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Biorefineries: A Contribution to the Human Face of Biotechnology

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Abstract: Plant matter represents a huge quantity of a renewable resource called biomass, which is the most important bioresource to sustain life on this planet. The question then arises of 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. Sustainability can be obtained together with higher health and living standards, if appropriate technologies are applied by the local society. As the value of the biomass content is related to the chemical and physical properties of large molecules, the challenges for the future are to be found in a combination of the biological, physical and chemical sciences to replicate an 'oil refinery' with a 'bio-refinery' thus replacing finite non-renewable fossil resources with biorenewable biomass resources for the production of food, feed, fertiliser, fuel, energy, industrial chemicals and related consumer products through the use of clean and green bioprocess technologies. In Asia several countries have embarked on this path of bioeconomic development and growth.

Keywords: Biorefinery, Biotechnology, Biofuel, Biodiesel, Biogas,Composting, Environmental Conservation, Ethical Concerns, Mushroom, Renewable Energy, Silage, Syngas, Thermochemical Energy, Waste Management, Poverty Restriction.

Introduction

Biotechnology, notwithstanding its dark side, has now been accepted as one of the four new empowering technologies essential for bioeconomic advancement and long-term sustainable development for at least the next five or six decades. Rich and rooted in traditional biotechnologies like the age-old dairy and food fermentations, biotechnology can make a significant contribution towards the unveiling of its human dimensions in efforts to curb the onslaught of

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poverty, improve the welfare of men, women and children —the primary investors and practitioners of rural biotechnology. Furthermore, it can build immunological firewalls against the intrusion of inimical entities that erode valuable indigenous and skilled human resources, and that gives the much needed substantive and tangible push to the development of the bioentrepreneurial spirit.

> *"The fuel of the future is going to come from fruit like that sumac*[1] *out by the road, or from apples, weeds, sawdust — almost anything," he said. "There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years."*
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> *——Henry Ford*[2]

In this context, biorefineries are particularly important for developing countries that use a combination of "old and modern" techniques for the improvements in the health and living conditions of 80 per cent of the world's population. For centuries humankind has used microbial intervention to sustain its agricultural and food systems in the maintenance of human health and welfare. As long as the development of biotechnology is driven only by commercial enterprise, human development will lag increasingly behind. Sustainable development and human development are closely related and cannot go into separate directions.

> *"The use of vegetable oils for engine fuels may seem insignificant today. But such oils may become in course of time as important as petroleum and the coal tar products of the present time". The diesel engine can be fed with vegetable oils and would help considerably in the development of agriculture of the countries which use it."*1911/ 1912
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> -Rudolf Diesel, 1912[3]

The geo-economic landscape and the geopolitical equation of the world are undergoing rapid changes driven by the emergence of new economic groups and markets enriched by the availability of genetically engineered products. The new driving force in the novel geopolitical equations of biotechnology can be found particularly in the southern hemisphere that has an abundance of biorenewable resources which gives significant meaning in the distinction between the twentieth century [the era of a finite petroleum-based economy that evolved from the use of fossil fuels, i.e. buried combustible deposits of organic materials, formed within the framework and pressure in the earth's crust into crude oil, coal, natural gas, or heavy oils, and the twenty first century which is beginning to see the use of biorenewable resources within the framework of short biological time that uses microbial enzymatic power, photosynthesis and specialized genetic engineering techniques to embark upon the constancy and consistency of a carbohydrate-based economy.

Oil Crops in South Asia with Potential for Biodiesel Production

Non-edible oils from plants such as: Jatropha, Karanj, Neem, and Kusum are being researched to supplement traditional highly polluting fuels and to provide employment for landless and marginal people. These plants that grow in low-rainfall areas are fast-growing, hardy, are rejected by browsing cattle and goats, and contain about 25 to 40 per cent of an oil that needs virtually no engine modification when esterified and blended with diesel. Moreover, the residual oil cake is rich in minerals and organic residues, which constitutes an excellent fertiliser as well as serves as a good soil-binding material.

Plant oil is highly valued as a source for Bio fuel 'Diesel' Bio Diesel refers to a diesel-equivalent, processed fuel derived from biological sources.[4] As a processed fuel it can be readily used in diesel-engined vehicles, which can distinguish biodiesel from the straight SVO or waste vegetable oils (WVO) used as fuels in some modified diesel vehicles. Biodiesel can also be used as a heating fuel in domestic and commercial boilers. Plant oils are of two types – (i) non-ediblie oils, and (ii) edible oils (Table 1). Other significant plant oils include: castor oil, coconut oil, corn oil, hazelnut, mustard oil, radish oil, ramtil oil, sesame oil, and tung oil.

In China *Jatropha curcas* is mainly distributed in the hot-dry valley areas of Yunnan, Sichuan, Guangxi, Guangdong and Hainan. In Yunnan some 33 thousand hectares are covered with Jatropha forest providing economic incentives to embark on the development of biodiesel as an alternative source of energy. *Jatropha curcas* grows abundantly in several Indian states. Over eighty different species of

Table 1: Non-Edible and Edible Oils Possessing Biodiesel Potential

Type	Oleaginous Plant Sources	Remark
Non-edible oils		
Copaiba	An oleoresin tapped from the species of the genus *Copaifera*. Used in Brazil as a major source of biodiesel	Used in Brazil as a major source of biodiesel
Honge oil	Obtained from derived from *Pongamia pinnata*	Pioneer research in India for use as a biofuel
Jatropha oil	Notwithstanding that over 80 species of the Jatropha plant are known the species *Jatropha curcas* is mostwidely used	Widely used in several Asian countries south and southeast countries as a biofuel oil and is the base fuel in serving the rail, automobile and rural sectors; large-scale Jatropha-based biodiesel plants planned in India.
Jojoba oil.	Extracted from *Simmondsia chinensis*, a desert shrub	Not widely used in Asia but as potential for development as a supplementary bioenergy source in desert areas of China, India and Central Asian countries
Milk bush	*Synadenium granti* from the family *Euphorbiaceae* is a poisonous plant widely found in Africa	Investigated by PetroBras, the Brazil as a possible source of biofuel
Petroleum nut oil	*Pittosporum resiniferum* from the family *Pittosporaceae*	The nut a native to the Philippines was found to be financially not feasible for exploitation as a biofuel following governmental research studies some two decades ago
Edible oils		
Cottonseed oil	*Gossypium herbaceum*	A major food oil, often used in the industrial food processing
Palm oil	*Elaeis guineensis*	The most widely produced tropical oil which is also used to make biofuel
Olive oil .	*Olea europaea*	Used in cooking, cosmetics, soaps and as lighting fuel for traditional oil lamps
Peanut oil	*Arachis hypogaea*	Flavoured cooking oil
Rapeseed oil	*Brassica napus*	One of the most widely used cooking oils; also popularly known as canola
Soybean oil	*Glycine soja*	About half of the worldwide edible oil production is met by soybeanoil
Sunflower Seed oil	*Helianthus annuus*	A common cooking oil

the Jatropha plant are also encountered as potential biodiesel sources.

