocos nucifera	100	Fruit
Ramie	Boehmeria nivea	100	Stem
Abaca	Musa textilis	70	Leaf
Sunn Hemp	Crotolaria juncea	70	Stem

Source: *Bolton (1994)*

The list reveals that the use of plant fibres is presently dominated by fibre from trees (wood). It is striking that the textile industry only consumes 1.2 % of the total fibre production. The main crops are cotton, jute and flax.

In his work, Bolton highlights how political instability in recent years has impacted upon the world supply and demand for commodities. He concludes that it seems inevitable that fibre grown on agricultural land could play an increasingly important role in stabilising markets and resource security - satisfying our demand for paper and structural sheet materials in the future. What is less certain is the time scale over which this will happen. Much of this fibre can come from residues such as cereal straw. It is clearly also possible to grow crops entirely for fibre on agricultural land. Bolton considers annually harvested fibre crops as much more desirable than planting trees.

For annually harvested fibre production to be an attractive proposition, Bolton presents three essential requirements:

- That the material will be produced at a large enough scale,
- Low price,
- Fibre characteristics are suitable for the end use.

It is also important that there should be a proven technology available for processing the new raw material. Bolton concludes that the industries producing commodities such as paper and sheet materials from wood are also likely to be the largest users of annually harvested plant fibre grown on agricultural land. The scale of wood fibre activities is such that even a small percentage drop in the supply of wood fibre could create huge opportunities for agricultural fibre. If annually harvested fibre begins to become an important resource, Bolton suggests that we might make greater use of the natural properties of trees. We could make greater use of our forest resource as a fibre buffer or 'bank' - as it is seldom a financial disaster if they are not harvested in a particular year.

Agricultural fibre supply for pulp production

In the use of renewable resources for material purposes the exploitation of fibre is dominant. This is especially true in the case of fibre from wood, with paper as the main application as can been seen in the table above.

Some researchers believe that using tree fibre for paper production is a poor use of trees as they are more appropriately used in applications of a structural nature; such as beams, furniture making and window frames. Researchers are therefore exploring the potential of fibre crops for papermaking.

According to Wong, the North American production of paper based on agricultural fibres has been very limited for more than 100 years. The total production is approximately 250.000 ton annually, accounting for only about 1 % of total pulp production in North America. The main agricultural-fibre grades consist of cotton (linter and staple) pulp for special printing and writing paper; flax pulp for cigarette paper; and abaca pulp for tea bag and other filter papers (Wong, 1997.)

Wong argues that there is a renewed public interest in the use of ordinary paper made from agricultural-fibre pulp. The reasons include preservation of the natural forests, elimination of air pollution from straw burning, new economical fibre sources, rural economic development and the reduction of farm subsidies.

He calls papermaking pulp made from annual plant fibres 'agri-pulp'. Hybrid poplar and bamboo are excluded from this definition because their growing and harvesting cycle is not annual. The fibre supply for agri-pulp production may be secured from agricultural crops which are either purpose-grown for fibre or for food, in which residual straw would be the fibrous raw material for pulp production.

The practice of cropping purpose-grown fibre is similar to the practice in traditional tree plantations. Land is deliberately set aside for non-food uses. Kenaf, hemp and switch grass are examples of purpose-gown fibres. Wong observes that cultivation of such fibre crops for paper making is presently uncertain and expensive. Large-scale plantations are needed for a supply of these fibres that would be sufficient to meet existing wood pulp mill industry requirements. A typical modern pulp mill producing 1.000 tons/day would require about 690.000 tons (dry basis) of fibre feed stock annually. Assuming continuous cropping, the required purpose-grown fibre cropping land base would be at least 50.000 hectares annually.

In Wong's view, the disadvantages of annual fibre crops are that they require herbicides, insecticides and fertilisers just like tree fibre crops, and that they raise the moral question of whether to use agricultural land primarily for growing food for fibres. He then points out the advantages of food grain production that provides both food and fibre from the same hectare of land. No new allocation of land for cropping is required and no additional fertiliser, herbicides and pesticides are needed.

In North America, cereal straw is the most abundant agricultural cropping residue available. Straw availability can be estimated from annual grain production. However, utilisation of agricultural cropping residues such as straw should follow strict soil conservation practices. Open field burning is currently disposing of most of the surplus straw. Considerable air pollution (in the form of undesirable particulate matter) is produced in such post-harvest activity. The crop variety grown, local climate, soil conditions and cultivation practices will determine the amount of straw that can be produced for non-agricultural purposes. Wong concludes that usage of surplus straw could alleviate the paper industry's fibre shortage almost overnight. Agricultural cropping residues are currently the only readily available source of fibre for agri-pulp production. Its aggregate quantity of 260 million tons in North America could have a significant impact in reducing forest-based wood usage for paper manufacture.

Alternative fibre for making paper

In their study on the effects of alternative fibres on global fibre supply, Mabee and Pande note that, as we move into the twenty-first century, the global fibre supply will change extensively. The intense competition for resources between corporations and countries around the world means that alternative fibre sources such as recovered non-wood fibres, will become more prevalent and desirable. At the same time most industrialised countries are becoming increasingly concerned about deforestation and the impact of fibre extraction on the environment. This has resulted in widespread support for the practice of more sustainable forms of forestry, and has provided impetus towards the development of alternative fibre sources. Mabee and Pande define non-wood fibres as non-woody cullulosic plant materials from which paper making fibres can be extracted. The most widely used non-wood fibres for paper making are straws, bagasse, bamboo, hemp, kenaf, jute, sisal, abaca, cotton linters, and reeds. Most non-woods are annual plants that develop full fibre potential in one growing season. The emphasis of the report is on establishing and analysing baseline data and preparing outlook scenarios for supply and utilisation of recovered wood and virgin/recovered non-wood fibre (Mabee, 1997).

Chapter 2

Resource potential of a plant

Although this report draws attention to fibre crops it is important to note that sustainable production requires a more holistic approach to crop exploitation. This means that the whole plant must be fully utilised by any sustainable production SME or group of SMEs whether their primary product is food, feedstock or fibres. The intention of the companies should be to use the full 'resource potential' of the plants that provide the raw resources for their industry.

The concept of resource potential considers plants to be a natural material system. They are part of a natural ecosystem and their function is to contribute to the overall functioning of the ecosystem concerned. From a natural resource point of view, a plant is a material object that can provide a collection of functions or potential uses to humans. As a natural material system or through its sub-systems it can fulfil certain functions that are useful. Thus, to humans it presents a certain resource potential. For example, plants fix carbon dioxide and produce oxygen vital for life; they house animals or insects that are valued by people; they may retain drinkable water and prevent erosion; they may also bear edible fruits or leaves that can be picked. When the extent of that fruit or leaf picking remains within certain boundaries - which is sustainable picking - then the plant concerned may serve several of its functions for many years. This will, of course, depend on the character and the life of the plant.

The 'resource potential' of a plant consists of the levels of its different potential uses. The character of its resource potential depends on the number, variety, complexity, combinations and uniqueness of the plant and its parts. The observation, recognition and valuation of these levels depend on the observer's reference framework, their knowledge, experience and value system. Humans recognise the properties of plants according to their relationship with them, which is determined by tradition, knowledge and experience.

The beginning of this relationship to plants is in gaining knowledge about its properties as a living organism and as an element of an ecosystem. These properties might be ones that people require. It may also be that other properties can be provided by the plant after it has been subjected to some kind of technology. This technology may either make a certain plant properties accessible or it may articulate, change or isolate certain properties. These then, through technology, can be further developed.

Thus, in addition to different properties and potential uses of a plant, there also are different levels of technology application. From a technology point of view, several levels of depth of treatment, intrusion or transformation can be distinguished that will respect, adjust or fundamentally alter the plant.

One way of identifying the various properties and potential uses of a plant is to focus on the property of edibility, which has been done through the ages. Another is to take structure as a dominant feature, which is also often done. The macro-physical structure concerns the biggest or strongest structural features presented. Different structure levels usually identified are the whole plant, the stem and the leaf. Meso-physical structures also exist in the form of branches or leaves. Micro-physical structures are found at the level of plant fibres, cells, crystals and chemical compounds.

Another approach to the valuation of a plant is to make a distinction in the different potential ways to fulfil elementary needs. A plant may provide food, furniture, fibres, fodder or fuel. Yet another valuation method would be to follow the complexity of the chemical substances that the plant may contain, such as vitamins, medicinal substances, aromatic substances, sugars and cellulose. In addition, several biological functions might also exist, involving oxygen production, the presence of micro-organisms, or the potential provision of enzymes.

From a single living tree, for example, various products can be derived in sequence. A felled tree does not produce oxygen anymore, but its structure can be used, as lumber or sawn timber. The use level of a log may be followed by other levels: log - plank - veneer - chips - wool - fibres - pulp. In this sequence, the resource potential from a physical point of view is decreasing. From a chemical point of view the property sequence can go on: lignin - hemi cellulose - cellulose - glucose - CO2 + H2O + Minerals. The felled tree in the previous sequence has the highest resource potential because the wood produces the largest number of original properties and thus the greatest number of potential applications. Both the most levels and the largest variety of uses are potentially available.

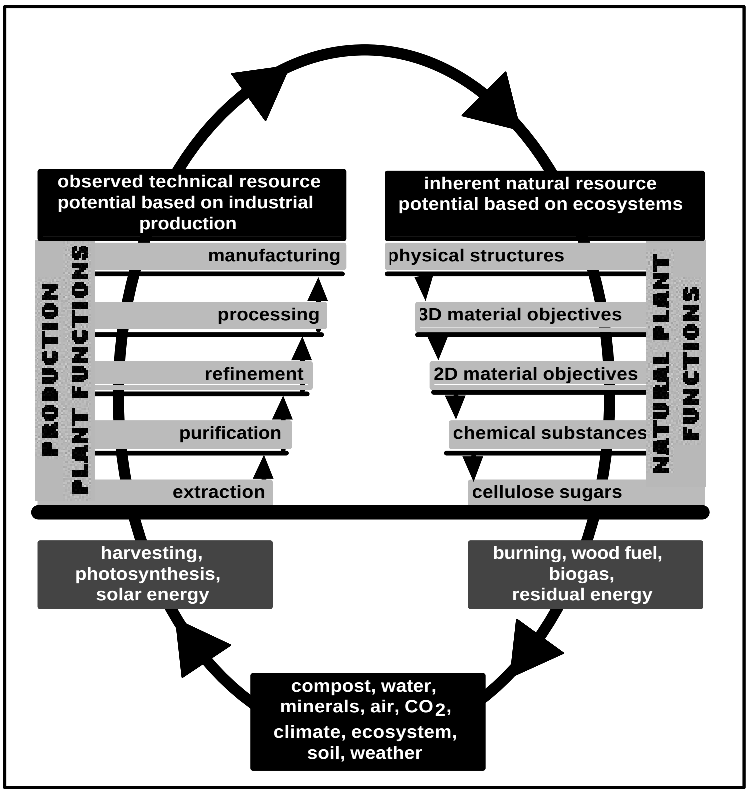
Once wood has been transformed to pulp and has been used in paper and cardboard, a number of applications either become less appropriate or are eliminated. The use of wood for the production of fuel or as a direct source of energy is considered to be the final use of wood. Once transformed into energy, all the other resource options will have vanished. At each and every of the other resource levels, the production of energy from (waste) wood still remains as a last and final option.

However, from a technological point of view, the positioning of activities at subsequently lower levels of resource potential can to some extent also be reversed. For example, it is possible to synthesise sugars from basic molecules, to produce structures from fibres, and to construct large planks by gluing small ones together. Thus certain natural features available at higher levels of resource potential of a plant can be created or emulated through production. Beyond that, of course, a huge diversity of chemical, physical and biological technologies and combinations thereof exist, through which an almost inexhaustible range of industrial products is presented.

Two main approaches can be identified in the use of the resource potential of a plant. The first approach is to start from the highest inherent natural resource potential that the plant can offer, which is its natural functioning in an ecosystem. Then, through production, its natural structure, the structures of its parts and its chemical and energy properties can be subsequently used. Finally, compost, water, CO2 and minerals would remain.

The second approach is to build properties and functions through production by starting at a lower level of observed technical resource potential and building up new potential uses. The 'production' approach involves deconstruction and disconnection, while the 'natural resource' approach involves synthesis and construction. Figure 2 shows the two approaches.

Figure 2: *Two main approaches of using the resource potential of a plant: deriving the natural resource potential and creating the technical resource potential*



Using a model based upon the various resource levels of a natural material system, Pothmann presents a hierarchy specifically for the use of waste materials (Pothmann, 1986). He distinguishes the use of:

- Total characteristics
- Physical components
- Chemical components
- Chemical bonding
- Elementary constituents

At the top of this list is the use of the all the properties belonging to any given waste product. Examples of this would be reusing a cupboard or using a newspaper as wrapping material. At the second level, the physical properties of e.g. paper are used, mainly present in fibres and filling materials. An example is the use of chips in chipboard. At the third level, cellulose is hydrolysed to glucose as a raw material for Ethanol production thus using the chemical components. The fourth level covers the use of energy in the endothermic links within the chemical substances, by using wood as a fuel. The final level concerns wood composting and the introduction of compost into the soil. Pothmann concludes that the hierarchical higher value use of materials is to be preferred.

An illustrative example of the complete use of the potential of a resource is the story about a tree going to Brooklyn (Johnson, 1987). Johnson tells how a fir tree planted in 1920 ends up in 1987 with a bar of soap used in someone's morning shower. What he claims to illustrate is how recycling can work, and that everything we use eventually is returned to the environment, where it is reprocessed and returned to us for further cycles of use. The fir tree was harvested in 1946, and cut into building timber. It was part of a building, which after some thirty years was demolished. The wood studs cut out from the fir tree had been turned into waste, and were processed into a wood chip fuel which was used by a giant soap producing facility. The ash residue from the wood burning was sold for use in blending with topsoil. The major product however was a bar of ivory soap, which decomposed in a water treatment plant: "And the cycle is ready to begin again."

Thus, the resource potential of a plant is the collection of resource use levels and the variety of application options that it represents, which is determined by the knowledge, experience and values of the potential user.

For the use of this resource potential, various concepts exist such as 'Full Use', 'Whole Crop Use', 'Multi-Purpose Use', 'Integrated Utilisation', and 'Total Resource Recovery'. They are presented next.

