

BIO-REFINERY - CONCEPT FOR SUSTAINABILITY AND HUMAN DEVELOPMENT

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Summary

Our planet's abundant life is nature's storehouse of solar energy and chemical resources. Whether cultivated by man, or growing wild, plant matter represents a huge quantity of a renewable resource that we call biomass. This biomass is the most important

renewable resource to sustain life on this planet. Sustainability can therefore be maintained only through an improvement of the natural cycles of matter.

The question arises, of course, how nature is able to cope with an increasing human population, which automatically results in a higher animal population and demands for food, feed, energy and commodity products. A socio-economic strategy for sustainability has to take these demands into consideration.

Sustainability can be obtained together with higher health and living standards, if appropriate technologies are applied according to the climatic region and local society. As the value of the biomass content is related to the chemical and physical properties of the large molecules, the challenges for the future lays in the establishment of 'biorefineries', where a combination of biological, physical and chemical sciences is able to replicate an 'oil refinery' with a 'bio-refinery', replacing the non-renewable fossil resources with renewable biomass resources for the production of food, feed, fertiliser, fuel, energy, industrial chemicals and related consumer products. All biotechnological and technological future developments should therefore be aimed at improving the quality of life of our communities and sustain our environment by using clean bioprocess technologies.

This revolutionary thought may require sacrifices, particularly in developed countries, through reduction in profits, product range and product variability in return for a stable and less polluted environment. It seems there is little choice but to accept these sacrifices as it becomes more and more clear that the earth and its atmosphere cannot continue to act as an infinite sink for the waste products of industry, agriculture and urban living.

These biotechnology issues are particularly important for developing countries combining "old" and "modern" techniques for the improvements in the health and living conditions of 80% of our world population. As long as the present biotechnology development is driven only by commercial enterprise, human development will lag increasingly behind. Sustainable development and human development should not and can not go separate directions.

This article will demonstrate possibilities by offering farmers attractive alternatives, which means security through a change from a mono- to a multiple-product agricultural industry, which is job creating and will also foster de-urbanisation. Examples will be given for agricultural farming and agro-industrial manufacturers in various regions of our planet earth.

1. Introduction

1.1. Developed Countries

The processing of biomass and control of pathogens in waste management depends entirely on the particular socio-economy adopted for rural and urban sustainability. In order to sustain life and improve the standard of living, the general advancement of scientific knowledge should be used for the application of clean technology strategies, which support the natural cycles of matter [see also – *Environmental Biotechnology*].

These strategies should drive towards a pollution free environment, resulting in the prevention of diseases and an improvement of our natural cycles of matter to increase our renewable resource production. At the same time they need to be flexible to guarantee the rural farmer and the urban workforce a sustainable per capita income.

Sustainability refers therefore to the ability of a society, ecosystem or any such ongoing system to continue functioning into the indefinite future without being forced into decline owing to exhaustion of key resources, weather conditions or world market price forces. A sustainable community effort consists of a long-term integrated system approach to developing and achieving a healthy community by jointly addressing economic, environmental, and social issues. Fostering a strong sense of community and building partnerships and consensus amongst key stakeholders are important elements of such efforts. The focus and scale of sustainability efforts depend therefore on local conditions, including resources, politics, individual actions, and the unique features of the community.

Socio-economic strategies have therefore to be designed in a way that individual choices are shaped by values, emotions, social bands and judgements rather than a precise calculation of self-interest.

Such a strategy requires a sound knowledge of the natural cycles of matter as well as consumer demand and gives domestic markets a much higher priority over foreign or export markets. Furthermore, it is highest time that we make everybody, including many scientists and the majority of expert advisers, aware of the fact that microorganisms are the most powerful creatures in existence as they play an integral part in determining life and death on this planet.