In India, Karanj or the pongam tree has the rare property of producing seeds of 30-40 per cent lipid content. The seed oil is an important asset of this tree having been used as lamp oil, in soap making, and as a lubricant. It is of especial significance as it is one of the few crops well-suited for commercialisation by India's large rural poor population. Several unelectrified villages have recently used Honge oil derived from *Pongamia pinnata* to fuel their diesel generators, and to create their own grid systems to run water pumps and electric lighting. Recently, the seed oil has been found to be useful in diesel generators and along with Jatropha it is being explored throughout India as a feedstock for biodiesel. The feasibility of the Neem (*Azadirachta indica*) oil seeds for production of biodiesel as well as power in the state of Karnataka is being assessed. Similarly, Kusum (*Schleichera oleosa*) is being tested for it potential use in the production of biodiesel.

Biodiesel[5] is an alternative to the petroleum-based diesel fuel and is made from renewable resources such as vegetable oils, animal fats or algae. It is a fuel comprised of a mix of mono alkylesters of long chain fatty acids. A simple transesterification production process is used to convert the base oil to the desired esters and to remove free fatty acids. Unlike straight vegetable oils (SVO), biodiesel has very similar combustion properties to petroleum diesel, and can replace it in most current uses. However, it is most often used as an additive to petroleum diesel. In summary, biodiesel is renewable, non-toxic, clean and biodegradable. Studies in Germany have shown that the substitution of fossil fuels by locally produced renewable energy contributes to an improved trade balance. Furthermore, some 15 jobs per 1000t of biodiesel production were created. A wide variety of biodiesel fuels are in use throughout Asia and the Pacific (Table 2).

Bio-Refinery Concept and Platforms

A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass.[6] The biorefinery concept is analogous to today's petrorefineries, which produce multiple fuels and products from petroleum oil (Figure 1).

Industrial biorefineries have been identified as the most promising route to develop a new domestic bio-based industry. By producing multiple products, a biorefinery can take advantage of the differences

Table 2: Types of Biodiesel Biofuels used in Asia and the Pacific

Country	Activity/Goal	Socio-economic and Human benefits
ReBionewable Resource: Jatropha ***curcas -Family Euphorbiaceae***		
Cambodia	Biofuel for Rural Sustainable Development and Poverty Alleviation through Cambodia / Canada, and French NGO collaboration with focus on: poverty restriction; conservation of the rural environment through reduction in use of diesel fuel; promotion of the rural aesthetics and cultural dimensions of village life and long-term economic sustainability. Provide through Cambodia/Australia collaboration via the Maharishi Vedi University (MVU) - Cambodia's only rural university opportunities for rural youth who lack normal access to higher education with government recognized undergraduate degrees in agriculture and management.	- Nw source of income and job opportunities for women householders; biofuel oil to be sold locally to provide water pumping, battery charging and electricity services; seed cake to be used as fertiliser - Design, build, and operate a small, self-sufficient a MVU bio-diesel production facility using waste vegetable oil and plant oil that will directly contribute to the development and campus of MVU local market needs and surrounding communities. - Creation of a model of decentralized sustainable energy production for replication throughout Cambodia.
India	Jatropha cultivation has been selected by the Indian government as a renewable energy source to provide an alternative fuel – biodiesel for the future.-Jatropha plantations have been initiated or planned in the Indian states of Andhra Pradesh, Chhattisgarh, Gujarat, Haryana, Kerala, Maharashtra, Rajasthan, and Tamil Nadu.[7] - The Tamil Nadu Agricultural University operates a Pilot Plant for biodiesel production with a capacity of 250 litres / day.- The Indian Railways has started to use the Jatropha plant oil (blended	- Employment opportunities to the rural poor as a means to attain local and national energy independence. - Opportunities for small business enterprises to be developed through R&D activities and support for developing alternate biorenewable energy resources. - Indian Government promotes alternative bioenergy initiative in using cleaner transport fuels.

Table 2 continued

Table 2 continued

Country	Activity/Goal	Socio-economic and Human benefits
	with diesel fuel in various ratios) to successfully power its diesel engines. The rail line between Mumbai and Delhi is planted with Jatropha and the train itself runs on 15-20 per cent biodiesel.	
Indonesia	Directorate of Estate Crop Development, Directorate General of Estate Crop, Jakarta, 2005 proposes 'Development of *Jatropha curcas* plantation as source raw material biodiesel with aims to: - reduce import of petroleum; create opportunities for employment in the national labour market; enhance the security of biodiesel supply and conserveforeign-exchange earnings; and develop the plantation area of eastern Indonesia. - National Seminar on Biodiesel: *Jatropha curcas* - Development for Biodiesel and Burning Oil organized by Institute Pertanian Bogor (IPB), Bogor, 2005, to promote private and public consultations within framework of the theme 'Biotechnology for the Welfare of the People'.	- Jatropha found in the in the islands of Flores, Java, and non-eastern Timor are used to create living border fences; produce ornamentals; prepare medicinals; and provide domestic fuel for lighting.
Laos	Promotion of sustainable development and agroforestry through project focus on: development of investment opportunity in the production of biodiesel from Jatropha curcas plantations in the Sang Tong District at the National Agricultural Research Centre, Vientiane in collaboration with the private sector and an NGO in collaboration with a licensing company based in Vientiane and the local organic farmers association to use Jatropha as a bioresource to generate electricity for remote villages in Laos.	- Reduction of poverty through farmers' involvement in programmes of reforestation with *Jatropha curcas* using thisto produce biodiesel as a suitable substitute for fossil-diesel consumption; and to use the seed cake as soil binding and fertiliser material. - Set up with the Ministry of Agriculture and farmers in the Saythany district, Vientiane, Jatropha 'biodiesel' Saythany district, Vientiane, Jatropha 'biodiesel' nurseries to promote biodiesel business and by-products operations.