Concepts for use of resource potential

A natural resource can be used for different purposes. Generally three main functions of plants can be distinguished as a part of a:

- Natural ecosystem
- Natural/cultural ecosystem
- Human-made production system

Among the plant species, trees are very complex life forms. They are varied with respect to their physical structure, different parts, and diverse chemical composition. To the tree and potentially to humans they can fulfil a variety of different functions. Therefore they provide attractive opportunities for multi-purpose use. However, the same structural, physical and chemical functions and properties also exist for other plants such as agricultural crops, or as in the case of this study, fibre crops.

Thus, the resource potential of a plant is a fundamental concept. The resource potential of a tree, shrub or plant is formed by its natural characteristics and by the observed potential of use of the species concerned, which depends on the reference frame of the observer, consisting of values, knowledge and experience. Based on this understanding, several types of plant use can be distinguished to exploit that resource potential. They are discussed below.

Multi-purpose use

When a tree or a plant actually is used for several purposes at the same time, subsequently in a certain period or at various stages of its life, this is called the 'multi-purpose' use of the plant. It is a sophisticated manner of using a plant when its various parts and their components are used for both food and non-food purposes. An example is the diverse use of various parts of the Coconut tree (Taffin, 1993), and of the Neem tree (Agarwal, 1996).

Integrated utilisation

When the non-food processing and use of various plant parts, their components and products derived from them is predetermined, systemic, combined, and linked, this is considered to be the 'integrated utilisation' of that plant. This systemic use of a plant involves the combined natural, social and economic functioning of a plant for a community. An example is the use of the Jatropha plant in Mali. The wood and fruit of Jatropha can be used for numerous purposes including fuel. The seeds of Jatropha contains viscous oil (50% in weight), which can be used for manufacture of candles and soap, in the cosmetics industry, for cooking and lighting, either on its own or as a diesel/paraffin substitute or extender. This latter use has important implications for meeting the demand for rural energy services in West Africa and for exploring practical substitutes for fossil fuels to counter greenhouse gas accumulation in the atmosphere. Despite these characteristics, the full potential of Jatropha is far from being realised. In a workshop organised in 1998, the potential market for various Jatropha products was examined, the value of these products to the rural population was assessed, optimum combinations for their use were determined and a strategy was proposed to maximise rural development, energy equity and employment (Henning, 1998).

Whole crop use

The whole crop use of a plant is its total use, either by diverse use of all parts of the plant or the single use of the plant as a whole. In the latter case its complete structure is used. It concerns its complete non-food use, in which its total structure - from the roots to the top - remains intact. One example is the whole crop use of Jute, in which the whole plant, roots included, is used for application in furniture. This was practised in a project of the National Productivity Centre of India.

Total resource recovery

The total resource recovery of a plant is the full use of a plant or part of the plant based on the design of a complete recovery process aimed at achieving the highest efficiency. Thus the plant is not only considered as the bearer of a particular substance to be recovered, but as the bearer of everything else it contains. The total recovery concept involves the design of methods to recover the principle substances and as much as possible of the other components, preferably on an economic basis. This concept is particularly known in the area of mining but could also be applied to plants. The focus then would be on its chemical substances content (Van Weenen, 1990; Lambert, 1985; Marijnissen, 1984; Marijnissen, 1988).

Usage classification of resource potential

Of course, differences between species exist that will influence their resource potential and how they can be compared, valued or classified. In the West-African country of Benin, for example, various natural materials are used to fire cooking pots: people use trees, branches, leaves, coconut shells, husks of palm fruits, charcoal from wood, and wastes from palm oil production. These natural materials all have their own specific energy content, to which the energy applications somehow could be matched in order to realise the best possible usage at the potential resource use level presented.

Clearly many different approaches exist and various ways can be identified in which sequences of use levels of plants can be classified. Below some of these classifications are presented.

Classification of properties

- Total collection of properties
- Main properties
- Specific properties
- Combination of properties
- A particular property

The total collection of properties of a tree, shrub or plant may be of interest for the user. More frequently, however, only some major properties will determine its use value. It is even more common to only focus on specific properties, such as the production of plant oil, or the extraction of plant fibres. In addition, some typical combination of a few properties may be decisive for the choice and the use of a plant. Finally, only one very particular property might be dominant in the use of a plant, as it may for example be the source of a very specific chemical substance such as a poison or a medicine.

Classification of quality and number of properties

A similar, broader classification would be one in which quality and number of properties are expressed. This would lead to the following matrix of options:

		QUALITIES	
		Common Properties	**Unique Properties**
NUMBER OF PROPERTIES	**Many properties**	Many and common properties	Many and unique properties
	Few Properties	Few and common properties	Few and unique properties

From a point of view of deriving as much value as possible from a plant, a hierarchy of preference of resource properties could be:

- Many and unique properties
- Many and common properties
- Few and unique properties
- Few and common properties

Classification by scientific disciplines

- Physical structure
- Biological composition
- Chemical composition
- Energetic composition

A more traditional distinction would be based on scientific disciplines, usually leading to a more reductionist approach in which the focus is on very specific parts or elements of a plant, while neglecting the overall potential that a plant may present. The physical structure can be of interest because of the strength of the plant concerned, the flexibility of its stem or the strength of its fibres. The plant's biological composition concerns its ability to function as a source of enzymes or of micro-organisms that it contains or for which it is a natural substrate. The plant's chemical composition may be of interest when it is considered as a small chemical factory, or as a small bio-refinery. Finally, the plant contains substances of varying caloric value. Seeds that contain oil will have a different energetic potential than the leaves of the plant.

Classification by plant parts

- Fruits, Nuts, Seeds, Flowers
- Leaves, Buds
- Branches, Twigs
- Trunk, Stem, Stalk
- Roots, Tubers

Here, the focus is on the direct use of the main parts, in which the plant's dominating features dictate the main applications. This classification is a very general one for the identification of the main parts of a plant. The parts themselves may produce edible material or substances, or be wholly edible. They can be interesting because of their potential in construction or in making three dimensional objects, they may serve as a source of chemical substances, provide energy, or serve as the raw material for the production of e.g. compost.

Classification within a plant part

- Whole Fruit or Seed
- Husk
- Nut
- Oil

Within a fruit or seed, different levels or types of resource use potential may be distinguished. An example is the olive, which consists of the fruit, its kernel and its oil content. Another example is maize-grain. It contains - among other substances - starch, glucose, dextrose, and proteins. Also, the seed of a sunflower consists of various kinds of materials and substances.

Classification by application of a plant's parts, materials or substances

- Non-durable consumer goods (e.g. packaging)
- Durable consumer goods (e.g. furniture)
- Producer goods (machinery and tools)
- Means of transport (e.g. cars)
- Building purposes (e.g. houses)
- Infrastructure purposes (e.g. roads)

In this classification by application of a plant's parts or constituent materials or substances, each sector encompasses a variety of products.

Classification of plant based materials

- Structural materials
- Fibres
- Oils and fats
- Plastics
- Composite materials

Yet another classification is based on a distinction in the different kinds of materials that can be made from renewable resources. It encompasses classes such as structural materials, fibres, oils and fats, plastics and composite materials. Materials from these classes can also be used in various combinations.

Classification by resource potential utilisation

- Ecosystem
- Three-dimensional structures
- Two dimensional structures
- Fibres
- Chemical substances
- Raw materials
- Residual energy

A categorisation of renewable material resources can also be based on different forms of resource potential utilisation. In general, renewable resources can be utilised as:

- part of an ecosystem (e.g. for fruits or recreational purposes)
- three-, or two-dimensional physical structures (e.g. timber, poles, veneer)
- fibres (e.g. cotton fibre)
- chemical substances such as oils or fats (e.g. palm oil)
- raw materials at a molecular level (e.g. starch)
- biochemically converted (into biochemicals, e.g. into methane, or into bioplastics).

These utilisation forms are related to different pathways from resource to utilisation as shown in Figure 2.

Finally a more general classification can be applied both for different types of resources and for different types of utilisation, as is indicated in the following table.

TYPE RESOURCE	UTILISATION
Trees and shrubs	Information from nature, making soft wood hard, natural pesticides
Agricultural fibre and oil crops	Geo-textiles, composite materials, natural paints and varnishes
Roots and tubers	Bioplastics
Other plants and applications	Bioplastics
Agricultural waste	Paper, compost, energy
Organic waste	Bioplastics

When a plant is holistically considered as a system, then clearly all kinds of applications could be identified that otherwise would not at all or less likely be acknowledged, used and developed. If an interest only exists in the potential of one particular component of a plant, such as a chemical substance in an oil seed, than the potential of other components of the seeds and of the plants can easily be overlooked. The remaining potential should rather be considered within the bigger framework of a systematic scheme of resource assessment, valuation and usage.

The plant as a source of inspiration

The plant itself may provide all kinds of insights or clues about ways in which its substances and materials can be used, either independently, in combinations, or in an overall systematic approach. A plant may provide starch or sugar, in addition to fibres. In the plant itself these components can usually be found in some kind of embedded structure. It might be possible to take the starch and transform it into a material matrix while using the plant fibres as reinforcement material. Thus, a renewable resource based composite material could be produced with identical or similar properties to the material structure in the plant itself. In this case, it would become transformed into a structure of a larger size in the form of an adapted technical structure that meets certain application requirements. The product would have similar properties to the plant materials in their original setting. For example, it could provide structure, strength and flexibility, properties for all kinds of technical applications.

Chapter 3

Fibre crop examples for a sustainable production SME

This study is intended to highlight fibre crops that can be used to explore the potential of sustainable production SMEs in the EU. The crops concerned will be treated as models to stimulate debate on the issues and exemplify practice. The choice of crops does not imply an unconditional preference for the crops selected, as it is likely that most of the principles expressed through the model crops will also apply to any other available crops. The availability and potential of a particular crop will vary according to conditions such as climate, soil quality, available technology, culture and tradition, and the social-economic system.

Globally, there are many fibre crops with potential for small production units such as: agave, cassave, crambe, cuphea, elephant grass, fibre hemp, flax, bamboo, guar, guayule, jojoba, kenaf, lesquerella, maize, meadow foam, oil palm, peas, plantago, potato, pyrethrum, rape seed, safflower, soybean, Stokes aster, sugar beet, sunflower, vernonia, and wheat.

However, most of these crops are not suitable for the conditions that prevail in the E.U. Some of the crops that are most likely to do well as a model crop are well known, especially flax, hemp and maize (corn). Flax is an old and traditional crop, hemp is an old industrial crop that is currently being rediscovered, and maize is largely produced as animal feed but is also used for biopolymers and biofuel production amongst other things. However, bamboo, maize, grass and the stinging nettle offer a more surprising insight into the potential of crops for sustainable production.

The range of fibre based products that can be made from different crops is substantial. Some of these crops are commonly known and are of little surprise. For example, novel applications for flax fibres in non-textile markets now exist, including packaging materials, reinforcements for plastics and concrete, lining materials for the automotive industry, alternatives for fibreglass reinforcement in composite materials. These applications utilise shorter fibres, which are not acceptable for textiles.

These crops are described in more detail next (all pictures in the following section are sourced from the website of NF-2000, 1999 (http://nf-2000.org).

Flax and Linseed (Linum usitatissimum)

The plant species Linum usitatissimum is grown in two notable forms: as flax for its fibre qualities and as linseed for its oil.

The plant is an annual, forming a short tap root. It may grow to a height of 120 cm, but varieties grown for oil production are usually considerably shorter at maturity. The stems are thin and wiry, the degree of branching depending upon plant type and density; the leaves are unstalked, small, narrow and pointed and dark or greyish-green in colour. Linseed flowers are commonly bright blue. For both the fibre and the oil crop, a fine and firm but uncompacted seed bed is essential for even establishment, sowing taking place when the soil is sufficiently warm in spring.

Flax is sown thickly in narrow rows, to obtain a close stand of up to 2000 plants per square metre, thus minimising basal branching and so improving fibre quality; sowing rates for linseed are lower, the objective being a plant density of about 500 plants per square metre. Soil phosphate and potash status should be good for both crops, but nitrogen requirements are low at 75 kg per ha, for linseed when applied to a young crop. Flax is frequently given no nitrogen in order to discourage sappy growth. Neither crop is very competitive with weeds, however, some herbicides are available to alleviate this problem. Pesticides are also required to control fungal diseases and insect pests.

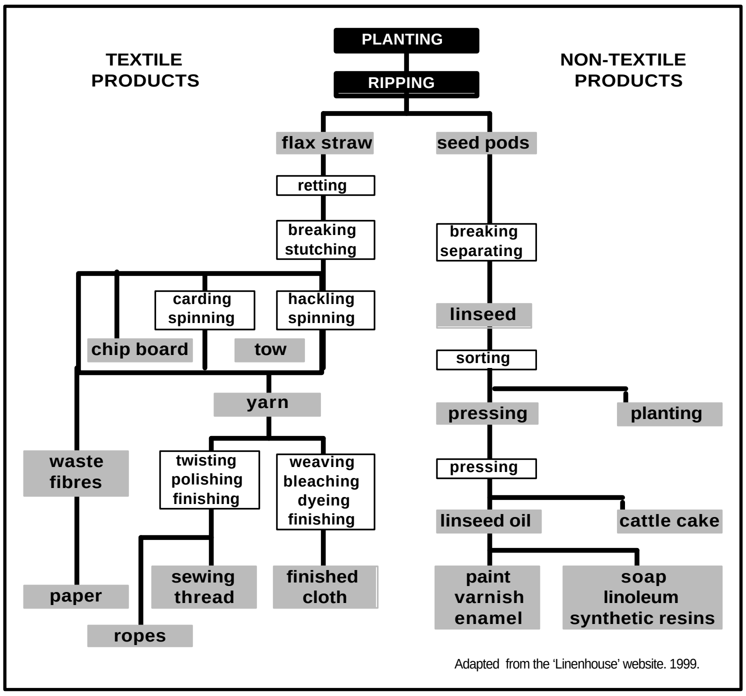
Flax crops intended for best quality fibre are pulled when the lower leaves have fallen. The pulled flax is then retted (this is a controlled rotting process), and scutched (to separate the loosened fibres from the bulk of the stem tissue), yields of fibre normally being in excess of 1 ton/per ha. Linseed is harvested when the capsules are ripe and yields of 2 tons/per ha are generally obtained.

The long fibres of flax provide the basic material for the production of linen but can also be used for a variety of high value materials for industrial application such as filters vessels, insulation material, light weight and strong plating materials for car interiors, and geo-textiles (Smallegange, 1992). Flax is an extremely high value fibre because of its light weight, its strength, environmental friendliness, and versatility, to name just a few of its attractive properties. However, in the recent decades flax has hardly been used by industry, perhaps due to a general lack of knowledge about the plant.