As we know, some can kill merciless (= pathogens), but the vast majority can be harnessed to sustain life. We have also to realise and to admit that over the past decades we have managed to foster the killer-type pathogens through population growth and density, overuse of antibiotics, use of raw waste onto farms, and reduce and/or eliminate the beneficial type (eg soil microflora) through overuse of chemical fertilisers, pesticides and farm management resulting in ever increasing areas of soil infertility. The salt problems experienced with large areas of agricultural land together with the increasing effects of chemical fertiliser leaching effects on the Great Barrier Reef in Australia are strong reminders. In addition, our present waste management destroys immense natural resources for energy and value-added product formation. Here I have only to draw your attention to the flares over our sewerage plants, use of anaerobic ponds, reduction of BOD through aeration etc etc.

In order to reverse this trend, it should be a first priority of any region, eg sugarcane area, grain area, vegetable area, urban area etc to establish so-called Bio-Refineries, where agriculturists [responsible for maximal biomass production], microbiologists [responsible for beneficial and control of pathogenic microorganisms] and chemical engineers [responsible for plant design and construction] together with other advisers work together to fully exploit our natural renewable resources using clean technologies with no useable waste accumulation. Such a bio-refinery is therefore totally based on biomass, human and animal wastes as raw materials.

1.2. Developing Countries

In considering all the available technologies together with those under development, the first and basic priority thinking has to be the fact that technologies in general do not transfer from developed to developing countries. Rather they need to be built up *in situ* using local knowledge and innovative ability after which, if successful, they are being adopted. Social aspects of psychology, religion and gender are of paramount importance.

The most serious problems in the developing countries are:

- Health. It has been estimated by UNDP that 2.4 billion people are without access to basic sanitation and 11 million children under five are annually dying annually from preventable diseases.
- Poverty. Approximately 1.2 billion people live on less than US\$ 1 a day and 2.8 billion on less than \$ 2 a day
- Starvation. The developing world has still over 800 million undernourished people.

We have the biotechnological knowledge to abolish the health and poverty problems, with the reduction or even eradication of starvation using modern genetically modified agriculture. It should therefore be possible to create an environment in which people can develop their full potential and lead productive and creative lives in accordance with their needs and interests.

2. Bio-Refinery Concept

A *biorefinery* is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass. The biorefinery concept is analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum. Industrial biorefineries have been identified as the most promising route to the creation of a new domestic bio-based industry.

By producing multiple products, a biorefinery can take advantage of the differences in biomass components and intermediates and maximize the value derived from the biomass feedstock. A biorefinery might, for example, produce one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel, while generating electricity and process heat for its own use and perhaps enough for sale of electricity. The high-value products enhance profitability, the high-volume fuel helps meet national energy needs, and the power production reduces costs and avoids greenhouse-gas emissions.

Microorganisms and plants are *biofactories* that derive their transforming power from their inherent powerhouses of enzymatic machinery and symphonies of cyclic and interactive metabolic inputs and outputs. These '*green and clean*' biorefineries are at the basis of bio-molecular transformations that contribute to the production of biochemicals, biofuels and biomaterials. These biofactories, using a carbohydrate-based platform, mimic the crude oil fractionates that serve as fossil-based fuel feedstock to

produce the vast array of petroleum-based products in use that sustain current styles of living. Bioconversion of plant biomass and agroindustrial residues results in the production of a number of industrially useful biointermediates that give fiscal meaning to the concept of a biobased economy through the use of several platforms:

- Whole Crop Biorefinery Platform' uses raw materials such as cereals or maize.
- The 'Green Biorefinery' Platform uses materials with relatively high water content, such as green grass, used phytoremediant plants and water hyacinths
- The 'Lignocellulose - Sugar Feedstock Biorefinery' uses 'nature-dry' raw material with high cellulose content, such as straw, wood and paper waste.
- The Thermochemical or Syngas Biorefinery uses thermal processes for gasification of black liquor residues from primarily the paper and pulp industry
- The Biogas Biorefinery Platform" that uses natural consortia of microorganisms in anaerobic digesters to produces methane (natural gas) from decomposing organic material, organic wastes and treatment of manures at animal and poultry feedlots
- The Oil recovery Biorefinery Platform that uses the process of transesterification in treatment of vegetable oils, animal fat, and domestic cooking oils originating from soybean, corn, palm, and canola to yield fatty acid methyl esters commonly known as biodiesel.
- The Genetic Engineering Plant Products Platform which uses — selective breeding and genetic engineering to develop plant strains that produce greater amounts of desirable feedstocks or chemicals or even compounds that the plant does not naturally produce i.e. biorefining takes place in the biological plant rather than the industrial plant