Table 2 continued

Table 2 continued

Country	Activity/Goal	Socio-economic and Human benefits
Nepal	Through Nepal/UK collaboration and at Tribhuvan University, Kathmandu provides 'hands-on action training' in the propagation, establishment and cultivation of an additional 120,000 oil-bearing plants on marginal lands, in harvesting of seeds from mature plants in the Tanuhun District to reduce the dependence of the Nepalese economy on imported oils, fuels and chemical fertilisers in cooperation with the Women's Development Section of the Ministry of Local Development in the district.	- Promote and establish the economic empowerment and independence of poor rural women and conserve their health by reducing the drudgery of the poorest women through their involvement in income-generating activities : cultivation and collection of oilseeds, soap production and marketing of oil and by-products such as seed cake residues as soil fertilizer.
Philippines	Plantation of Japtropha trees in military camps and unused land to lessen country's dependence on oil imports.	- Use biodiesel as a suitable substitute in fossil. - diesel consumption.
Sri Lanka	Alternative Resource Income for Women in the Tanamalwila area.	- Promote efforts to engage rural women in sustainable income-generating activities like: production of high quality soap, raw material for cosmetic products and use seed cake residues as soil fertiliser, and fuel for cooking and lighting.
Thailand	Through Thailand/UK collaboration that embraces the Kyoto Protocols Clean Development Mechanism a national biodiesel programme was initiated. Several pilot plants are now operating such as the Royal Chitralada Projects at Raja Biodiesel Co. Ltd in the Donsak District in Surattani Province [and, which was the first established biodiesel plant and pioneer in developing non-fossil diesel fuel in Thailand]; Department of Alternative Energy Development and Efficiency, Royal Naval Dockyard	- Several petrol stations in Bangkok and Chiang Mai distribute B5 biodiesel.-Regional cooperation amongst ASEAN countries was initiated by the Renewable Energy Institute of Thailand and the Asia-Pacific Round Table for Sustainable Consumption and Production as a result of the linkage of the economic corridors between Thailand with Myanmar (Burma), Cambodia, Vietnam, Laos and the southern provinces of China. - In Chiang Rai in the northern most province of Thailand the Khom Loy Development Foundation

Table 2 continued

Table 2 continued

Country	Activity/Goal	Socio-economic and Human benefits
	and the Thailand Institute of Scientific and Technological Research.	with an NGO is funding the plantation of 26000 Jatropha trees within the framework of the Jatropha Biodiesel and Village Development Project that is of environmental and economic significance to the local tribal communities. - Contribution towards capacity-building of the local hilltribe communities' to direct their own future through their involvement in the implementation of the biodiesel project. - Provision of local jobs and income-generating activities for the hill tribe people of Mae Yao sub-district in the reforesting ofdepleted sections of jungle with biofuel plantations.
Vietnam	Vietnam Institute of Ecological Economy and Institute of Tropical Biology promote preliminary study on physic nut (*Jatropha curcas* to produce biodiesel and by-products and to cover wasteland with a green cover and to combat desertification.	- In current use in Vietnam as traditional medicine and hedge borders in: Hoa Binh, Son La, Quang Tri, Ninh Thuan, Binh Thuan, Khanh Hoa, Lam Dong, Dong Nai provinces and Ho Chi Minh City.
Biorenewable Resource: Catfish oil (*Ictalurus punctatus*)		
Vietnam	Seafood processing company aims to clean up pollution of the Mekong Delta through bioconversion of catfish fat into clean biodiesel that has been approved for use by the Vietnam National Institute for Standards and Technology.	- Catfish fat normally used as lubricant and fish feed following its transformation into biodiesel for local cars; and to provide an intermediary glycerine platform for the production of cosmetics, dyeing and pharmaceuticals.
Biorenewable Resource: Coconut oil (*Cocos nucifera***)**		
Indonesia	Promote multifeedstock flexibility that involves in later stages the use of coconut and other vegetable oils in biodiesel plants using palm oil as the base biofeedstock.	- Reduction in use of fossil-fuel diesel.

Table 2 continued

Table 2 continued

Country	Activity/Goal	Socio-economic and Human benefits
Malaysia	Promote multifeedstock flexibility that involves in later stages the use of coconut and othervegetable oils in biodiesel plants using palm oil as the base biofeedstock.	- Reduction in dependence on the use of fossil-fuel diesel.
Papua New Guinea	Processing plant established in Bougainville island.	- Used as local automobile biofuel.
PacificIslands	Reduce dependence on fossil-fuel diesel in Pacific island countries.	- Use environmental-friendly coconut oil to minimize pollution. - provide income-generating opportunities for rural island communities.
Philippines	Philippine Coconut Authority launches national program promoting use of coconut oil biodiesel.	- Use biodiesel as a suitable substitute for fossil. - Diesel consumption.
Singapore	Promote multi-feedstock flexibility that involves in later stages the use of coconut and soybean oils and other vegetable oils in biodiesel plants using palm oil as the base biofeedstock.	- Use biodiesel as a suitable substitute fossil-diesel consumption. - Prime distributor of biodiesel in South-east Asian region.
Solomon Islands	Virgin Coconut Oil (VCO) has been in use for several years in a 50/50 diesel/VCO in the Solomon Islands as a biofuel for: a Toyota Hilux 4WD, a Mitsubishi Truck and for tractors.	- Environmental friendly non-polluting biofuel that is sediment-free, that give sweeter smell fumes and that allows engines to run smoothly with a minimum of noise.
Thailand	Reduction in dependence on fossil-fuel diesel.	Use environmental-friendly coconut oil to minimize pollution. - Provide income - Generating opportunities for rural communities.
Vanuatu	Since 2000, 200 minibuses were running on a coconut / diesel oil mixture.	- Promote economic development in Vanuatu to help sustain rural livelihoods heavily dependent on the coconut crop and its processing.