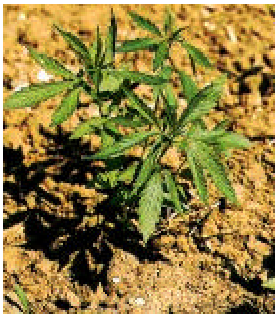
Dual purpose crops are now being grown for fibre and oil. The dry straw of the plant is mechanically processed to produce relatively short flax fibres that may be used in the manufacture of specialist papers, composite materials, and biodegradable matting products. By-products of oil extraction such as protein flours and mucilage are finding increasing application in the food, cosmetic, and pharmaceutical industries. Winter-hardy varieties of linseed, and also yellow-seeded cultivars with altered fatty-acid profiles, are being introduced to commercial cultivation; the latter are intended for edible oil production but industrial uses are also possible.

Figure 3 shows just some of the many opportunities that exist for exploiting flax fibre and oil.

Figure 3: *Production stages and product possibilities from Flax oil and fibre*



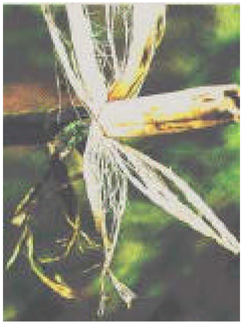
Hemp (Cannabis sativa)



The hemp plant is a herbaceous annual with a deeply penetrating tap root. The main stem is erect and may attain a height of up to 4 m. in fibre types. The degree of branching varies with the closeness of planting. The stalked compound leaves each consist of up to 11 leaflets, radiating from a common centre - each leaflet is pointed and has a lightly serrated edge.

Flowers are in groups on the upper portions of the plant. Male and female flowers may occur together on the same plant, but in many varieties occur on separate unisexual plants. The male flowers are individually small, usually cream or pink-tinged; female flowers are green and unobtrusive. Generally, female plants tend to be larger than male ones, the latter ceasing to grow and maturing after flowering. Successful hemp culture requires a deep, well-drained soil and the absence of frost during early growth. Seed should be sown thickly, to establish a population of 150-200 plants per square metre. This encourages straight growth of stems and an absence of branching, improving fibre quality and aiding weed suppression. Nitrogen fertiliser may be required at a rate of up to 125 kg per ha, while phosphate and potash needs may be met by application of 50-75 kg each per ha. No pest or disease problems have yet become apparent.

For best-quality fibre the crop should be cut at flowering (usually during August), and treated so that field retting can take place.



The fibres are loosened from the central core of the stem, which may take several weeks. The yield of dry stem may be 7-12 t per ha, with a fibre content of approximately 25 percent. Breeding and research work is currently being undertaken in several European countries, including studies into utilisation of the crop. For example, in the United Kingdom, the pith in the centre of the plant stem is being marketed as an absorbent and easily compostable bedding material for horses. The current emphasis is on the development of distinct markets for the long fibres in textile mixtures and as reinforcement in building materials.

Bamboo

Bamboo is a plant with remarkable properties and plays an important role in the daily life of about 2.2 billion people mainly in Asia. Different species of bamboo are established in all parts of the world except in Europe where they did not survive the last glacial period. It is estimated that 1200 species are spread over the world. The total area represents about 18 million hectares with 3 million in China and a further 8 millions in India. The interest in bamboo has increased worldwide (since 1980) and numerous international meetings are organised on an annual basis.

Since the first introduction of bamboo in Europe (1827), about 400 different genotypes have been imported. With suitable management procedures, bamboo can produce an average of 10-15 tons/ha dry biomass annually. In the South and North America, extensive trials have been implemented allowing the study of important aspects such as mechanical harvesting.

In introducing bamboo as an economically viable and suitable crop for sustainable production in the EU, major questions still have to be resolved. Namely, how to integrate it into non-food agriculture, the industrial production of bamboo in Europe and market its potential. To this end, nine partners from five European countries have taken up the challenge, and three independent experts will assist in resolving problems as they occur (NF-2000, 1999).

Nettle (Urtica dioica)

The nettle is commonly known as a weed but has interesting fibre possibilities and is currently being explored in two FAIR Programme projects:

- FA-S2-9215. Nettle - reintroduction of stinging nettle cultivation as a sustainable raw material for the production of fibres and cellulose.
- FAIR5-CT97-3784. Optimisation of the production chain for high performance "light natural sandwich materials" (LNS) as a basis for scaling-up.

The first project explores the exploitation of nettles for textiles by a consortium of five SMEs. As is common with many of the crops suitable for sustainable production, little is known of their

production potential. Currently, there is a general lack of knowledge regarding technology and production systems to realise the full potential of the plants for fibre use. In some cases, this is a case of lost knowledge. The nettle was first cultivated for textile purposes in the Middle Ages, when nettles were the primary raw material for producing fibres and fabrics in Central Europe, along with flax and hemp. Today, laboratory production and processing of nettle fibres have shown that their fineness is suitable for the production of very fine fabrics that feel particularly comfortable against the skin. It has also been found that this very fine material has the positive characteristic of warming the body in the same way as wool. Nettle fibres are therefore ideal for the manufacture of clothing fabrics and bed linen. However, in order to be able to assess the economic potential of this raw material, research will be required in the areas of fibre production and processing. The fibre itself is twisted and forms a bundle in the plant. For this reason, special industrial methods will be necessary to ensure that fibre extraction produces a competitive and high quality raw material. One of the benefits of growing nettles for fibres is that it thrives on nitrogenous and over-fertilised soil. It would be a very useful alternative that could add a completely new aspect to agriculture in Central Europe if it were accepted on the market, resulting in additional jobs; independence of imports and reduced transport distances.

Bredemann (1959) gives the required number of cuttings for one hectare of land in the case of different planting widths. Because of the spacing between rows it is possible to multiply the number by the average dried stalk weight and obtain the stalk yield per hectare. Thus calculated, the nettle straw yields are between roughly 6,000 and 9,000 kg/hectare. The production figures for the fibre nettles obtained give a fibre yield of some 750 kg/hectare with a simultaneous yield of 4,500 kg/hectare of woody matter or 2,000 kg/hectare of cellulose. These figures speak for the fibre nettle, especially as these values have already been achieved in the short research period since 1993. As far as can be judged at the present time, the mechanised processing of nettle fibres is certainly a competitive proposition, particularly in what are currently still niche markets for regional ecological products. In Europe, growth rates in the ecological product sector are well above average. PAPTEX's growth record reflects this trend. The expected transport costs alone (a major criterion in the case of ecological products) from regional growing areas are a fraction (approx.1/10) of the costs involved when importing cotton.

Grass

Grass can be used in a process called 'bio-refining' in which the grass is separated into protein, sugar, minerals and fibres. In the Dutch company AVEBE, on this basis several agro-products have been produced such as yellow-green grass paper, grass fibre board for construction and fibrous grass wool which possibly could be used as a substrate for plant growth. In addition, the grass refinery produces fertiliser, alcohol, feed stock and eventually it might even produce food. In the bio-refining process, freshly mown grass fist is intensively worked on. Then the fibres are freed mechanically. They comprise about 30% of the grass. What remains is a grass soup with sugars, proteins and minerals. The proteins, about 20% of the grass, are flocculated together by treating the soup with overheated steam. Subsequently the sugars, 15% of the grass, are fermented to ethanol, which can be isolated through a distillation process. Finally, minerals such as phosphate and potassium can be derived from the grass and send directly to a fertiliser industry thus further closing the cycle in cattle farms. If desired, the grass soup can be thickened to become a green strong feedstock that might present important savings to the farmer. Another 'cycle opportunity' is presented within the grass refining process. The grass fibre cannot only be used as a substrate in agriculture but it can also replace peat. Some of the new applications of grass such as the use in fibre board materials, still have to be further researched. However it still remains to be ascertained whether it can be produced more cheaply than wood fibre board.

Where farmers are rotating crops in production, grass offers an attractive additional alternative. In addition, the production of grass from natural areas is expected to increase. As the market for compost in The Netherlands already is well served, other markets for grass usage are welcomed. Grass is also conceived as a 'mega-biofilter', which can turn low value substances from cow dung into high value protein. Therefore grass processing is considered a more sensible government investment than is cow dung processing (Didde, 1999).

In Germany, Biorefining of grass has also received interest from the research community. In October 1997 the symposium 'Green Biorefinery Brandenburg' was organised. It was focussed on the sustainable production of sustainable raw materials for which ecological technologies were considered to be required. Such technologies should be value added, regionally presentable and use regional resources from a sustainable use of the land. From grass a variety of products would be produced in addition to the traditional feed stock use, such as lactic acid. Through a Biorefinery access would be provided to biodegradable materials, such as foils and surgical materials. Scientist and engineers from Sweden, Denmark, Germany and Austria participated in the seminar (Grüne Bioraffinerie Brandenburg, 1997). The characteristics of the 'Green Biorefinery Brandenburg' project - potentially a regional industrial park - are:

- A residue free use of renewable material resources
- A broad variety of products that can be further processed in a flexible manner
- High flexibility: depending on the market conditions several products can be produced
- Integration of ecological requirements related to regional agricultural requirements (Krotschek, 1997).

Maize

Maize, or corn, is a plant of many uses. It provides seed, food, starch, alcohol, sweeteners, and animal feed. It is generally exploited solely for the cob. The cob is used in many ways, and there are an estimated 3,500 different uses known for corn. Some nine billion bushels are produced each year and the United States of America is by far the world's largest producer. Uses include:

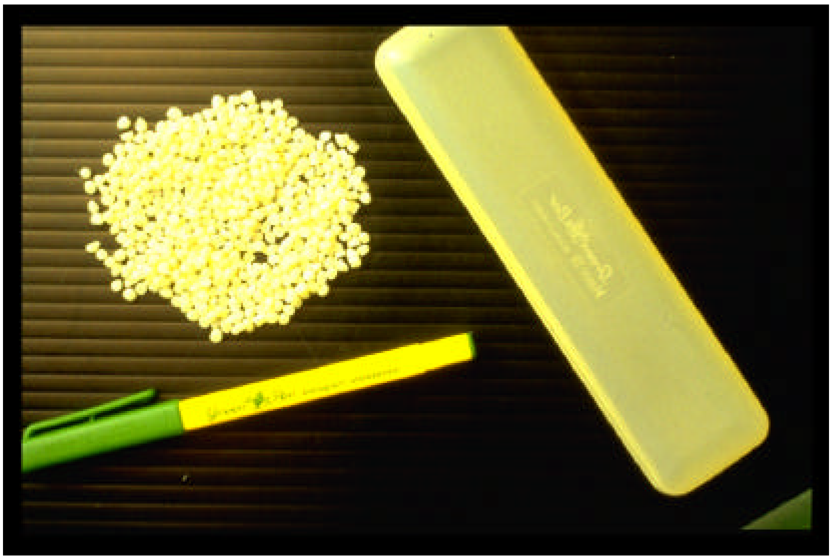
- 0.2% Seed - High-yield hybrids are planted annually.
- 1.2% Food - Americans eat little whole kernel corn, but eat 120 million bushels in processed foods.
- 2.6% Starch - This extract thickens foods and is used in numerous new industrial products such as biodegradable plastics.
- 5.0% Alcohol - Ethanol from corn powers cars and a variety of other engines.
- 8.0% Sweeteners - Corn syrup has replaced imported sugar in a host of products like soda and candy.
- 50.1% Animal Feed - Feed for cattle, pigs and poultry continues to be the largest market for corn.

The U.S. exports 22.6% of its output and provides about 80% of the world's corn. The U.S. holds back 10.3% of stocks at each year's end to provide a sustained food supply in bad crop years.

Different parts of the plant can be exploited for their different properties. Extract from the germ is used as cooking oil. The versatile starch can be a food ingredient, a component in building materials, or can be converted to ethanol fuel or corn sweeteners. The hull, or shell, is high in protein and is an important source of livestock feed. (Ohio Corn Marketing Programme, 1999).

However, maize plants can also be used for their fibres - particularly the stems and husks. Its fibres can be used to make paper, alone or in combination with fibres from recycled paper. Some companies in Quebec, Canada are looking at corn as a future paper-making fibre. In addition, bioplastics, coatings and biodegradable polymer products are made from maize. According to a web-site on corn and the environment, there is an increased demand in the United States for disposable items such as flatware, plates, diapers, milk jugs, razors, and golf tees now being made with cornstarch that completely biodegrades.

Figure 4: *A pen and case made from maize-based biopolymer. The injection moulding granules are top left*



Source: *UNEP-WG-SPD* ©

Several companies have developed these products by using cornstarch-based plastics. Laundry detergents are made with corn-derived citric acid and it is claimed that they have more cleaning power and use less phosphate than traditional laundry detergents (Ohio Corn Marketing Program, 1999). Glue is made from the starch in the seed. This starch is also used in cosmetics and in the manufacture of glucose. A semi-drying oil is obtained from the seed that has many industrial uses, in the production of linoleum, paints, varnishes, soaps, etcetera. Some parts of the corn are already used for the production of paper, straw hats and small articles such as little baskets. Fibres obtained from the stems and seed husks is used for making paper (Bell, 1998). They are collected after the seed has been harvested in late summer, cut into usable pieces and soaked in clear water for twenty four hours. Then they are cooked for two hours in soda ash and beaten in a ball mill for one hour and used to make a greenish cream paper (Plants for a Future Database, 1999).

In Mexico the maize plant is used for food, industry and feed stock. All the parts of the plant can be given to cattle as feed stock. In Belgium it is almost exclusively grown for feed stock purposes. The core of the cob can be used as polishing material, or made into charcoal or alcohol. The stems and leaves of the maize are used in paper production and in the production of explosives. In Mexico, some parts of the plant are used to manufacture dolls, toys and little statutes of saints. Not only the covering leaves are applied for this purpose, but also the cob core and the stems. Handbags are woven from the leaves and they are also used as packaging material and for preparation of all kinds of food. Cigarette paper and rope are still further other maize-based products.

In rural areas some parts of the maize plant are used as toilet paper. Finally, the core of the corn, the stem and leaves are used as fuel. Chopped, the stems and roots are mixed with animal dung to form an organic fertiliser. The stems are also used in the construction of walls and as roof coverage (Ronse, 1993).