- Biofuels
 - solids*: bagasse, lignin residues
 - liquids*: biodiesel, ethanol, methanol
 - gaseous*: hydrogen, methane
- Biochemicals
 - agricultural chemicals*: fertilizers
 - fuel additives*: metal deactivators e.g. N,N'-disalicylidene-1,2-propanediamine used for gasoline and jet fuels and corrosion inhibitors e.g. hexamine and phenylenediamine
 - industrial surfactants*: wetting agents such as glycols
 - *intermediate chemicals*: acetic and fatty acids, fuel additives, furfural, phenols
 - *speciality chemicals*: food esters/emulsifiers and acidulants; botanicals and extracts, vegetable oils
- Biomaterials
 - absorbents, biopolymers, biodegradable plastics, composite and compressed fibre materials for packing and

transportation, dyes, industrial adhesives and gums, inks, oils, ornamentals, paints, pigments and varnishes

Table 1. Range of Biobased Products

The production of biobased products other than food and feed derived from renewable bioresources --- agricultural and forestry materials, animal (skins, horns, etc) and marine (seaweeds) materials have good commercial or industrial value (*see* Tabel 1)

In principle a biobased product is one that can be derived not only from petroleum but also from biomass. Biobased products in comparison to their petroleum-derived counterparts are non-polluting , environment friendly and sustainable, and do not use injurious and toxic substances to human and animal health. Moreover such products reinforce rural economies, improve gender equality, and restrict the spread of poverty through provision of new job opportunities and new markets for farm commodities and residues.

Biomass in the form of plants and trees capture solar energy through photosynthesis and stores it as chemical energy in the bonds between the carbon, hydrogen, nitrogen and oxygen atoms that form lignocellulosic plant material together with starchy, sugary, fatty as well as proteinaceous crops. Biomass is solar energy stored in a chemical form, which is available for bioenergy, biofuel, food, feed, fertiliser and many other products formation.

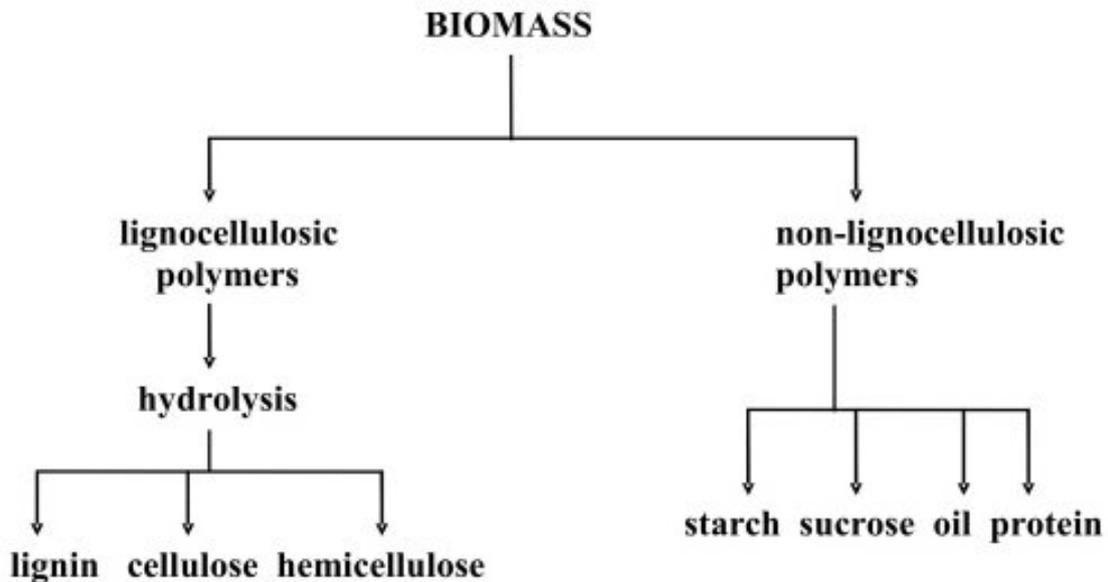


Figure 1: Biomass raw materials

It should be the aim of each bio-refinery management to assure self-efficiency in food, feed, fuel, fertiliser and energy production with marketing products depending on the surplus encountered after the first priority, which must also include improved health standards, has been satisfied.