Table 2 continued

Table 2 continued

Country	Activity/Goal	Socio-economic and Human benefits
Biorenewable Resource: Cotton, Cottonseed Oil (*Gossypium herbaceum***)**		
Kazakhstan	Biodiesel plant using cotton and cottonseed oil as base feedstock which will be supplemented later by multiple feedstock flexibility.	- Meet local needs and provide neighbouring EU countries with biodiesel supplies.
Biorenewable Resource: Palm oil (*Elaeis guineensis***)**		
Malaysia	A biofuel hub, comprising the Tanjung Langsat Port and a 480ha biofuel park, Johor was set up to cater to the fast growing palm oil-based sector. A strategic move has been made by governmental authorities to refocus the use of palm oil towards production of biodiesel as a response to pressing demand from several European countries confronted by an interruption and insecurity of routine transboundary transport of fossil-fuel supplies that result from political considerations, and the rising prices of fuel. Malaysia has already begun preparations to change from diesel to bio-fuels by 2008, including drafting of legislation that will make the switch mandatory.	- Palm oil is one of the least expensive vegetable oils. - First integrated palm biodiesel plant in the world; and first to commercialize technology for biodiesel production with ancillary benefits in the labour and employment sectors.
Indonesia	A biodiesel plant with a capacity of 250,000 tonnes is expected to come onstream this year in Riau.	As the world's second producer of palm oil opportunities for improvement in the labour and employment sectors are planned to boost economic advancement.

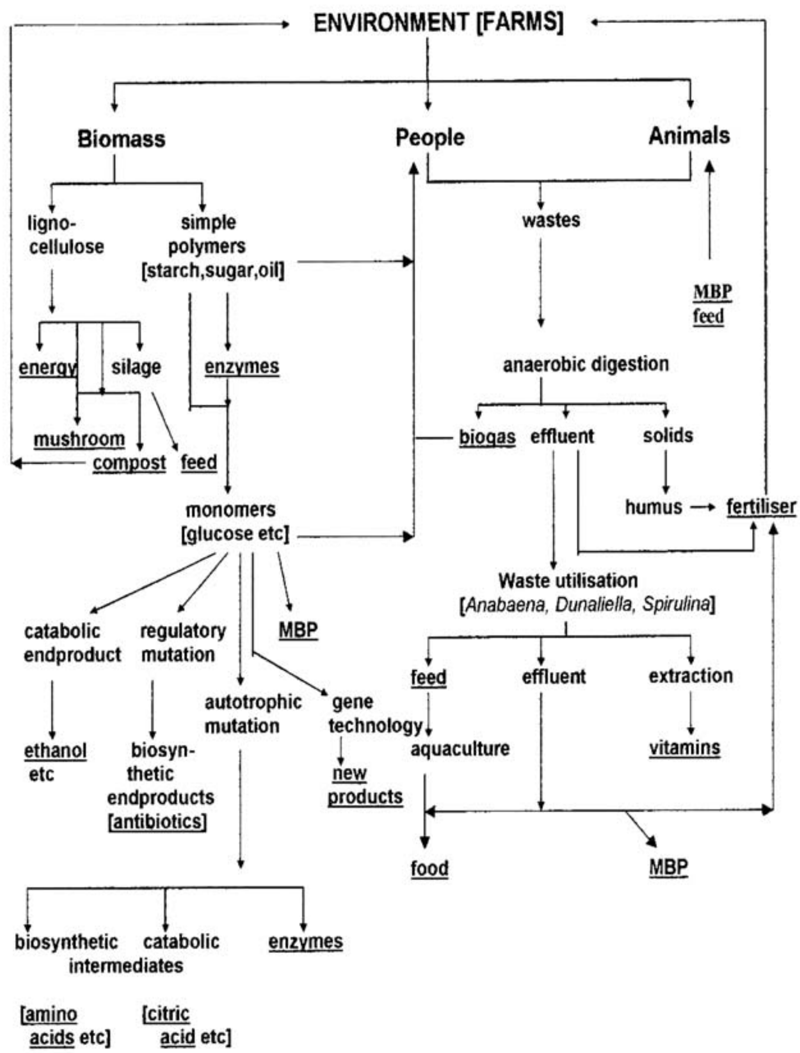
Table 2 continued

Table 2 continued

Country	Activity/Goal	Socio-economic and Human benefits
Singapore	By virtue of its crucial geographical connectivity and *city-state* stature in the global economy and financial markets two biodiesel plants using palm oil as the base biofeedstock in Jurong island which in later stages will be supplemented by multifeedstock flexibility that envisages the use of soyabean and other vegetable oils.	- Both plants—one in cooperation with the biodiesel plant in Darwin, Australia, and the other with a joint Singapore-USA venture will function as a biodiesel hub with ancillary benefits in the labour and employment sectors - The Australia/Singapore venture will be one of the largest producers of pharmaceutical foods and food-grade glycerine which as the glycerol platform has multiple end-use applications in the food and cosmetics industries and in the production of solvents.
Thailand	Daily transportation between the Hatyai district in South Thailand to Sugaikolok district (Thailand-Malaysia border)—a distance of 214 km, using 50per cent biodiesel from stearin palm oil.	- Significant financial savings in use of fossil-diesel fuel. - Plans underway to expand use of biodieselin rail transport.
Biorenewable Resource : Soybean oil (*Glycine soja***)**		
South Korea	Biodiesel is an approved B-20 blend biofuel for use in local automobiles.	- Plans are being formulated to issue market soy-bean biodiesel for use by the middle-income class. Biorenewable Resource: Vegetable oils
China	Develop biodiesel as an alternative biofuel to fossil-fuel use by using as feedstock rapeseed oil, cottonseed oil and recycled frying oil; first commercial plant on stream in 2001 (10,000 t/a) with extension in production in 2003 (100,000 t/a).	- Significant financial savings in use of fossil. - Diesel fuel

Source: Compiled by co-author

Figure 1 : The Biorefinery Concept



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-cost, but high-volume liquid transportation fuel, while generating electricity and process heat for its own use and perhaps enough for the 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 scientifically referred to as natural cycles of matter are at the basis of biomolecular 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 a number of industrially useful bio-derived intermediates that give fiscal meaning to the concept of a biobased economy through the use of several biorefinery platforms[8]:

- ***Whole Grain Crop Biorefinery Platform'*** uses raw materials such as barley, maize, sorghum or wheat and in which economically recoverable plant components such as , agro-fibre residues and sugars are then subjected to thermochemical gasification, and to fermentation respectively to yield ethanol[9], other transportation fuels, and other bio-chemical intermediates such as the glycerol and succinic acid intermediate platforms which altogether result in the availability of a wide variety of biobased products and oleochemicals such as biolubricants. Fructose or fructose syrup from starch and sucrose are very important for people with diabetes and can be amongst the various ancillary by-products produced.
- ***The Green Biorefinery' Platform*** uses materials with relatively high water content, such as green grass, used phyto-remediant plants and water hyacinths. Old environmental biotechnologies such as composting and wastewater treatment have been used to accelerate and facilitate the biodegradation of pollutants and the biocleansing of soil and water resources contaminated by uncontrolled weed growth. Phytoremediation, for example, uses plant-based technologies such as phytoextraction, phtyto-stabilisation, phytotransformation and rhizoinfiltration to clean up pollution from sites polluted by metal, oil, and pesticide

deposits and residues in soils and groundwater. Some examples of plants used in phytoremediation practices are water hyacinths (*Eichhornia crassipes*), poplar trees (*Populus* sp.), forage kochia (*Kochia prostrata*), alfalfa (*Medicago sativa*), Kentucky bluegrass (*Poa pratensis*), Scirpus sp., Coon's tail (*Ceratophyllum demersum*), American pondweed (*Potamog nodosus*) and the emergent common arrowhead (*Sagittaria latifolia*). Groundbreaking work in phyto-remedation relies on the use of transgenic plants[10] to detoxify metal pollutants such as cadmium, mercury, nickel, and zinc.

- ***The Thermochemical and/or Syngas Biorefinery Platform*** uses thermal processes for gasification of cellulose and lignocellulose from crops as well as black liquor residues from primarily the paper and pulp industry and agro-industrial residues. Thermochemical production of biofuels involves gasification[11] to form synthesis gas, and cogeneration to facilitate the production of heat, alcohols and diesel fuel substitutes. There are four primary classes of biopower systems: direct combustion, cofiring, cogeneration and gasification.
- ***The Biogas Biorefinery Platform*** that uses natural consortia of microorganisms in anaerobic digesters produces methane (natural gas)[12] from decomposing organic material, organic wastes and treatment of manures at animal and poultry feedlots.
- ***The Plant Oil Recovery Biorefinery Platform*** uses the process of transesterification in the 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.[13]
- ***The Genetic Engineering Plant Products Platform*** uses selective breeding and genetic engineering to develop plant strains that produce greater amounts of desirable feedstocks or chemicals or even compounds which the plant does not naturally produce, i.e. biorefining takes place in the biological plant rather than the industrial plant.[14] Genetically-engineered plants, shrubs and trees can be developed to produce either high-value chemicals or de novo compounds that are not naturally produced by the non-genetically engineered plants. The production of biobased products other than food and feed derived from bioresources such as agricultural and forestry materials, animal (skins, horns, etc) and

marine (seaweeds) materials have good commercial value (Box 1*a*) and have given rise to established and emerging bioindustries (Box 1*b*).

Box 1*a*: Range of Biobased Products

- **Biofuels**
  — *solids*: bagasse, lignin residues
  — *liquids*: biodiesel, ethanol, methanol
  — *gaseous*: hydrogen, methane
- **Biochemicals**
  — *agricultural chemicals*: fertilisers
  — *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
  — s*pecialty chemicals*: food esters/emulsifiers and acidulants; botanicals extracts, vegetable oils
- **Biomaterials**
  — *speciality 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

Box 1*b*: Established and Emerging Biobased Industries

- **Established Biobased Industries**
  — Recycled packaging materials from agro-industrial residues
  — Bioabsorbents for use in odour control, pet litter, animal bedding
  — Biocement in building, insulation, and road materials
  — Biocontrol products - soil amendments, fertilisers and pesticides
  — Biobased products - cellulose-based paints, cosmetics,
  — textiles, and landscape products, e.g. decorative barks, floral ornamentals
- **Emerging Biobased Industries**
  — Plant-based plastics, starch-based biodegradable polymers, films
  — Biodegradable soybean oil-derived lubricants, greased-refined fluids
  — Soybean derived inks and paints
  — Enzymes—Cellulases for fruit juice clarification and stone-washed jeans —Amylases for nutrition enhancement
  — Renewable carton packaging materials from bagasse, kenaf
  — Biochips involving mating of bacterial proteins with silicon chips
  — Edible vaccines, rub-on vaccines

Source: Adapted from DaSilva (2001).

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 substances injurious and toxic 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.[15]

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 and proteinaceous materials. Biomass is solar energy stored in a chemical form which is available for bioenergy, biofuel, food, feed, fertiliser and many other products formations.

The ultimate goal of each bio-refinery management is to ensure self-efficiency in food, feed, fuel, fertiliser and energy production with marketing products depending on the surplus encountered after the first priority, i.e. improved health standards welfare, has been satisfied.[16] Thus, and for the different categories of biorefineries 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.

Natural Biorefineries at the Rural and Village Levels

In nature, natural biorefineries occur which are of significance at the rural and village levels. Examples of these are:

* *Mushroom production*

Mushrooms rich in vitamins and with a dry basis 20-35 per cent protein content bioconvert through extracellular enzymes, complex lignocellulosic materials and other inedible organic residues and wastes that have little or no market value into building and soil-binding materials. The productions of edible mushrooms make an important contribution to the nutrition and economic welfare of rural populations that have little access to meat-protein. A fast-growing rural and village income-generating venture that facilitates conservation of environmental aesthetics, the age-old medicinal value of mushrooms has given rise to a new development, i.e. the production of nutriceuticals.

* *Composting*

Composting is the controlled microbial bio-oxidation process involving biodegradable organic matter, conducted under *controlled* environmental conditions. A *controlled* process offers a self-sanitizing mechanism by which pathogens, seeds and heat-labile microbial and plant toxins are destroyed, and, which distinguishes composting from the putrefaction of organic matter. The final humus-like material, the compost, is a dark, crumbly, earthy material which has good soil structuring characteristics. The related process of *vermi—composting*, i.e. composting with earthworms in conjunction with aerobic micro-organisms to bring about the subsequent stabilisation of biodegradable organic matter, requires the addition of anaerobic digester sludge.

* *Silage fermentations*

Silage is forage, crop residues or agricultural and industrial by-products preserved by acids, either added or produced by natural fermentation. Silage making is practiced widely in intensive animal production systems in a temperate region, such as Europe, to bridge periods of the year when there is no high quality feed available in the fields and to supplement feed to improve milk production in the dairy industry.