Chapter 4

Sustainable production concepts based on resource potential

In Chapter 2 the 'resource potential' concept was explored and examples were given of plants that can be sustainably exploited. This thinking is in contrast to the latest agro-industrial developments which can be viewed as beneficial in some respects (a move from finite fossil based resources to renewable ones) but often over-aggressively implemented. For example, as the agro-industry develops it does so with a model that involves such environmentally undesirable features as genetic manipulation, mono-crop culture and a waste stream of biomass. Intensive farming with pesticides and fertilisers can be added to a list of issues that lead us to a situation in which industries based upon renewable resources are no more sustainable than the ones they seek to replace, which have been primarily based upon finite resources.

However, the implementation of the 'resource potential' concept could also lead to the emergence of a new kind of sustainable production SME based upon fibre crops amongst others. Chapter 2 sets out starting positions on how sustainable renewable resource feedstock, can be realised if designed for, and substantial political, economic and societal resistance can be overcome. However, if the growing cycle of these crops is successfully realised then the raw resources resulting from the growing cycle should be exploited within a model of sustainable production and consumption. Some examples of renewable resource based SMEs already exist and have developed sustainable production and consumption know-how (Van Weenen, 1999).

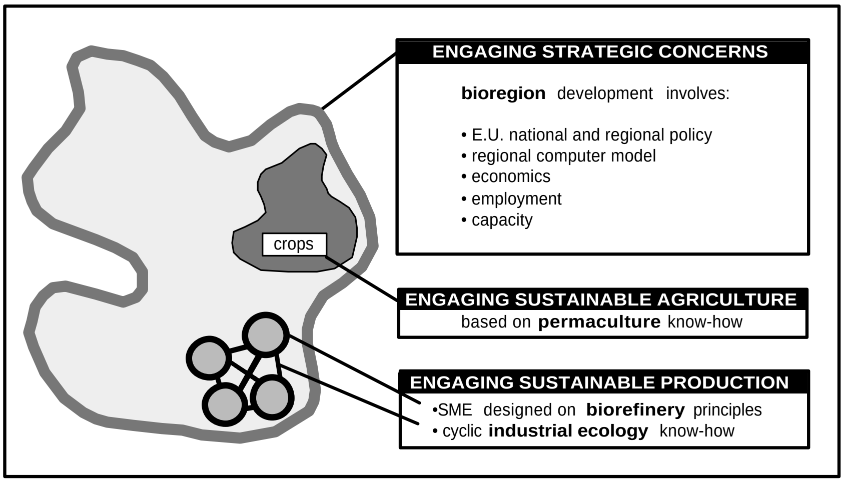
Towards sustainable production

Based on agricultural production of non-food crops, subsequent production can consist of an enormous variety of activities. For example, non-food plants can be used as a whole, or their structural parts can be used for material production, fibres, substances or combined to make 'renewables' based composites. A company may specialise in the extraction and purification of one particular chemical substance extracted from a plant, such as a pharmaceutical compound. The production can also be focused on combining a few plant derived materials. However, the plant can also be considered as a sophisticated and complex holistic system, which should be matched with a similarly holistic production system. This can be done either through a production facility that covers a complex of different production functions, or a combination of production facilities, in a particular geographic area or consisting of a network of different specialised companies. Several concepts involve just this type of integrated and holistic approach regarding the exploitation of plants within a sustainable production system:

- Bioregionalism
- Permaculture (also known as ecological engineering, integrated farming, cultivated ecology)
- Biorefining
- Industrial Ecology

Figure 5 shows how these concepts fit into a hierarchy of concerns:

Figure 5: *Four key concepts for sustainable development*



Each concept has a contribution to make to the sustainable production debate. Broadly speaking the concepts can be divided into:

- Approaches and values with a resource focus. e.g. Biorefining and Permaculture.
- Industrial systems design that mimick processes in nature. e.g. Industrial Ecology.
- Concepts that reinforce the need for local and regional spheres of operation rather than global ones. e.g. Bioregionalism.

Biorefining

For the realisation of sustainable production for renewable material resources, new ecological technologies are required. They should be applicable at a regional level and suitable for the use of regionally available resources derived from sustainable agriculture. The objective is to realise regional sustainable economic processes on the basis of renewable material resources from local sustainable agricultural production. For this purpose the concept of Biorefining is being developed. It is the systemic use of innovative technologies for the processing of bio-based resources aimed at the production of new products at a regional level. Thus it opens up a future materials-oriented agriculture, which enlarges the economic possibilities of agriculture and it helps to secure on the basis of modern innovation. This, of course, will succeed only if and when the resulting products are in demand, can be economically produced and meet a high level of environmental requirements.

Another aspect of the Biorefinery is that it provides an entrance to the domain of biologically degradable products, such as foils, surgical materials or slow-release materials for pharmaceutical applications (Grüne Bioraffinerie Brandenburg, 1997).

Biorefining is a term born out of the biotechnology industry. It has been defined as:

> ‘Using inputs that might include everything from stalks and stems to husks and grains, Biorefining systems employ innovative technologies to generate products that might range from basic food ingredients to complex pharmaceuticals, and from simple building materials to exotic industrial adhesives. It is also practical to begin Biorefining by using one or more waste products from conventional agricultural processing operations as the input material. There is already considerable activity in the retrofitting of existing plants to utilise Biorefining techniques in waste treatment, simultaneously cleaning the environment and creating new products. Ideally, Biorefining facilities will be designed to efficiently process a region's crop literally from the ground up. Such facilities represent a fundamentally different approach to value-added processing’ (Biological Process Technology Institute, 1999).

A European consortium have explored 'the Whole Crop Biorefinery'. The consortium recognises the concept of 'resource potential' and maximising the productivity of land. Instead of one or two marketable products coming from any given acre, Biorefining recognises that agricultural crops have physical and chemical characteristics that make them well-suited as raw materials for the production of a great number of non-food products. Emerging opportunities are found in crops, such as corn, wheat, oats, sugar beets, potatoes, soybeans or barley, and in minor crops, such as canola, flax, crambe or wild rice. It has been concluded that Biorefining is likely to occur in small-to-medium-sized facilities located in close proximity to the fields where the raw materials are grown. Value-added Biorefining is therefore more likely to take place within rural regions and could become a major source of wealth creation (NF-2000 and the Biological Process technology Institute, 1999).

However, NF-2000 states that only a very few cops have been commercially utilised for the following reasons:

- The technology is not available or is too expensive.
- The raw materials are too expensive.
- The market is small, either because there is no demand for the product, or because the market has not been fully exploited.
- There is no organised production chain from the farm to the processing industry and/or retailer/wholesaler.

The aim of the Biorefinery is to provide a link in the production chain which can break down some of the above barriers and hence aid commercialisation.

Under present market conditions a Biorefinery cannot produce bulk products competitively at the scale and level of integration conceived for this project. However, it can utilise its size, location and flexible production methods to develop niche markets, either producing tailor-made raw materials for further processing or speciality foodstuffs for direct sale. Hence, the concept is still at a precommercial level, requiring the creation of markets for the raw materials and products.

Marketing studies have shown that industry considers the following aspects of the Biorefinery concept to be positive:

- A controlled chain supplying only those products required (carbohydrates, proteins, fibres, etcetera), rather than the grain, straw or fibre crop, which allows the farmer to be paid according to the quality of the crop.
- By-product valorisation.
- Environmental benefits and natural, safe products as required by consumers.

On the negative side, it was felt that the Biorefinery could only compete economically if the resulting products were significantly better than those produced by conventional (bulk) processing.

The initial project ran from 1991 to 1994 and is now being developed by the Bioraf Denmark Foundation on the island of Bornholm. The Foundation was created in 1988 to conduct and co-ordinate research on whole crop utilisation within the Biorefinery concept. Funding is supplied by the Danish Government, by the European Union and by contracted project partners. A pilot plant has been established and two crops, wheat and oilseed rape are processed using the new techniques (ACTIN, 1998).

Studies in the U.S. (Morris, Ahmend, 1995) estimate that an average size Biorefinery might consume 100,000-300,000 tons of plant matter per year. By recovering agricultural wastes, and increasing the acreage of new carbohydrate crops, the U.S. could easily produce 200 million tons of plant matter, enough to supply 700 - 2,000 new Biorefineries.

One reviewer of this report concluded that:

> ‘… new crops must be introduced within the context of a whole production system, and attention must be given to how these crops could be grown in an environmentally sound manner’.

Biorefining would seem to have great potential and embraces the notion of exploiting the whole 'resource potential' of a plant. Many advocates, also are very aware of the need for keeping local production and regional markets together and for developing an ecologically sound route. However, careful husbandry of renewable resources is best demonstrated in the concept of 'Permaculture'.

Permaculture

Permaculture (Permanent agriculture and Permanent culture) is a sustainable design system stressing the harmonious interrelationship of humans, plants, animals and the Earth. To quote designer Bill Mollison, the founder of Permaculture:

> "Permaculture principles focus on thoughtful designs for small- scale intensive systems which are labour efficient and which use biological resources instead of fossil fuels. Designs stress ecological connections and closed energy and material loops. The core of Permaculture is design and the working relationships and connections between all things. Each component in a system performs multiple functions, and each function is supported by many elements. Key to efficient design is observation and replication of natural ecosystems, where designers maximize diversity with polycultures, stress efficient energy planning for houses and settlements, use and accelerate natural plant succession and increase the highly productive 'edge-zones' within the system" (Barnes, 1999).

Permaculture designs have been successfully and widely implemented in Third-World countries, but there is current need to expand these principles in temperate climates, and especially urban areas to create more enjoyable and sustainable human habitats.

According to Appropriate Technology Transfer for Rural Areas (ATTRA, 1999), Permaculture is about designing ecological human habitats and food production systems. It is a land use community building movement which strives for the harmonious integration of human dwellings, microclimate, annual and perennial plants, animals, soils, and water into stable, productive communities. The focus is not on these elements themselves, but rather on the relationship created among them by the way we place them in the landscape. This synergy is further enhanced by mimicking patterns found in nature.

The design of ecological landscapes that produce food is a central feature of Permaculture. Emphasis is placed on multi-use plants. However, Permaculture entails more than just food production. Energy-efficient buildings, waste water treatment, recycling, and land stewardship in general are other important components of Permaculture. According to ATTRA Permaculture has recently expanded its realm to include economic and social structures that support the evolution and development of more permanent communities, such as co-housing projects and eco-villages. As such, Permaculture design concepts are applicable to urban as well as rural settings, and are appropriate for single households as well as whole farms and villages.

'Integrated farming' and 'ecological engineering' are phrases sometimes used when attempting to describe Permaculture, with 'cultivated ecology' perhaps coming the closest. But although they are helpful, ATTRA believes that these phrases do not capture the holistic nature of Permaculture. To remedy this, the ATTRA web-site presents several definitions to provide additional insight (http://www.attra.org/attra-pub/perma.html#defined).

Industrial Ecology

Industrial Ecology employs a holistic view to study, assess, and improve the utilisation of natural resources (materials, energy and the assimilative capacity of the environment), in an industrial society (Berkel, et al., 1997.)

Locally applied, the concept seems identical to that of the 'eco-industrial park (EIP)' which is broadly defined as:

> “a community of businesses that cooperate with each other and with the local community to efficiently share resources (information, materials, water, energy, infrastructure and natural habitat), leading to economic gains, improved environmental quality, and equitable enhancement of human resources for business and local community”.

It has been presented as a new approach to economic development which provides a unique opportunity for communities to create jobs and protect the environment in a way that respects basic community values.

A good example of an eco-industrial park is the Riverside Eco-Park in Burlington, Vermont. The mission of this ecological-industrial park is to demonstrate and promote the commercialisation of technologies that effectively utilise indigenous renewable resources that may be transferred to other communities that are interested in sustainable and ecologically sound development. The focus is on biomass energy integrated with living systems and urban agriculture technologies. The objective is to maximise the utilisation of renewable resources to provide electricity and heat, whilst using living systems that add value to wastes and expand the ability to grow food and flowers locally. Projects integrating biomass energy, living technologies and urban agriculture can be applied to many sites throughout the world to retain existing or to develop new businesses that are challenged with issues of economical energy supply, food production, and waste disposal (Eco-Industrial Park Workshop Proceedings, October, 1998).

Industrial Ecology can be defined as the network of industrial processes that interact with each other and live with each other, not only in the economic sense but also in the sense of direct use of each other's material and energy wastes (Ausubel, 1992).

Industrial Ecology is concerned with the evolution of technology and economic systems such that human activities mimic mature biological systems by being self-contained in their material and resource use (Allenby, 1994). Its object of analysis is industrial processes rather than products and it emphasises the need for greater synergy, the potential for reduction in environmental impacts by linking different manufacturing process via their waste streams and encouraging cyclic flows of materials.

Programmes where Industrial Ecology has been implemented tend not to have a direct relation to LCA. However, companies entering Industrial Ecology programmes should expect an improved environmental profile of their products as they are reflected in an LCA. This requires that the allocation procedures used in LCA are developed further in order to handle the complex waste streams between several industries in a sensible manner. (European Environment Agency, 1999).

Bioregionalism

According to Mark Serhus (Serhus, 1996), Bioregionalism:

> "…is the dominant political paradigm that allows social and economic growth within the carrying capacity of the land while being supplemented by inter-Bioregional trade. Nation states have given way to region states that have situated themselves with the necessary critical mass to be self-reliant and prudent regional traders. Bioregionalism is not utter self-sufficiency or the end of trade, but a self-reliance in basic provisions for reasons including community security, ecological sustainability and personal fulfilment. While not abjuring material comfort, most Bioregionalists advocate some level of voluntary simplicity; viewing modern consumerism as evidence of a spiritual world left by the shattering of human communities and their connection with nature. Restoration of community life within the greater community of nature is the core goal of Bioregionalism".

The structure of this Bioregional culture is the model of society. This structure would:

- Reflect local resources
- Be built to benefit from the climate (not just withstand it)
- Embrace a local culture
- Stylistically reflect resources, climate, and culture in much the same way that ancient vernacular architecture has done.

First, designers need to study and estimate the wealth of the natural economy at the local level. Identifying and becoming intimately familiar with the resources of the Bioregion can develop an understanding of its potential. Next, they can assess material consumption by identifying wastes and investigating where these materials came from and where they will end up in the Bioregion. Additionally, they need to assess the long term value of the inhabitants' material possessions and to understand what role they play in their lives and that of the Bioregion. The final step would be to take a global view of the inhabitants' material lives and discover if materials from beyond our Bioregion having a negative effect on the native Bioregion. (Serhus, 1996).