In order to establish such bio-refineries, a sound knowledge is required in

- land availability
- biomass availability
- biodiversity in crop production
- maintenance of high soil fertility
- maintenance of high crop yields
- population growth and demand
- type of animal production (sheep, chicken, pigs, beef etc)
- type and amount of any waste accumulation from the production unit, human and animal population

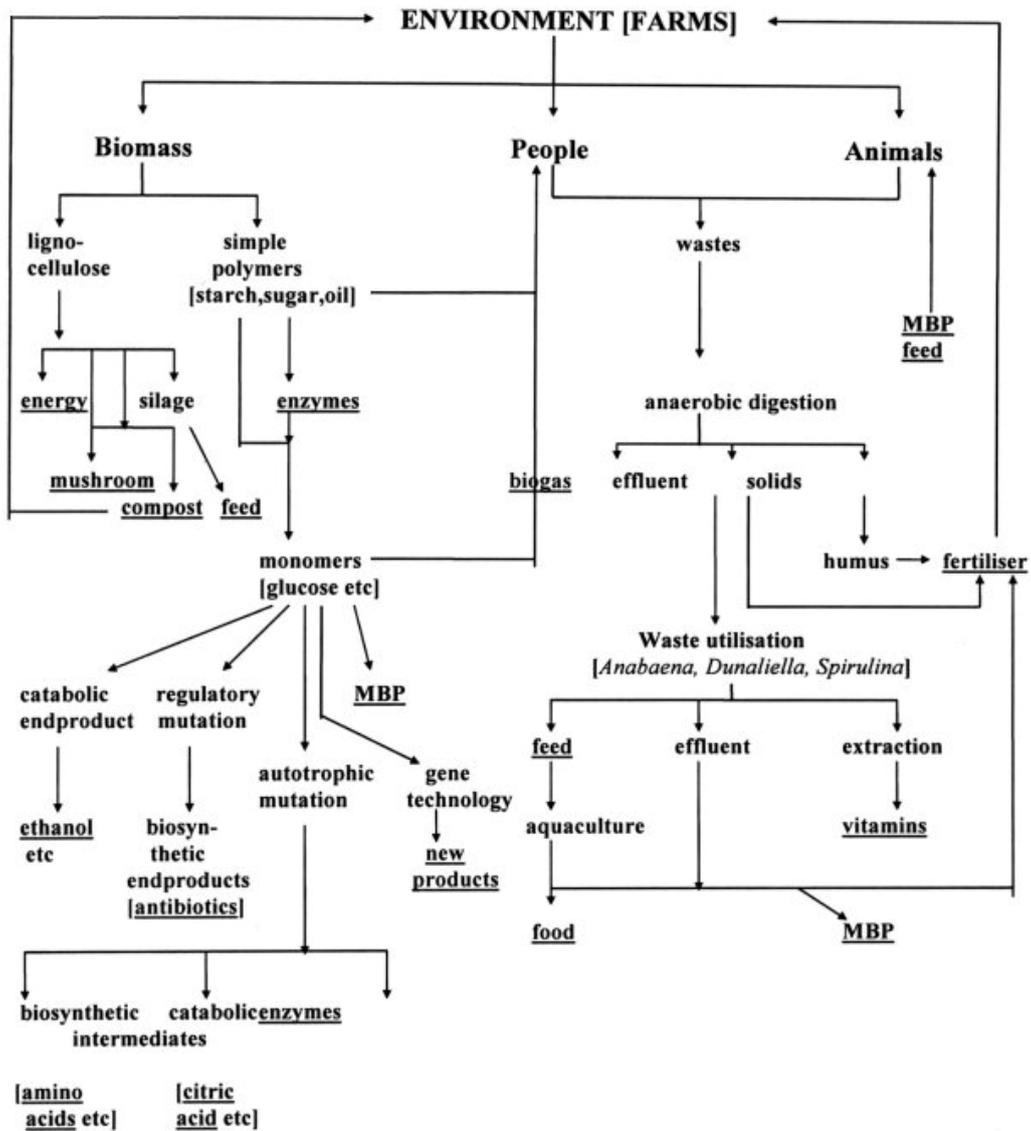


Figure 2: Processing of biomass and control of pathogens within the concept of a biorefinery