In summary, bioenergy production, composting, silaging and mushroom production ensures that lignocellulosic biomass is fully exploited rather than be discarded as waste. *De facto*, the natural small-scale biorefineries as devised by nature are bio-refineries that have been so enzymatically designed to establish a multi-product system that is evidenced in the availability of a number of commodity and utility by-products.

* *Bio-integrated systems of waste management and environmental conservation*

Anaerobic digestion as an integrated component of environmental biotechnology involves the use of mixed microbial populations in rural communities for the recycling of human, animal and vegetable wastes and effluent treatment providing in many cases valuable fertilisers and/or biofuel cooking gas. Mainly through empirical means a variety of biological treatment systems have been developed that range from cesspits, septic tanks and sewage farms to gravel beds, percolating filters and activated sludge processes coupled with anaerobic digestion for the sole purposes of counteracting health hazards, conserving the environment, and providing opportunities in the rural labour markets.

It also enhances gender equality, the institutionalisation of clean and green income-generating activities, and contributes towards improvement of the quality of life in the rural communities.

A number of bio-integrated systems have been established in developing countries. The most impressive installations of methane producing fermenters can be found in the Peoples Republic of China and the Philippines. Digesters up to 400 m^3 in a series of 5-6 are a common sight on the outskirts of Shanghai or in rural areas. It is in the rural areas where there exist some 4 million family size plants in China today.[17]

The Maya Farm on the outskirts of Manila in the Philippines and biogas plants in Sweden are typical examples of the utilisation of methane produced from animal waste for electricity, power, and heat generation.

The Maya Farm covered 36 hectares, contained 25,000 pigs, 70 cattle and 10,000 ducks, and comprised of three integrated farming systems, varying in size from a small family farm model to a large commercial feedlot venture

- The family farm is based on 1.2 ha of land with 1.0 ha used for crops (rice or corn) and the rest devoted to a cattle shed, fishpond, biogas works, accommodation and a pigsty containing four sows. The biogas, produced from the swine waste and manure from two water buffalo, is more than enough to supply the family's energy requirements for cooking, and also powers a refrigerator and gas mantle lamp.
- The medium scale system is based on 12 ha of land and a 48 sow piggery. The gas is sufficient to pump water for the farmhouse and livestock and to irrigate the 12 ha of cropland. The large system was designed for 500 sow units and no agricultural land, approximating an intensive animal feedlot. The gas produced is used for pumping water, lighting the pigpens and operating a feed mill; however, in this case there is a gas surplus amounting to roughly 40 per cent of the output. Payback periods varied from 18 to 39 months (for the family farm system).

In China, the best example is that of the Xinbu Brigade which started to install biogas units in 1976, and where 80 per cent of the families use biogas. These units supply some 50 per cent of the families' fuel requirements, and in addition, 17 families use solar roof panels which, with biogas, supply 70 – 80 per cent of their energy needs. The biogas is used for cooking and generating electricity for lighting, and the waste heat from the engine is used to dry silkworm cocoons. The slurry is used to feed fish ponds and fertilize the fields growing mulberry, sugar cane and Napier grass. In addition, some of the slurry is used to grow mushrooms. In the six years that the scheme has been in operation, the output from the Brigade (in Yuan) has risen by 150 per cent and the general sanitary conditions of the village have improved considerably.

"The integrated approach has to evaluate energy as a means to produce more food for the world and to consider food as metabolic energy. It is not surprising that in Nature these two aspects are connected, and this lead. The way to a similar consideration by rural planners. The combination of producing food and energy simultaneously, using the by-products of one as substrate, or complementary to the other, is the right path to be take"

Ethical and Environmental Concerns

Three decades ago ethical concerns were raised as to whether arable land and forests should be used or cleared to produce bioethanol - a biofuel that was to aid primarily the automobile industry and in general the transportation sector; *En bref*, it was the dilemma of investing either in food production or fuel generation, in short *Food versus Fuel* or the inability of the poor worldwide to physically and financially access food, and, on the other hand the need to use cheaper and cleaner fuels in response to the then fossil-fuel price hikes and environmental crisis.

In current times, especially in the context of the "gold rush" to tap biorenewable resources for the production of biodiesel, the clearance of vegetation and forest land for establishment of large-scale biorefineries using palm oil feedstocks[18] in Southeast Asia[19] has led to concern expressed by the non-governmental community especially in Europe that there are ethical and environmental issues that need to be addressed.[20] Such palm oil feedstocks produced in this manner have been termed as "*deforestation diesel*".

Poverty Restriction

The Johannesburg Declaration draws attention to the 'ever-increasing gap between the developed and the developing countries that poses a threat to global prosperity, security and stability' and emphasizes efforts aimed at eradicating poverty which erodes health, leads to hunger and starvation and the onset of preventable communicable and contagious diseases (Box 2).

Box 2: Hunger

Drought, hunger natural disasters, armed conflicts, poverty, malnutrition contribute to hunger in more than 20 countries. For example, in Afghanistan, Angola, Sudan, and Tajikistan:

- 830 million people suffer, worldwide, from malnutrition and hunger;
- About 33,000 people starve to death everyday;
- 800 million, at least, suffer from malnutrition;
- 790 million live in developing countries, often, home of the poor and hungry;
- 200 million are children under 5 years of age;
- 100 million go hungry due to drought;
- 180 million (sub-Saharan Africa), 525 million (Asia), and 53 million (in Latin America) subsist on 1,800 calories per day or less. Only in rare cases is hunger due to actual shortfalls of food. As a rule it is a direct consequence of dire poverty.

Sources: Novartis, Union of Concerned Scientists, World Food Programme.

The Plan of Implementation (PIM) of the World Summit on Sustainable Development acknowledges that biodiversity plays an integral role in sustainable development and poverty eradication and recognizes the Convention on Plant Biodiversity as an effective instrument to combat the loss of biodiversity. The PIM also calls for 'practical measures' for access to the results and benefits arising from biotechnology based on genetic resources' (Box 3).

Central Asia and Mongolia[21] have unique genetic resources, traditional knowledge concerning endemic medicinal plants and geographical and climatic conditions. However, these natural assets and dwindling petroresources and fossil-fuel bases economies are threatened by the modernizing forces of globalisation accelerating the erosion of Mother Nature's endowment of plant medicinal biodiversity.