According to the two Scottish scientists, Stevenson and Ball, Bioregionalism in essence involves the protection of the physical and ecological environments while promoting local cultural and economic stability. Each of these has a part to play in the evolving definition of a local vernacular approach to materials, past and future. Local interpretation plays a key role in the definition of a Bioregion. Definitions of what a Bioregion is vary from simple watersheds, through what are really biogeographic zones, to more complex definitions which include economic and social factors. A Bioregional boundary map should be organic, changing with place and through time because it is dependent on its definition and interpretation by local people with their changing goals and understandings of their surroundings. The authors state that there is a recognised shortage of information on the availability of environmentally benign materials and especially on the acquisition of materials on a regional basis (Stevenson and Ball, 1998).

Chapter 5

Developing Bioregions and Bionetic SMEs

The last chapter introduced the concepts of Biorefining, Permaculture, Industrial Ecology and Bioregionalism. In this chapter they are explored in relationship to a new generation of micro, small and medium-sized enterprises which are given the name 'Bionetic SMEs' in this report.

The ideas presented are to highlight some of the issues. They are not presented as 'the' solution but as a starting point to stimulate debate and to raise awareness of the opportunities.

However, in view of the focus on micro, small and medium-sized enterprises (collectively referred to as SMEs in this report) it is useful to highlight the importance of them to the E.U. in terms of economy and employment before discussing the Bionetic SMEs and Bioregional development.

Micro, small and medium-sized enterprises in the European Union

The importance and significance of very small enterprises in the European Union cannot be overestimated. Micro enterprises (less then 10 people), small enterprises (less then 50 people) and medium ones (less than 250) are a vibrant and essential ingredient of the E.U. economy and employment opportunities. In fact, very small enterprises form 93% of all enterprises in the European Union and represent one third of E.U. employment. They currently employ more people than large enterprises. The fact that they are major providers of current employment does not necessarily imply that they will continue to generate new and sustainable jobs. The ideal is to increase their sustainability, thereby creating more jobs with emphasis on better quality within those jobs (European Foundation, 1999).

The importance of SMEs is reinforced by 1997 figures, which show how they have generated new jobs in the past. SME-Web reports that there are about 17 million enterprises in the fifteen E.U. Member States. Less than 35,000 of these have more than 250 employees and are therefore categorised as large. Seven out of ten employees work in SMEs and 60% of GNP is generated in SMEs, whilst 50% of all investment across Europe is in these enterprises. In the last recession only SMEs continued to create jobs. While large enterprises rationalised and cut jobs, small ones continued to create them (SME-Web, 1997).

An essential feature of SMEs is the fact that the individuals responsible for them tend to be very flexible, committed and creative - people who take an idea and are bold enough to build a business around it. These qualities are also essential to the sustainable development movement and the growth of eco-design products and the green marketing that supports them. At present there is much encouragement for SME entrepreneurs wishing to enter the green goods market: the demand for ecological products is showing a marked upward trend on the European market. Marketing experts consider there is great potential for expansion of this technology. In recent years the annual growth rate in this segment has been over 10% (Telesis Beratungs GesbR, 1999).

Another feature of SMEs that affects their potential as agents of sustainable development is that they are rarely listed on the stock exchange (excluding high technology stocks). Their size and scale of business precludes most from having any sort of listing. This means that they generally do not have external shareholder pressure to regularly increase profit. That is not to say that small and micro enterprises do not have shareholders - they do. However, the major shareholders will often be the start up partners of the company, family and philanthropic individuals who have a benign attitude to the company, its culture and long term existence. They will often have widely based values and an ethical approach to the business they collectively have founded. They expect profit but not generally at the expense of all other concerns such as maintaining employment, and they are able to steer an individual path that reflects their own wider concerns.

To sum up, micro, small and medium-sized enterprises are the major employers in the E.U. They can be flexible in the work and market place whilst having significant control over their ethical and social approaches to business. Their lack of presence in the stock markets means they have greater freedom to evolve business practices in support of the goal of sustainable production than larger companies. However, they also clearly have considerable difficulties to overcome to reach that goal.

Constraints to sustainable production SMEs

Weighed against advantages that SMEs have over big companies are some limitations that deter or restrict their ability to change. We can assume that a major move to the use of renewable resources will involve a host of new technologies and research effort. However, the vast majority of SMEs are 'follower users' of technology and traditionally have had no direct interest in taking part in European research projects. This resistance is reinforced by a position paper on "SMEs in the 5th Framework Programme" presented by the Federation of European Industrial Cooperative Research Organisations (FEICRO) and the European Association of Contract Research

Organisations (EACRO). The paper identifies problems that face SMEs in accessing the European Union's Research, Technological Development and Demonstration (RTD) activities for the period 1998-2002 (CORDIS, 1999). The main problems are:

- Lack of in-house Research, Technological Development and Demonstration (RTD) capacity.
- Limited access to European RTD programmes and information.
- Limited management capacity, which is usually fully occupied with day-to-day matters.
- Focus on short-term technical problem solving rather than on longer-term strategic RTD.

Issues such as a lack of investment, training and equipment can be added to the list. The above problems for SMEs have to be addressed when developing a model SME based upon sustainable production and all the research and technology development that the model entails. In part, these technology and research demands can be met by evolving partnerships with bigger and better resourced companies. However, at present, a suitable environment in which to evolve sustainable agriculture, production and consumption development lies more in the control of SMEs than it does with large multinational concerns, as SMEs have more control over their own destiny. So, although partnerships with big companies may offer some benefits, SMEs are in a position to take the lead in implementation on the ground.

Support in Numbers - Bioregionalism

If it is agreed that SMEs are an attractive, even essential, vehicle with which to promote new employment opportunities within the context of a sustainable production system, then how they might be best supported becomes a central issue.

A single SME carrying out non-food agriculture and sustainable production practices will suffer many of the problems raised above, especially, being under-resourced in manpower, investment, equipment and know-how. The solitary sustainable production SME risks being isolated and vulnerable and involves extremely demanding work for the owners and employees. It is a struggle to survive let alone prosper. The company's production activities will tend to be disadvantaged and marginalised by conventional SME producers who have the benefit of cheap high volume feedstock and established market routes and acceptance.

To have a real impact, the sustainable SME must be a part of a more holistic concept in which the 'Bioregion' provides an organic framework for sustainable agricultural production and consumerism. In such a region a collection of SMEs would share certain facilities, resources and expertise and in this way could have a significant social and economic impact. Sharing cost and expertise towards a common goal is a well-established and proven approach. There is strength in numbers.

Such a culture in a Bioregion would help to create a successful economic zone working with principles of sustainability. Working collectively on areas such as shared research would assist in realising technologies, prototyping and bringing them to market more rapidly. It is also true that

SMEs working on certain commercial activities together would have greater economic and political power.

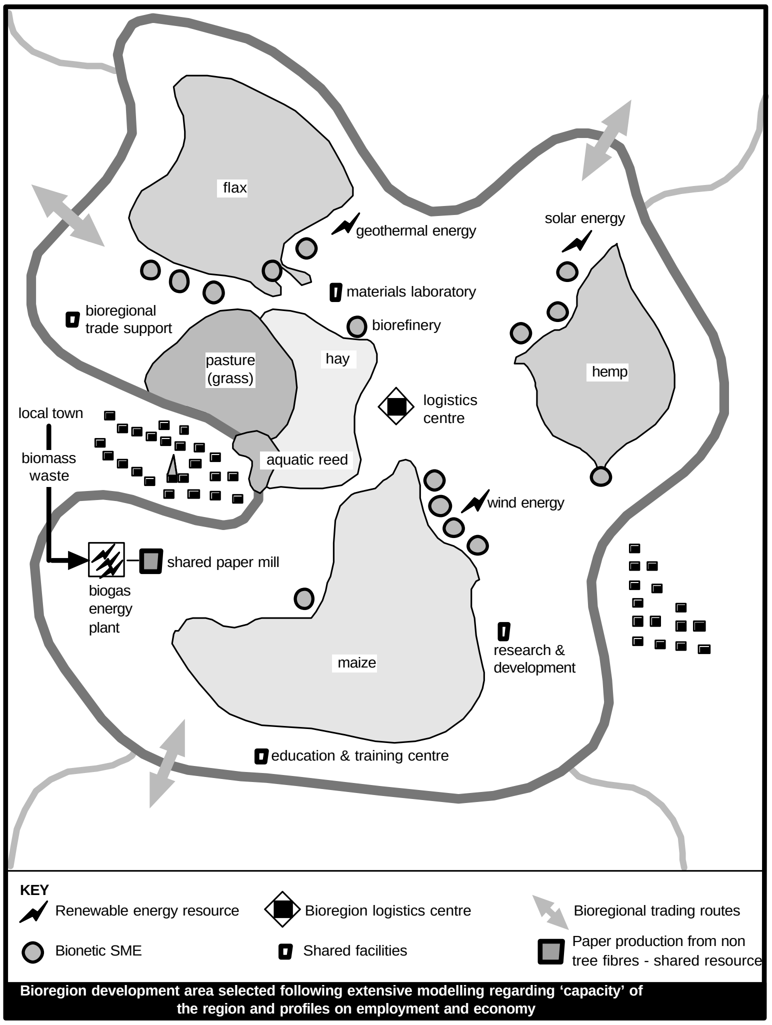
Bionetic SMEs

This report presents a new term **-** 'Bionetic SMEs' **-** to describe a new type of SME working in a Bioregion, its networking, and its involvement with advanced information and communication systems:

Bio **-** SME concern for natural life and supportive ecological systems;
Net **-** as the SMEs will participate in many networked activities and shared resources;
IC **-** Information and communication technology will play a significant role in the success of the SMEs, locally, regionally and internationally.

Figure 6 presents a model of a Bioregion, its Bionetic SMEs, and the resources and infrastructure it needs to develop in order to survive and prosper.

Figure 6: *A model Bioregion*



The issues presented in Figure 6 are explored in more detail in the following pages. However, before introducing the factors that might contribute to the character of a Bionetic SME the decision making process that might be used to select the area for the model Bioregion will be discussed.

Macro starting points for a Bioregion

The strategic (macro) starting points in evolving the model of a Bioregion shown in the diagram must be considered first. This section introduces three key concerns that need to be considered when assessing areas suitable for development as Bioregions in the EU:

- Bioregional capacity
- Bioregional employment
- Bioregional economy

Socio-economic impact and needs of the local community must be assessed against the objectives of a sustainable region. This can be achieved by using an agreed analysis and assessment (computer) programme that profiles the capacity, employment and economy of the Bioregion.

Broadly speaking, two main objectives need to be laid down for the Bioregion in order to frame, contextualise and establish limitations on the three concerns above:

- The Bioregion's natural capacity and diversity must be protected, developed and enhanced for the next generation (sustainability).
- Only human activities that utilise resources in such a way that the objectives of point one are not degraded must be engaged in (employment and local economy).

With these two objectives in mind, some fundamental starting points should also be adopted in developing Bionetic SMEs within a Bioregion. Bionetic SMEs should be based upon the resource potential concept and place a harmonious relationship with the Bioregion's environment and ecosystems at the heart of their commercial activity. This means that the level of a Bionetic SME activity is defined not by political or economic boundaries, but by the geographical limits of human communities and ecological systems. The influence of Bionetic SMEs on their Bioregion should be integrated within the computer model and a constant flow of data between individual Bionetic SMEs and the overall model for the Bioregion should be maintained.

To realise the objective of sustainability for the Bioregion and its Bionetic SMEs, the following starting points (which fall into two groups) should be considered:

Analysis and assessment of activity in the Bioregion

- Determining an area for the Bioregion.
- Bioregional capacity (natural capacity and environmental capacity), employment and economy.

Facilities to nurture and sustain a commercial Bioregion

- Logistical support and information technology.
- Shared infrastructure, resources and know-how.
- Bioregional trade mechanisms.

Analysis and assessment of activity in the Bioregion

It is fundamental that Bioregional development is applied in an area that will support it. This requires the local community, ecological systems and resource potential factors to be analysed and assessed holistically.

Determining an area for the Bioregion

There are no rules regarding the land area of a Bioregion. Bioregions can range from hundreds to tens of thousands of hectares. The essential features are that the region is able to maintain its ecosystems and environment while supporting the needs of the people who live there sustainably. Therefore the area of a Bioregion is a fluid and organic concept which can only be determined once the exact location is known and all its elements largely understood.

Community

At the local community level, it is assumed that the radical concept of Bioregional development will only be acceptable in areas where the existing system has failed. That is, rural economies in which modern farming practices, markets and subsidies have all reduced employment opportunities and depressed incomes. In addition, areas where the community has already engaged in aspects of Bioregional production will be receptive, although these are very scarce.

Therefore, the local community needs to be in favour of the idea. In turn, they need to be supported by local, national and E.U. public offices to steer strategic concerns such as planning, infrastructure development, and grant assistance. These ongoing investments and activities need to be evaluated against the ability of region's ecological systems and environment to deal with the changes.

Bioregional capacity model

Having obtained community support, a key starting point in the development of a Bioregion must be to identify its ecological systems, their biodiversity and the capacity of the area to sustain human activities. Various concepts can be used in measuring these factors - for example, carrying capacity, environmental capacity and the ecological footprint. All can be loosely summarised as measuring the amount of activity or population that can be supported in a sustainable manner. As this report focuses on fibres for sustainable production, the model Bioregion is one suitable for these types of non-food agriculture.

As already mentioned, the three concerns of Bioregional capacity, employment and economic potential need to be modelled by an agreed computer programme at the beginning of the Bioregion and to be monitored constantly throughout its development and long-term evolution.

The global results would be transparent and made publicly available via the Bioregion's Logistics Centre.

Bioregional economy and employment models

While the model of Bioregional capacity might draw upon well known approaches such as 'ecological footprint', models to track and anticipate the impacts in employment and the Bioregion's economy are also necessary. The Socio-economic multiplier model for rural diversification through biomass energy deployment (BIOSEM Model- FAIR3-CT96-1389) outlines a suitable approach for biomass energy schemes (NF-2000, 1999).

The model has been adapted below to outline a possible procedural approach for evaluating the impact on employment and economy within a Bioregion and integrating with the Bioregion 'capacity' model.

Objective

The objective of the Bioregional employment/economic study would be to develop a quantitative and qualitative model to analyse the socio-economic impacts of renewable resources through rural diversification. It should also measure the distribution of benefits and costs of policy packages, particularly the European Union Common Agricutural Policy (CAP) to the region. This modelling would help policy makers in the strategic planning and support of the Bioregion.