Figure 2 exhibits what we regard as a general outline for the functioning of a bio-refinery. Each region consists of biomass, people and animals. Let's concentrate first on the plant biomass itself, which consists of about 25% lignin and 75% carbohydrates or sugars. The lignin holds the carbohydrates cellulose and hemicellulose together in the form of lignocellulose. Other carbohydrate molecules such as starch, sucrose and free cellulose can be found in the fruit or crops of the plant.

3. Lignocellulosic biomass

The lignocellulosic material can be used very efficiently for energy, food, feed and fertiliser production. Energy production, mushroom production, composting and silage are very important industries.

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Biographical Sketches

Horst W. Doelle, born in 1932, studied biology at the University of Jena [1950-1954]. He studied for his doctorate at University of Goettingen [1955-1957] on antibiotic production. After receiving his doctorate, he worked in the Wine and brewing industry in Germany before taking up an appointment with CSIRO in Australia in 1960. After 4 years wine research, he took up the challenge to build up microbial physiology and fermentation technology at the Department of Microbiology at the University of Queensland in Brisbane. He received his Doctor of Science in 1976 and his Doctor of Science honoris causa in 1998. He participated and conducted numerous training courses in developing countries. After 29 years teaching he retired in 1992. His research area was regulation of anaerobic/aerobic metabolism, microbial technology [*Zymomonas ethanol* technology] and socio-economic biotechnology using microorganisms for waste management.

Edgar DaSilva, a graduate of the University of Bombay in microbiology and chemistry, was awarded, in 1962, the Bachelor of Science Degree (First Class with Honours). In 1966, he obtained the Master of Science Degree, and in 1969 his Doctoral Degree for research studies on the cyanobacteria. As a NORAD Fellow, his research study, on the marine algae at the Norwegian Seaweed Research Institute, Trondheim, Norway, in 1970, was followed by a teaching assignment at the University of Helsinki, Helsinki, Finland. Two years later, he joined the Institute of Physiology, University of Uppsala, Uppsala, Sweden as a UNESCO fellow. A former Vice-President of the World Federation for Culture Collections (WFCC), author of several scientific publications, and member of well-known microbiological societies. Moreover, he has also been a keynote plenary speaker at several international events in, Argentina, China, Kuwait, Nigeria, South Africa, Sweden, Thailand, USA, etc. on biopolicy issues in regional co-operation, microbiological education, and on globalization and sustainable development.

At UNESCO since 1974 in various capacities within the Division of Scientific Research and Higher Education and the Division of the Basic Science Dr. DaSilva has been instrumental in the planning and implementation of several UNESCO regional and international programmes in applied microbiology as well as in the development of the global networks dealing with management and use of microbial resources and training opportunities in the fields of marine and plant biotechnology. Moreover he mobilized several extrabudgetary programmes in close cooperation with UNEP and UNDP and Donor Member States for activities in national development in biotechnology and regional cooperation in microbiology.

He also was the Director, Division of Life Sciences that was subsequently transformed into a Section of the Life Sciences within a new Division of the Basic and Engineering Sciences prior to his retirement from UNESCO.

Currently Dr. DaSilva has had teaching assignments as Visiting Professor at the International Centre for Biotechnology (ICBiotech) in Osaka University and its outreach station, and teaching assignments at the UFS, and at the Outreach station of ICBiotech at Mahidol University, Thailand and at the University of the Free State, Republic of South Africa

A fellow of the World Academy of Art and Science and following a keynote lecture to the Biotechnology Division of the Royal Swedish Academy of Engineering Sciences and the Biofocus Foundation, Dr. DaSilva was awarded the Biopolicy Award in 2003