Mining, hydro-electric power projects, high-tech agriculture and the biopiracy of traditional knowledge erode once-thriving economies that now are stricken with poverty health-deteriorating symptoms.

Given the inexorable impact and severity of the phenomenon of globalisation, capacity development programmes have been initiated. The focus of these programmes is on the following: biodiversity conservation; the promotion, protection, and safekeeping of traditional

Box 3: Global Status of Commercialized Biotechnology based on GMO

& Global status of Commercialized Biotech crops

– **Milestones reached in 2006 in an total of 22 countries comprised of:**

- 6 industrialized countries in the European Union (EU) ! the Czech Republic, France, Germany, Portugal, Slovakia and Spain;
- 4 non EU countries ! Australia, Canada, Romania and the USA;
- 12 developing countries ! Argentina, Brazil, China, Colombia, India, Iran, Honduras, Mexico, Paraguay, Philippines, South Africa and Uruguay.
- Approximately 10.3 million in 22 countries planted 102 million hectares of biotech crops.
- More than half [55 per cent or 3.6 billion people] of the global population of 6.5 billion live in the 22 countries where biotech crops were grown and generated significant and multiple benefits.
- The six principal adopters of biotech crops in order of planting were the USA, Argentina, Brazil, Canada, India and China.
- The global biotech area of the commercialisation of biotech crops during the period 1996-2006 was 577 million hectares or 1.4 billion acres equivalent to the more than half of the total land area of the USA or China, or 25 times the total land area of the UK.
- For the decade 1996-2005 the global accumulated impact of biotech crops in terms of net economic benefits to biotech crop farmers was US$ 27 billion [$13 million for developing countries and $14 million for industrial countries].

***Source*:** James, C. (2007). Global Status of Commercialized Biotech/GM Crop 2006, ISAAA Brief No. 35-2006, *Crop Biotech* Special Edition, January 18, 2007.

knowledge which helps to ensure the rational use of renewable bioresources for biofuel production as well as for initiating professional education and public awareness in rural and sustainable development (Table 3).

The Asian Club of Emergent and Rising Biobased Economies

The club of the emergent and rising biobased economies is widespread and includes Brazil in South America, South Africa in Africa to clusters in Asia (Box 4). These countries invest in *white* and *green gold* in comparison with the Middle Eastern region that has a vast natural but finite resource of fossil-fuel rich *black gold*. In the greening of their energy requirements in the transportation sector, China and India have initiated policy initiatives that emphasize the use of biofuels to reduce

Table 3: Some Capacity-Building Initiatives on Biorefinery Issues in Asia

Year	Country	Activity	Remarks
Biocommercialisation			
2006	Singapore	Commercialisation of Biotechnology Crops in Asia	Theme**:** *Moving from ideas to useful products in farmers' fields*; Sponsor(s):Asia Biobusiness Pte Ltd., the National Institute of Education and ISAAA[22]
Biogas			
2000	Turkmenistan	Conservation ofhuman health	A Turkmenistan 2000 Demographic and Health Survey by the Ministry of Health and Medical Industry, Ashgabad, found that virtually all rural households use biogas to meet their energy, cooking and heating needs.
2002	Kyrgystan	Hybrid of 4 biogas units and a micro hydro plant has been established in the Kizil-Charba village in the Talas region.	Power supplied to 22 households by the biogas units which are heated in the winter by electricity from the micro hydro plant and which 4 gas units yield fertiliser as by-product.
2003		UNDP with local NGO introduces bio-gas plant in Nurmanbet village in the Issyk-Kul region.	The aim is to provide local people with alternative and autonomous sources of cheaper, clean and non-polluting energy.
2004	Kazakhstan	Creation of an Education Biogas Centre.	The biogas centre known as *Azure Flame* is located in Karaganda for Purpose of introducing biogas technology and allied process benefits is to improve the economical, environmental and social situation of rural communities.

Table 3 continued

Table 3 continued

Year	Country	Activity	Remarks
	Mongolia	Development of a biogas plant by a local enterprise -the Inner Mongolia Huaqi Biotechnology Co. in cooperation the with the Experimental Animal Research Centre of the Inner Mongolia University and Inner Mongolia Livestock Improvement Centre as a showcase model highlighting a sustainable system of agriculture that uses high-efficiency, low-pollution technologies that are replicable elsewhere in the rural areas of Mongolia	Based on a breeding base of several million dairy cows in theLiangcheng County in the zone that includes: Hohhot - the capital city of the Inner Mongolian Autonomous Region; Jining - in the middle-western part of Inner Mongolia is the administrative centre of Ulaan Chab, and Datong in the Shanxi Province of China, 400 km northwest of Beijing, in attempt to control the spread of diseases; enhance rural electrification and enhance income-generating activities such as marketing of digester residue as soil conditioners and biofertilsers
2005	Uzbekistan	UNDP with the Ministry of Economy, and authorities of the Tashkent Province , and an NGO of local farmers established a pilot biogas plant in Zangi-Ata Rural District.	The attempt of a 4-year duration is to demonstrate to local farmers the efficiency of using biogas as a clean low-cost biofuel which is accompanied by several ancillary benefits and income-generating activities that can provide an impetus to some 9340 farms that have cattle, sheep, pigs and chicken, to adopt this environment-friendly technology.
2006	Tajikistan	UNDP Tajikistan is promoting the use of biogas production in Sharak, a village in the district of Muminabad that has 13,000 inhabitants who derive their energy needs from the use of Tapak cakes [i.e. cattle dung mixed with straw and water and then dried] which emits toxic and non-environmental friendly fumes injurious to human heath and the environment.	The aim of introducing biogas technology and allied process benefits is to improve the economical, environmental and social situationof rural communities.

Table 3 continued

Table 3 continued

Year	Country	Activity	Remarks
Bioremediation			
2005	China	Bioremediation of Contaminants in the Water and Soil Environment.	Sponsors: Sun Yat-sen University; INRA[23] French Ministry of Foreign Affairs and Guangdong Provincial Department of Science and Technology.
2006	Malaysia	Remediation and Management of Contaminated Land: Focus on Asia.	Sponsors: Petroleum Nasional Berhad, Department of Environment Malaysia, The Institution Engineers Singapore *et al.*
	Thailand	Bioremediation and Wastewater Treatment.	King Mongkut's University of Technology.
Biosafety			
2004	Sri Lanka	Biosafety in Asia: Setting a research agenda for the conservation of natural resources.	Sponsors: International Development Research Centre (IDRC) and International Union for the Conservation of Nature and Natural Resources.[24]
	India	Economic Considerations of Biosafety and Biotechnology Regulations in India: A Policy Dialogue.	Sponsors: IFPRI[25] and RIS.

dependence on the use of fossil-fuel. In fact, China and India, now widely acknowledged as the new emerging superpowers on the international scene [and often described as the *Chindia*[26] phenomenon], along with the ASEAN community of Member States and the Asian component of the APEC entity, constitute the new power base of the geography of the biosciences and biotechnologies .