It is anticipated that the Bioregion will aid in increasing farming incomes and contribute to the development of associated commercial and industrial activities. For example, transport infrastructure and specialist machinery manufacturers could benefit from increased business within the Bioregion, creating additional spending in the community and adding to the strength of the local economy. Many of these factors would be directly or partially connected to the activities of the Bionetic SMEs.

Basic methodology

The Bioregional economy model should draw upon existing data for the region so that the employment and income benefits from Bioregional development can be assessed against the existing situation. The model should simulate the interaction between Bionetic SMEs working with agricultural crops, biomass production and energy production, and other sectors of the economy. The model should also use data from the chosen Bioregional capacity model so that analysis and assessment can take place to safeguard principles of sustainability for the Bioregion.

The main aims of the model would be to:

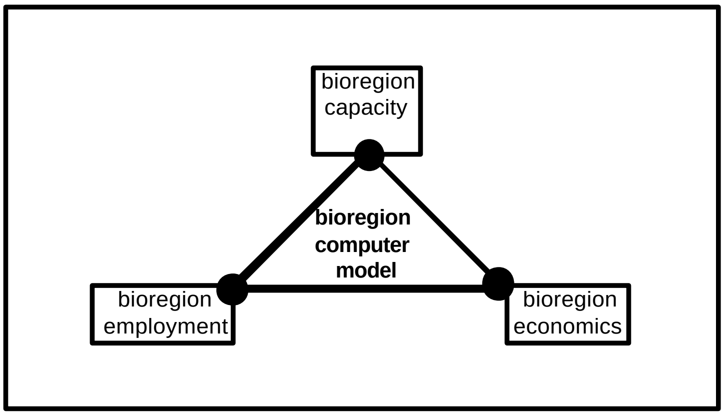
- Identify depressed rural areas that would benefit from Bioregional development.
- Estimate the direct and indirect effects on employment, income, local services and government revenue caused by Bionetic SMEs working in the Bioregion.
- Make recommendations for CAP policy reform to assist and promote rural diversification through Bioregional development and the implementation of Bionetic SMEs.

- Ensure that Bioregional development creates new Bionetic SMEs, employment and economic opportunities without undermining the objective of protecting the ecosystems and sustainability of the region.

Expected Results

The three part computer model (economy, employment, and sustainable carrying capacity) will assist policy makers in identifying potential areas in the E.U. for development as Bioregions, and deciding where to site renewable resources, Bionetic SME production and processing plants. It should help to identify where to target investment to obtain the highest production response or optimal income distribution effects in all the participating European countries. The chosen model and its simulations should help policy makers identify recommendations for rural policy and CAP reform and assist in nurturing rural planning towards Bioregional development goals.

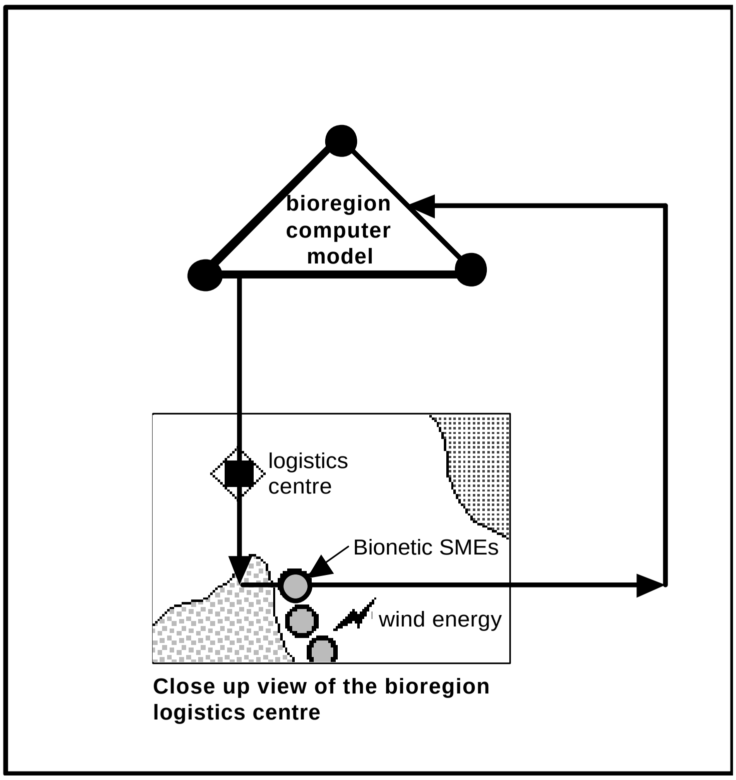
Figure 7: *Showing the primary data to be modelled for choosing, developing and improving a Bioregion*



Facilities to nurture and sustain a commercial Bioregion

The computer model presented should be an organic design and open to change and review by independent experts. It would be maintained and supported by the introduction of a 'Logistics Centre' to the Bioregion. The centre will play an essential role in maintaining data flows from the Bionetic SMEs linked to it. They would semi-automatically update the Bioregional model by contributing employment, economic and agreed information from sustainable indicators. In this way, every new Bionetic SME would join the network and have its influence monitored and unacceptable impacts tackled at source. Bionetic SMEs with a high performance ratio of employment, economic growth and benign impact would be identified as models of best practice. The relationship between these elements can be seen in Figure 8.

Figure 8: *The Bionetic SMEs constantly update the Bioregional computer model*



Logistical support - beyond the computer model

The constant modelling of the Bioregion would only be one of the important tasks undertaken by the Logistics Centre. The Logistics Centre would have many other functions. As an essential shared resource it would have information and communication support at the heart of its mission. In previous pages it has been stated that Bionetic SMEs would benefit by working together on certain activities. The Logistics Centre would network these activities and maintain a series of initiatives designed to support Bionetic SMEs.

The following table (Figure 9) segments the interconnected activities in a Bioregion and uses the same iconic key as Figure 6 to help identify the main elements.

Figure 9: *Bioregion support for the Bionetic SMEs indicating actors and activities*

BIOREGION SHARED SERVICES	BIONETIC SME INFORMATION EXCHANGE	BIONETIC SME PARTNERSHIPS
R & D Services	**Public information**	**Internal Partners**
ecosystems research	weather forecasts	new processing technologies
agriculture research	overall volume & state of bioregion production	materials science
renewable resource materials research	renewables commodities trading	patents
process & production technology research	new employment & training opportunities	staff exchange
education, training, health & safety centres	government & market trends	shared production
Structural Services	**Secure Information**	**External Partners**
Information technology	resource trading between Bionetic SMEs	market research
shared transport & logistics	individual crop status and predicted yields	advertising campaigns
regional renewable energy	local energy usage	ecommerce via www sites
cyclic management of biomass & waste streams	environmental impact	cross boarder bioregional trading
alternative trading systems such as LETS	ecological impact	eco-zone collaboration
shared paper production from non-tree fibres	waste flows	
maintaining the bioregional computer model		
KEY		
Renewable energy resource	Bioregion logistics centre	Bioregional trading routes
Bionetic SME	Shared facilities	Shared paper production from non tree fibres

Interconnected Bioregional Activities

Bioregional shared services

The pubic authorities of the Bioregion would provide certain shared services to help the Bionetic SMEs develop knowledge on a range of subjects. The services would also feed back into strategic policy for the Bioregion. For example, they might decide how much crop harvest to hold back (bank) to protect against loss of resources in the case of poor seasons in future years.

The following ideas are presented to stimulate discussion - the details can be developed in many different ways. For the sake of easy reading, the different activities are identified as separate entities but they could just as easily exist in a different and more integrated organisational structure.

Research and development

Bionetic SMEs would have access to first class expertise in research and development centres that they have traditionally resisted. One such centre would focus on the Bioregion's ecosystems. It would build up a picture of the region, monitor changes and, from knowledge gained, underpin planning policy for the Bioregion. It would be a major contributor to the Bioregion's 'capacity' computer model.

Associated with this research would be facilities for agricultural practice and training. In our example the Centre focuses on fibre crops and attempts to anticipate future fibre market developments. This Centre would also pay attention to latest developments in biogenetic engineering and the like. As in the case of all the Bioregional research centres it should have a forum for experts from the Bionetic SMEs to impart knowledge and support policy.

Bionetic SMEs would also receive assistance in new renewable resource materials research and associated processing and production technologies. Resulting research innovations would help give the Bioregion a competitive advantage either by increasing processing or production performance of fibres, or by evolving products with unique selling points. Alongside the innovative technologies, education and training programmes would be implemented to help workers with the new technologies. The holistic integration of the Bioregion's 'capacity' model across all areas would be reflected in health and safety concerns. The core objective for new research activities for improving working conditions would ensure that workers would be protected from the outset. A centre would support this aspect of Bioregional work.

Structural services

The region's shared services would be designed to realise efficiency gains and minimise impacts of Bionetic SMEs. The Logistics Centre would manage many of these services. One such essential service would be open access to a wide range of information relevant to the needs of the Bionetic SMEs, quickly accessible and regularly updated. For example, the Centre would provide comprehensive scheduling tools so that the transport of renewable resources, manufactured products and necessary supplies could be cost effectively shared between the Bionetic SMEs. Likewise, renewable energy based supplies would be developed using low grade biomass, solar, water, wind and geothermal (groundwater) technology. The scale and type of renewable energy power plant would depend entirely on the Bioregion and its specific needs. As well as centralised power systems, it is likely that individual SMEs and clusters of them might have localised power supplies. As is common practice in renewable resource power supplies today there would be continuous 'power trading' by the Bionetic SMEs so that overcapacity would be redirected to Bionetic SMEs needing power, or to local towns.

Cyclic management of biomass waste from the sustainable production work would be integrated with the transport logistics system and the biomass power supplies. In this way low grade biomass waste would be utilised for power and transported at efficient times. Higher grade biomass would be traded between Bionetic SMEs to serve different production needs.

Within such a Bioregion, localised trading between different companies and within the community as a whole would typically become the norm. This would give greater opportunity to introduce alternative trading systems such as the 'Local Exchange Trading System' (LETS).

Systems such as these help to localise commercial activity in the region and are often more sustainable and have less environmental impact than global trading.

Another resource shared by the producers of fibre in the model Bioregion would be the paper mill. The mill would take fibres from producers to make non-tree based paper. Here there would need to be a degree of processing and production innovation to deal with the different length of fibres from flax, hemp and maize crops. However, with the establishment of computer aided manufacturing and ever more intelligent flexible manufacturing systems these issues are technically soluble, although the economics of the solution compared with current approaches might still be challenging.

Underpinning this Bioregional service approach would be the computer modelling of the area in an attempt to measure progress towards sustainable production systems and identify new planning opportunities and policy initiatives.

Bionetic SME information exchange

Information would be available online via websites to support the Bionetic SMEs. In some cases the SMEs themselves would provide the information. Two types of information could be shared:

- Public information.
- Secure information.

Public information

The traditional weather forecasting information would be just as important for Bionetic SMEs as for conventional farmers, so short term and long term forecasts would be available, reducing climatic risk to crops. Figures for the current and predicted volumes of fibre production for the Bioregion and its international competitors would also be useful. As trading in renewable resources in one form or another is central to the Bioregion economic performance, 'markets' trading renewables would be available 24 hours a day.

Bionetic SMEs would maintain a register of jobs via the logistics' centre and, anticipating future needs, could advertise skills that would required, for example, for a particular crop harvest. In response to this, unemployed workers could be trained (at the Bioregional training centre) in the skills required once the crop has been harvested.

The Bioregion would focus much of its information technology on local issues. However, it would also link to other Bioregions and related activities around the world. The objective would be to promote the region but to also draw upon other experiences around the world in developing the sustainable exploitation of renewable resources.

Secure information

Some commercially confidential information would not be available to the public. For example, details about renewable resource trading between Bionetic SMEs, prices agreed, volume and delivery dates. Other secure information might involve the profile of a Bionetic SME's energy use, environmental impacts, influence on ecological systems and the amount of waste produced. These issues would be addressed by the Logistics Centre and suitable agreements made on an ad hoc basis.

Bionetic SME partnerships

The shared services of the Bioregion would also be developed to stimulate private partnerships between Bionetic SMEs. Therefore, although the companies would be involved in open public networking, there would also be many closed private initiatives. These would be of two sorts:

- Internal partnerships
- External partnerships

Internal collaborations

Bionetic SMEs might join to developed new processing technologies and renewable resource materials. Such collaborations could result in valuable patents for the companies, and also staff exchange programmes and even shared production facilities. The Bioregion's shared services would help to bring people together in local versions of partnership programmes such as the European Commissions 'Community Research and Development Information Service' (CORDIS). Partnerships such as these would remain confidential as is usual in commercial arrangements.

External collaboration

External collaboration would involve agencies, consultancies and cross regional partners that are not part of the immediate Bionetic SME networking. However, in pooling financial resources Bionetic SMEs might be able to take advantage of reduced individual costs for carrying out exercises such as market research. Consultancy based work is generally very expensive, and the culture and uniqueness of the Bioregion development would make such collaborations to share costs tempting. Similarly, advertising campaigns for the Bioregion as a whole and also for small collaborative groups of Bionetic SMEs would be more cost-efficient than campaigns by individual companies. It would be possible for Bionetic SMEs to use 'ecommerce' to sell direct to the public via websites for marketing.

This external activity by the Bioregion could also manifest itself in cross border Bioregional trading with one region selling sustainably realised renewable resources to another. In time it may well be possible that the practice of 'eco-zone trading' would emerge as Bionetic SMEs traded over a distance with similar enterprises.

Nature of sustainable production Bionetic SMEs

This section considers the character of Bionetic SMEs in broad terms. Bionetic SMEs will use a blend of old and new technology selected to exploit renewable resources in the most benign way. Advanced manufacturing systems will enable these SMEs to change production runs and manufacturing timetables whenever necessary. This flexibility will be essential to alleviate problems caused by factors such as crop failure or delays in delivery of feedstock.

Whereas the region as a whole integrates concepts of Bioregionalism, carrying capacity and macro employment and other economic tools, the development of Bionetic SMEs will draw upon the principles of Permaculture, Biorefining and Industrial Ecology.

Permaculture

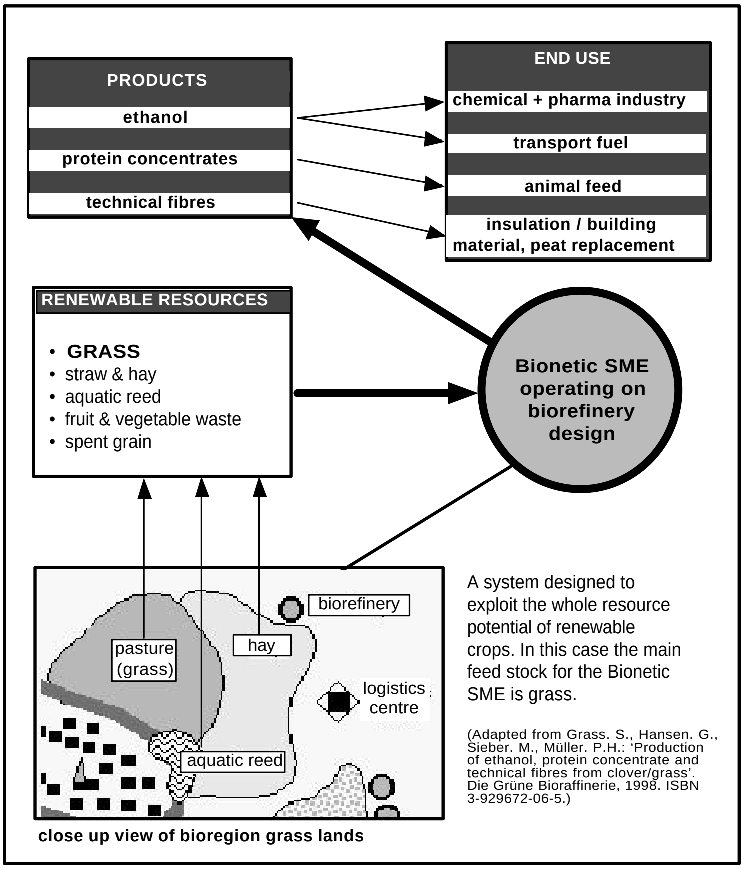
It is evident from the results of conventional agricultural practice that crops are not renewed by natural ecological cycles or even by sound management practices. Much arable land is artificially maintained for aggressive crop rotation by artificial fertilisers and harmful pesticides. Most fertilisers are based upon non-renewable minerals whilst pesticides are generally made of fossil-based oil, and fossil energy resources are also extensively used in their manufacture. Nowadays, many people are concerned about the exhaustion of soil and the impact of fertilisers and pesticides on ground water. Our society has created a mass-market agricultural system for food and non-food that relies on resources borrowed from the earth and that is artificially realised. As each year passes, more and more intervention by man is required to keep the same piece of land profitable, until it reaches a point where it just has to lie fallow in an exhausted state.

The new generation of Bionetic SMEs will be designed to work within limits of Bioregional capacity and this will greatly influence the types of agricultural practice that can be developed. Permaculture practice can provide guidance on all aspects of benign management of renewable resources and crop cycles. The application of Permaculture will focus on the cultivation and care of the feedstock used by the Bionetic SMEs.

Biorefining

To realise the commercial potential of their crops, Bionetic SMEs should use the knowledge and techniques of Biorefining. Figure 10 demonstrates how this technology aims to deconstruct plant matter into its component parts.

Figure 10: *Biorefinery using grass as the main renewable resource feedstock.*



This example delivers the following yields. One ton of dry grass/clover provides:

- 200-250 litres of ethanol
- 150-300 kg protein concentrate
- 200-300 kg of fibres (all values on a dry basis).

All plant components are converted into products and no solid waste stream leaves the plant. The 2B AG group who developed the production unit on which the above diagram is based claim that independent study has given an energy output/input ratio of 4. Regarding the economics of the Biorefinery 2B AG state that they primarily depend upon:

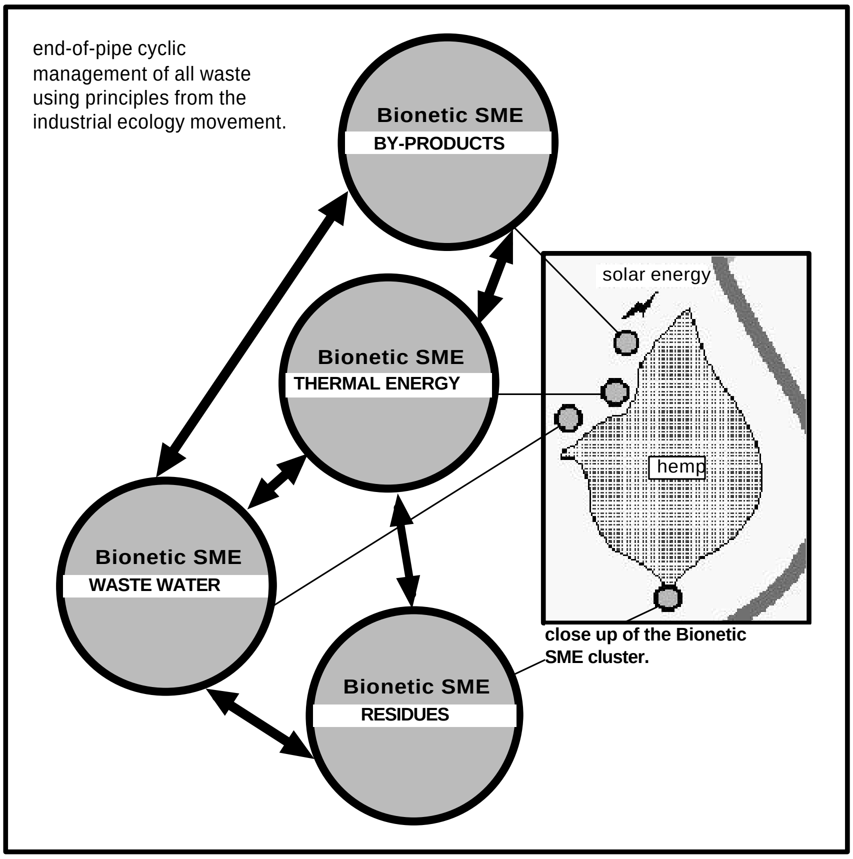
- Capacity of the production unit.
- Availability of suitable infrastructure (building, energy supply).
- Market value of end products.
- Cost of the raw material (grass).

The plant allows a return on investment of between 10-15% without the use of any government help or other subsidies. This figure is based on processing 5-10,000 t of dry matter per year and uses the figure for industrial site rent and market prices prevalent in the EU.

Industrial Ecology

Using methods drawn from Permaculture it is possible to provide sustainably produced renewable resource crop fibre to the Bionetic SME. The SME itself would utilise aspects of Biorefining technology which is extremely efficient in exploiting the full potential of the resource in question. However, it is inevitable that sometimes end-of-pipe care will be required to safeguard Bioregional ecosystems and to support the objective of sustainable production. For best practice in this area, and having done as much as possible to minimise end-of-pipe waste, the Bionetic SMEs will be able to learn from Industrial Ecology experience as shown in Figure 11.

Figure 11: *Bionetic SMEs sited and designed to maximise end-of-pipe efficiency*



The most forward looking Industrial Ecology concepts encourage the design and siting of companies to use each other's waste products from the outset - that is, an integrated systems design that maximises the efficiency of the all the different production activities. This approach is recommended for the Bionetic SMEs. As part of this integrated approach, they would transfer by-products such as thermal energy in the form of hot air, water or gas. For example, when one Bionetic SME has used water for cooling purposes, the resulting hot water can be pumped to another SME and re-used for heating.

Product Mix

In the model Bioregion presented in this report, three main crops have been described: flax, maize and hemp. Between them, these crops can provide the majority of the material resources for Bionetic SMEs. If the full resource potential of these crops is used in the Biorefining process, a fantastic range of product development opportunities is opened up.

Hemp is reputed to have over 25,000 different product uses, while 3,500 different uses are known for corn (maize), including biodegradable plastics, alcohol-ethanol fuel for cars, sweeteners, syrup, animal feed, cooking oil and fibres from the stems and husks. A similar, staggering number of products is also available from flax.

The number of products that can be made from the three crops is too great to list here, but collectively (and even individually) these crops have a massive range of uses - for food or fuel - from fibre to biopolymer. They can be exploited to make paints, cosmetics, flooring materials (linoleum), body oils, textiles, shoes, candles, and many other products.

Bionetic SMEs and their supporting Bioregion would seek to develop these product uses further and increasingly look for new material combinations, for example, using pressure and heat to mould three dimensional products from biopolymer and fibres. The potential applications are endless. They have not yet been extensively exploited as the industrialised world has focused its research and development in the area of fossil based materials. In the model Bioregion, Bionetic SMEs would be at the forefront of engineering a 'new material' world based upon using the full resource potential of crops such as these.

Local integration

In this report many ideas have been put forward for a model Bioregion that works in the interests of its communities and their environment. A main feature of this approach is that the community and trading links are localised. The Bioregion draws local people together to work in Bionetic SMEs that trade regionally and even internationally, but ultimately, at their heart, have an element of self-sufficiency, and self-reliance. The emphasis on local people and know-how will provide pleasurable working conditions that are safe and satisfying for those involved. Workers in the company should have a sense of belonging and feel that they have a stake holding in the company and its future. Not least, all employees will understand that their production activities extend beyond the factory gate and involve the ecosystems that surrounded them and in which their families live.

The company will produce useful products based upon sustainable renewable resources and employ approaches to product design, development and marketing that are responsible and profitable. At the core of the company will be the ambition to ensure that all its activities have a neutral or positive impact upon local ecological conditions and society. Although this vision of a

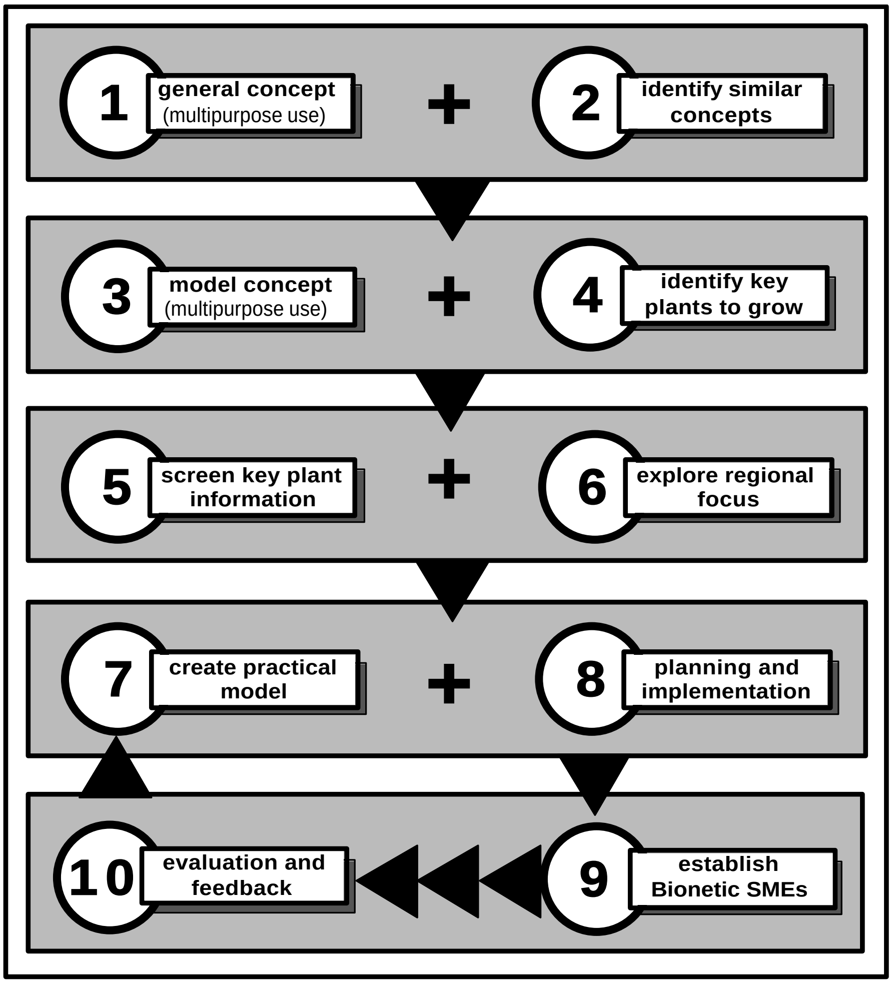
Bionetic SME is perhaps ambitious and even utopian, it is possible given time and the will to make it work.

As a starting point the following ten steps provide a foundation for setting up and developing a Bionetic SME.

Ten steps towards a Bionetic SME

Figure 12 shows ten basic steps which are essential when creating a Bionetic SME.

Figure 12: *Developing a Bionetic SME*



Step 1: *General Concept*
Formulate a general concept for the multi-purpose usage (Biorefining) of a renewable materials resource in the Bioregion where the Bionetic SME will be located.

Step 2: *Other Concepts*

Identify identical or similar concepts in practice, literature or on the Internet and known by experts, that have been used for plants, shrubs and trees in the area concerned, in identical or similar areas in the country involved or abroad.

Step 3: *Model Concept*

Combine the results of Step 1 and Step 2 into an improved, broadened and more sophisticated model of the multi-purpose use of a renewable material resource. Integrate Permaculture values.

Step 4: *Key Plants*

Collect information from all around the world on the industrial use of the key plants that are to provide the basis for the Bionetic SME in the region concerned.

Step 5: *Screening Information*

Screen the information resulting from Step 4 using the model concept derived from Step 3. This will lead to a better understanding of the specific, different and prominent characteristics of the key plant or plants concerned, whilst helping to identify less obvious, forgotten or undervalued properties, and applications. The objective is to map the full potential of the resource for the Bionetic SME.

Step 6: *Regional Focus*

Focus on the country or region in which the plant is to be grown. The plant may have been used in the past, is still being used or others are considering its usage for similar or related purposes. Local people, companies, experts should be consulted, as well as research institutions, government programmes and projects, and policy documents. In this way the context for the production of the plant is assessed.

Step 7: *Practical Model*

The information obtained from Step 6 is compared with the results and new insights from Step 5. Innovative ideas can be identified, as well as gaps in information and areas for research and development. This step should result in a practical model for the use of sustainably grown plants for local or Bioregional sustainable production.

Step 8: *Planning and Implementation*

The plant is sustainably grown (Permaculture). Ideally, renewable energy is used for cultivation, harvesting, processing, production (Biorefining) and transport purposes, product life-cycle closed loops are established (Industrial Ecology). All the crops grown are interrelated both with respect to their cultivation and to their multipurpose-use potential, creating inter linkages between plant components and the (intermediate) materials produced.