Box 4:Asian-Pacific Geoeconomic and Geopolitical Strategic Ventures

- Fifteen per cent of the total consumption of transport fuels in China will be replaced by biofuels by 2020.
- China promotes South-South cooperation with establishment of ethanol plants in Philippines and Nigeria.
- China engages in biofuel research and production with Madagascar, Malaysia, Mauritius, and isle de Réunion.
- With *Jatropha curcas,* India embarks on the greening of deserts and wastelands.
- Transcontinental South-South cooperation established within framework of the India-Brazil-South Africa (IBSA) Summit.
- Development of an export market of Indian '*Maruti*' cars within the framework of South-South *green mobility* in Angola, Benin, Chile, Costa Rica, Djibouti, El Salvador, Ethiopia, Guatemala, Morocco, Sri Lanka, and Uganda.
- ASEAN[27] Energy Ministers call for harmonisation of standards for biofuels and cooperation in use of renewable energy to counteract the negative impact of soaring fossil-fuel prices on 'one of the world's most dynamic regions'.
- APEC[28] creates a Biofuel Task Force to study and implement bioenergy products across Asia.
- Malaysia, Indonesia and like-minded nations engaged in palm oil production are proposing the creation of an OPEC-style cartel "to regulate international prices [of palm oil], fight tariff barriers in developed countries, and promote palm oil as a feedstock".

***Sources*:** See BIOPACT 2006 and Asia News.[29]

The club of the emergent and rising biobased economies in the developing world constitutes the third wave of globalisation that follows from the first wave when these countries were dominated by a period of discover, colonisation, and exploitation of natural resources and historical treasures; and from the second wave that was characterized by licensed development via the implantation of the multinational corporations.

Conclusion

Countries in the Asia-Pacific region[30] are dependent upon imports of fossil-fuel diesel to maintain and sustain the current advances made in the economic and technological sectors. Simultaneously they are faced with the need to reduce air pollution and greenhouse gas emissions as well as reduce their dependence on imported fossil fuels.

In this situation of contradictions and paradoxes several of these countries are turning to a series of bioconversion processes that are encompassed by the biorefinery concept, and emphasise investment in and the utilisation of a variety of biorenewable low-cost feedstocks such as the Jatropha plant[31] and palm oil. Such a strategy helps boost export earnings coming from making available locally produced biodiesel at prices that are welcomed by the EU and other industrialized societies that are faced with the unreliability of available oil supplies particularly in the context of harsh winters and of rising oil prices as was the case in 2006.

In summary, resort to the use of biorefineries has a human dimension in opening up novel and cheaper vistas for the production of food and utilisation of agricultural products with greater efficiency and in larger quantities in environmental management, sustainability of economic progress, poverty eradication and health improvement in developing countries. Biotechnologies for environmental improvement (sanitation, clean water, and bioremediation) and genetically modified crops help increase biodiesel feedstock availability and quantity and the authenticity of genetic resources in developing countries.

It can only be hoped that the presently existing industrial concept of one source to one product plus multiple wastes will be converted into a more sustainable biorefinery concept of one source to a series of products without waste in the very near future. Such a change would not only benefit Mother Nature, but also contribute to the reduction of poverty and starvation apart from making living on this planet easier.

Endnotes

1. Rhus is a genus approximately 250 species of woody shrubs and small trees in the family Anacardiaceae. They are commonly call sumac or sumach. The name derives from the Greek name for sumac, rhous.
2. Ford Predicts Fuel from Vegetation,» New York Times, Sept. 20, 1925, p. 24..
3. http://catfish.colorado.edu/~gregorys/BiodieselEmissions2.html
4. "Energy Independence is the lifeline of a nation"—Dr. A. P. J. Abdul Kalam, President of India, 2006.

[5] IEA Bioenergy (2003).
[6] Doelle (1982) and Doelle (1986).
[7] Currently, Tamil Nadu is the only state to have a formal Bio-Diesel Policy to distribute wasteland to the poor farmers for the growing of Jatropha crops.
[8] Doelle et al. (2000).
[9] Doelle & Doelle (1989).
[10] DaSilva (2001).
[11] Enebish (2005).
[12] Bui et al. (1997).
[13] AFDC 2000; Schöpe 1996; Freidrich 2004; van Gerpen et al. (2004).
[14] DaSilva (2001).
[15] Doelle et al. (1993a).
[16] Doelle (2001).
[17] FAO (1992).
[18] Prateepchaikul and Apichato (2003).
[19] Asia Pacific Biodiesel Market Likely to Display Significant Growth—http://www.marketresearch.com/map/prod/1374508.html
[20] Scientist are taking 2nd look at biofuels —Rosenthal, E. In: International Herald Tribune,, Wednesday, January, 2007, Paris Edition, Paris, France
[21] Enebish (2005).
[22] International Service for the Acquisition of Agribiotech Applications.
[23] Institut National de la Recherche Agronomique
[24] The International Union for the Conservation of Nature and Natural Resources [IUCN]. Use of the name "World Conservation Union" began in 1990. The full name and the acronym are often used together since users still know the Union as IUCN.
[25] International Food policy Research Institute; and, Research and Information for Developing Countries.
[26] Chindia is a newly coined word that refers to China and India together in general and their economies in particular. The credit of coining the now popular term goes to leading Indian economist and politician Jairam Ramesh. China and India are geographically proximate, and are as emerging superpowers that are amongst the fastest growing economies in the world. Together, they account for one-third of the human population, have been named as countries with the highest potential for growth in the next 50 years in the Goldman Sachs BRIC report.
[27] Association of South East Asian Nations.
[28] Asia-Pacific Economic Co-operation.
[29] BiofuelsMarketplace. com
[30] Raju (2006).
[31] Euler and Gorriz (2004).

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