Step 9: *Bioregional Development*
A system is set up consisting of one or more Bionetic SMEs involved in the production of materials, components and end-products entirely based on renewable material resources and (locally produced) renewable energy input.

Step 10: *Evaluation and Feed-back*
The concept and its implementation should be continuously monitored and evaluated. This may lead to improvement of both concept and practice. Step 7 can serve as a re-entrance to the sustainable industrial development process.

Chapter 6

Reflections

Global issues

- We are using up valuable finite resources which have been exploited to build our material world.
- There is significant scientific evidence of climate change that is related to our industrial production systems and aggressive use of resource.
- We need to find new sustainable production approaches to meet the tremendous demands that new people (population growth) will have for products, services and energy - innovations for implementing sustainable development.
- There is a need for quantitative information in order to determine limitations and effects of different resource consumption, population level changes, etcetera.
- Governments should make it their responsibility to ensure that the essential research is being done, that what is done helps progress, and that it is being done while there is still time to change.

Traditional industry trends

- Fossil resource based industries tend to be centralised and disconnected from the raw material resource extraction.
- Too much attention is given to limited specific uses such as the chemical content of traditional agricultural crops.

- Little attention has been given to issues such as the whole crop use or total resource potential.
- In general, moving to renewable resources appears to be perceived as simply involving the substitution of one raw material by another for feedstock into the traditional industrial production model.
- There is a tendency in industry to imagine that fossil resource based technology and production facilities can remain the same for renewable resource based production.
- There is still an aggressive agricultural approach of monoculture crops and genetic modification developments supplemented with an over reliance on fertilisers and pesticides.

Renewable resource based industries

- Renewable resource based industries require reconsideration, reformulation and redesign of the existing production structure.
- Renewable resource based industries are intrinsically variable, diverse and complex.
- Great opportunities exist for the development of projects that are embedded in and based on locally available diverse bio-resources and renewable energy.
- Currently projects are decentralised, designed in their local context and small-scale.
- Projects have provided examples of how to move to sustainable production (although the economics may be questioned when using current criteria).
- There is a potential for realising important qualitative benefits in our working and living conditions.
- Spin-offs may be realised such as community engagement in the work place, trading in support of the local economy, capacity building in the local community, regional self reliance and associated security.
- Projects deserve more support, investment and recognition especially in depressed rural areas.
- SMEs are the biggest employer in the E.U. and a good vehicle for moving to Bioregional development.

The transition

As a result of the growth in non-food agriculture there will be many opportunities for agricultural companies. As a first step, the extent to which the production of food is related to the handling and throughput of potentially valuable non-food substances and materials must be assessed. This may lead to new contacts between food producing companies and other types of business, such as those in the area of packaging and building materials. The traditional food producing companies may also choose to become directly involved in the exploration of new markets for themselves. At the same time, existing processes and technologies will have to be adapted or abolished and new ones researched and developed. Literature and information presented on the Internet indicates that major improvements in renewable resource usage could already be achieved by implementation of the concept of total resource potential. New applications of plant parts, process wastes and residues will undoubtedly emerge, for which new process, product and market development will be required. Companies that already have a potentially sustainable resource base will naturally tend to move towards greater product diversity.

However, these new opportunities can be hindered by E.U. policies and subsidies which restrict their development. Since its introduction in 1962 the Common Agriculture Policy until recently favoured large and traditional farming and specific crops without the need for using end products. Historically, the policy supported products rather than farmers and this led to subsidy and the over production of certain farm products, resulting in the infamous food 'mountains and lakes'. In certain regions, intensive production encouraged by the policy has created negative environmental effects and it did not take adequate account of the agricultural incomes of the vast majority of small and medium-size family farms.

When considered against the ideas presented in this report the old CAP would hinder progress and even constraint it all together. A major reform of the CAP was undertaken in 1992 and has continued through the 1990's. Within Agenda 2000 the CAP will enter another major revision to prepare European agriculture for the internal and external challenges awaiting it in the year 2000 and beyond. This reform will encourage agriculture to be more competitive and environmentally friendly. It also marks a further stage in the policy of supporting farmers rather than products, and of remunerating not only farmers' output but also their additional contribution to society, the aim being to meet the challenges posed by the depopulation and abandonment of many rural areas.

These adjustments to CAP remove much of the direct subsidy that led to past problems and also confrontation with (international) trading partners who considered the CAP subsidies unfair to their own farmers. This issue has been regularly placed in the table of the World Trade Organisation (WTO) Agreement negotiations. The new plans for the CAP place greater emphasis on the social, employment and local conditions of European farming. There are new 'direct support schemes' that place local rural development high on the agenda. Although, theses schemes will attempt to support local regional development world trade agreements will in complete contrast support Globalisation and continued large scale farming which can be viewed as an additional concern for small local farm enterprises.

Therefore, considerable policy hurdles still exist that will hinder a transition to a Bioregional sustainable production system based on local resources, knowledge, materials and infrastructure.

Likewise, the transition will not be so smooth and easy for existing companies that are entirely based on the processing and use of fossil resource based raw materials. Most of the processes and technologies involved have been designed with mineral oil input in mind. Mere replacement of non-renewable to renewable feedstock will not produce real change. It is therefore surprising how many industries have recently demonstrated an interest in the shift towards a renewable resource basis without apparently fully understanding the obvious problems presented. Fundamental differences exist regarding the properties of the raw materials involved and how they are nurtured and gained.

It is even more surprising (and disappointing), however, that some recent international conferences on sustainable and renewable raw materials have displayed a strong preference for the superficial approach of feedstock replacement and genetic modification of plants simply to obtain better specifications and more of the same substances. This recent development, which is particularly obvious in the case of genetic modification of plants, seems to reflect a philosophy in which existing fossil resource based technology specifications and concepts are imposed upon agricultural crops and methods. In this way, the old and unsustainable industrial processing technology attempts to dictate the characteristics of crops and the agricultural system that produces them. However, when renewable resources such as plants and the complex and diverse solar production systems they represent are taken as a starting point, the old unsustainable approaches must be abandoned. Instead, already existing, adapted or totally new processes and technologies which have been developed by taking into account the characteristics and the properties of the plants and their parts and derivatives, are required.

This doesn't completely rule out the possibility of individual processes or technologies from the fossil production system being transferred to the renewable system. But when the concept of exploitation of the total resource potential is involved, or if a specific new raw material is involved, totally new processes and technologies - such as Biorefining - will also have to be developed.

During the transition from fossil based resources to renewable resources it is important to consider the problems that might emerge from areas where the two systems meet and merge and where hybrid combinations might develop. This can be observed, for example, when composite reinforcement fibres are replaced by natural fibres; or in packaging, when non-biodegradable plastics are mixed and mingled with biodegradable ones. Here again, it seems easier to combine materials from both systems in the short term and then to go on to develop new composites within the renewable resource based system. Flax reinforced starch matrix composites, new three dimensional products made from combinations of natural fibres and combinations of pure natural fibres with consumer waste natural fibres are examples of such new composites.

In conclusion, as the resource base of the production-consumption system changes, so will the whole context of production, and this should lead to the development of new processes, technologies and markets that take into account the origin and natural characteristics of the renewable resources they utilise. There is a vast area of new options waiting to be explored, exploited and implemented, while at the same time we must try to learn from our past unsustainable use of resources and build upon the lessons offered.

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Annex 1

Main European Non-food agriculture networks and activities

The following information comes from the NF-2000 web site (NF-2000, 1998) which provides very good information on European initiatives in the area of NFA. However, please note that the European Union funding for the site finished in November 1999. The reader is advised that it is not known if the site will be continued in the year 2000.

In several European countries, national agencies have been launched as a focus for the development of non-food applications of agricultural raw materials:

- ACTIN Alternative Crops Technology Interaction Network, UK.
- AGRICE Agriculture pour la Chimie et l'Energie, France.
- AIACE Agricoltura Innovativa per l'Ambiente, la Chimica e l'Energia, Italy.
- FNR Fachagentur Nachwachsende Rohstoffe eV, Germany.

These four agencies have grouped together as ERMA with the following objectives:

- Promote the exchange of information between all interested parties in each country and throughout the European Union.
- Ensure the efficient coordination of research projects, avoiding duplication of effort to improve cooperation between organisations involved in research, development and demonstration projects, with the support of the European Commission.
- Contribute to the adaptation of laws and regulations for non-food industrial applications of agricultural raw materials by providing scientific and economic data.

ACTIN

ACTIN is the UK representative in the EU-Concerted Action CTVO-net (Chemical-Technical Utilisation of Vegetable Oils). It is an independent national agency established by industry in 1995 in the United Kingdom in reaction to a worldwide industry interest in crop-derived products such as oils, fibres, starches and speciality chemicals. ACTIN addresses market opportunities, supply chain issues and barriers to progress, and promotes networking in the non-food crops industry.

ACTIN considers plants as natural, clean and sustainable 'Biorefineries' which are non-toxic, biodegradable and CO2-neutral. They believe that there is a huge potential for the use of plants to supply an array of raw materials for industry in place of mainly petrochemical sources. The key issues that need to be addressed if plants (biomass) are increasingly used by industry are:

- Revaluation of the manufacturing process.
- Establishment of new supply chains.
- Technical hurdles.
- Environmental and regulatory issues.

According to ACTIN these key issues must be tackled in order to achieve the desired result of novel and competitive products from a renewable feed stock. Plant biochemistry and biotechnology, biochemical and process engineering, chemistry materials science and processing, and life cycle analysis or processing modelling will all play an important role in this process (Bartle, 1999).

ACTIN works in close relationship with the UK Government LINK programme 'Competitive Industrial Materials from Non-Food Crops'. The objectives of this programme are to overcome technical barriers to the wider use of crop-derived raw materials by industry, with an emphasis on crops of medium to high value that are economically viable. The programme priorities are technologies which:

- Improve the value of existing crops
- Improve the quality and reliability of crop-derived materials
- Address the need for changes in process strategies
- Produce new crops from plants.

AGRICE

In France, activities have been undertaken in the framework of AGRICE (Agriculture for Chemistry and Energy) programme created in 1994. It is aimed at creating new fuels and materials from agriculture. Research activities are targeted on specific qualities of new agromaterials, such as natural polymers (cellulose, starch, proteins) and substituting plastic, molecules with surface active properties, vegetal origin lubricants, solvents, and drilling fluids.

AIACE

As a result of reports on technical and economic feasibility, as well as the social benefits of some areas of innovative use of agricultural raw materials, Italy and other European countries have formed common interest groups. AIACE, which roughly translates as the Scientific Interest Group for the Development of Innovative Agriculture for the Environment, Chemistry and Energy was established in Italy with the support of the following bodies: Consorzio Interuniversitario, CIRA, AGER, Agronomica, AISO, Consorzio Umbria AGREE, CTI, Novaol and VITA. Other members include ITABIA, the NF-2000 National Representative for Italy and RENAGRI, who act as hosts for this activity.

In assigning priorities, AIACE recognised the following sectors:

- the production of industrial oils from herbaceous oilseed crop.
- the production of paper pulp from herbaceous crops.
- the production of intermediates or fuel additives derived from ethyl alcohol.

FNR

FNR, the National Representative for NF-2000, is the central coordinating agency in Germany for the promotion of renewable resources, including non-food activities. Since the field of "renewable resources" is like any other new technology still subject to uncertainties, public sector promotion of research together with the commitment of industry is of particular importance in research and development efforts and prototype applications.

Since January 1993, responsibility for the support of this sector has been assigned to the Federal Ministry of Food, Agriculture and Forestry, who in turn initiated the establishment of FNR as the central coordinating agency for promotion and coordination of all relevant activities. This was officially set up as a registered association in October 1993.

Other networks

IENICA

IENICA, Interactive European Network for Industrial Crops and their Applications, is a project funded by DGXII of the European Commission for three years and began during February 1997. It has three principal and four supporting objectives.

The principal objectives of IENICA are:

- Create synergy within the E.U. industrial crops industry by developing an integrated network linking key individuals from industry, government and science in all member states.
- Identify and create scientific, industrial and market opportunities for specific industrial crops or applications.

- Identify the strengths of each E.U. member state in order to maximise the efficiency of RTD funding for industrial crops and encourage industrial and scientific collaboration between member states.

In support of these primary objectives IENICA will also:

- Determine the current state of scientific, industrial and commercial knowledge of industrial crops or their applications at member state and later at E.U. level.
- Identify barriers to the progress of industrial crops - these could be scientific, technical, legislative or economic.
- Identify and evaluate the environmental benefits arising from industrial crops or their applications; identify European RTD priorities and make recommendations to policy makers on the basis of that analysis.

NF - 2000

Non-Food Agro-Industrial Research Information Dissemination Network (NF-2000) has the promotion of NFA research and a commitment to industry as key objectives. Since January 1993, responsibility for the support of the NFA sector has made information available from EC-funded programmes and other sources. NF-2000 makes this information available in the form of photocopied ITEMS, on CD-ROM and on their World Wide Web.

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Annex 2

Related Publications

Foundation publications are on sale from the official sales agents of the E.U. or the office for Official Publications of the European Communities, L-2985, Luxembourg. Where prices are not quoted, the document is free of charge and is available on request from the Foundation.

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- Design for Sustainable Development: Concepts and Ideas (1997 - Cat. No. SX-06-97-682-EN-C, ISBN No. 92-828-0861-0, EUR 7).
- Design for Sustainable Development: Guides and Manuals (1997 - Cat. No. SX-06-97-690-EN-C, ISBN No. 92-828-0862-9, EUR 7).
- Design for Sustainable Development: Networks Directory (online, http://www.eurofound.ie/themes/sustainability/index.html).
- Design for Sustainable Development: Practical Examples of SMEs (1998 - Cat. No. SX-18-98-906-EN-C, ISBN No. 92-828-5267-9, EUR 18).
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- European Workshop on ECO Products, Conference Proceedings (1996 - Cat. No. SY-97-96-330-EN-C, ISBN No. 92-827-7790-1, EUR 7).

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- Report on the European Conference on the Role of the Social Partners in Sustainable Development, 25-26 February 1999 (1999 - Cat. No. SX-23-99-960-EN-C, ISBN No. 92-828-7427-3).

Design for Health

- Design for Health - creating a brochure (1995 - Cat. No. SY-89-95-365-EN-C, ISBN No. 92-827-41141).
- New Materials for Environmental Design (1995 - Cat. No. SY-85-994-115-EN-C, ISBN No. 92-826-86124, EUR 13.50).

For further information

Further information on this project and related Sustainable Development projects is available on the Foundation website - http://www.eurofound.ie.

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