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A Model for Zero Emission Biotechnology in Asian Countries

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Abstract: Our civilization which began to depend on oil in the twentieth century is now entirely dependent on it. For example, the gasoline used to fuel automobiles is a mixture of hydrocarbons from C_6H_{14} to $C_{12}H_{26}$ that are refined from crude oil. Kerosene is made from C10–C15 hydrocarbons and is used as a jet fuel. Diesel fuel (light oil) is made from C10–C20 hydrocarbons, and the heavy oils used to fuel ships are made from longer-chain hydrocarbons. The residue from refined fuels is called coal tar and is used for making roads. Electricity is generated using heat produced by burning coal, oil, and, recently, liquefied natural gas. Crude oil is also used in the manufacture of light and non-biodegradable plastics and its extensive use during the twentieth century has contributed to global warming and the ongoing climate crisis. The oil from which petroleum is produced is a fossil resource and its global production and availability is expected to peak in the coming decades. Several options for switching over to alternative energy sources such as zero-emission biotechnology and biorefineries are being explored to ensure the security of energy supplies but also for military security. However, the ultimate goal is the construction of biorefineries that are fully integrated with nature in contributing to the sustenance of economic development and a safe and unpolluted environment.

Keywords: Biorefineries, Climate crisis, Green chemistry, Sustainable chemistry, White biotechnology

Climate Crisis and Global Warming

The problems of the climate crisis and of global warming are increasingly pressing. The fourth assessment report of the Intergovernmental Panel on Climate Change[1] said that the average temperature at the end of the twenty first century will be about 1.8°C (1.1–2.9°C) higher than that in 1980–99 if we achieve the recycling society—a society that sustains the environment by saving resources— whereas it will increase by about

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4.0°C (2.4–6.4°C) if high economic growth is maintained. Sea level will rise by about 18–38 and 26–59 cm in these two scenarios, respectively causing, of course, extensive damage.[2] Islands such as Tuvalu, Fiji, the Marshall Islands, and the Maldives Islands which have already been exposed to the crisis of submergence will vanish if such predictions are fulfilled. Moreover, coastal areas, especially the heavily populated mega-delta regions in South, East, and Southeast Asia, will be at great risk because of increased flooding from the sea and, in the case of some mega deltas flooding from rivers.[3] The lives of 228,000 people have been devastated by flood damage in Asia between 1987 and 1997. In Japan, an area of about 861 km^2 is below the water level of the flood tide, i.e., the area is below sea level; and, has a population of 2 million people and property worth 54 trillion yen.[4] A large number of homeless people might have become environmental refugees. The effect of global warming is not limited to a rise in sea level. It is thought that global warming caused by greenhouse gases resulted in the deaths of about 35,000 people during the heat wave that hit Europe in 2003.[5] Global warming also has a serious effect on the ecosystem. For instance, it is not possible for plants and grass to survive because the trees can grow, on average, only at 40 m/year. The climate belt to which Japan belongs, is moving northwards at 6 km/y as a result of global warming. Many scientists have suggested that global warming contributed to Hurricane Katrina, which hit the USA in August, 2005.[6] Katrina caused extensive damage to oil refineries off the Gulf of Mexico. Methane hydrate, which is frozen within the permafrost and the frozen ocean off Siberia, will begin to melt if global warming continues to increase at its present rate. If this happens, methane gas, which has a warming effect 21 times more than carbon dioxide will be released into the atmosphere, following which it will be difficult to prevent global warming.[7] In addition, there is a possibility that the crisis may exceed our expectations and fears with a sudden change in the sea current.[8]

End of the Age of Oil Wastage

Our civilization in the twentieth century is characterized by our dependence on the use of oil in the twentieth century; and we are still dependent upon it. Gasoline used to fuel automobiles is a mixture of hydrocarbons from C_6H_{14} to $C_{12}H_{26}$ that are refined from crude oil. Kerosene is made from C10–C15 hydrocarbons and is used as a jet fuel. Diesel fuel (light oil) is made from C10–C20 hydrocarbons, and the heavy oils used to fuel ships are made from longer-chain hydrocarbons. The residue from refined fuels is called coal tar and is used for making roads. Electricity is generated using heat produced by burning coal, oil, and, recently, liquefied natural gas. Crude oil is not used only in the generation of energy, it is also a raw material in the manufacture of plastics. Plastics are light, non-biodegradable, easy to process, economical to use, and were extensively used during the twentieth century. The oil from which petroleum is produced is a fossil resource, and the peak of its production has already passed.[9] It is clearly evident that the abundant use of petroleum figures prominently in the history of the human race when considered from a longer perspective.[10] We can use the oil of OPEC and non-OPEC only for 84 years for 25 years, respectively.[11] These periods were calculated from the mass of oil technically extractable and economically profitable which was divided by the production in a specific year. It is of much significance that the USA and Europe are developing alternative energy sources with no effort spared, not only to ensure the domestic security of energy supplies but also those for military security.

Kyoto Protocol

A number of countries took a concrete step towards implementing measures to counteract global warming by becoming signatories to COP3[12] (Conference of Parties to the United Nations Framework Convention on Climate Change),[13] which was held in December 1997 and was aimed at finding ways to reduce the production of carbon dioxide (Kyoto Protocol[14], 1997). Although initially the value of the Kyoto Protocol was questionable because the United States refused ratification, the requirements for implementation were fulfilled when Russia ratified the protocol in November, 2004, and the protocol came into force on February 16, 2005. On February 27, 2007, 172 countries, including many Asian countries, fulfilled the treaty of the Kyoto Protocol. Each country included in Annex B of the Kyoto Protocol has committed itself to reducing and controlling emissions of greenhouse gases within the assigned numerical target during the first commitment period (2008–2012) (Article 3). Under this protocol, Japan has been requested to reduce greenhouse gases in the first commitment period by 6 per cent, compared with its emissions during 1990. However, neither China nor India where industrialization is advancing rapidly is included in Annex B. Moreover, the Southeast Asian countries, with abundant biomass resources are also not included. The framework of a post-Kyoto Protocol was first discussed at COP10[15] in December, 2004. The post-Protocol included the participation of the USA and developing countries such as China, where rapid increase in emissions is expected to be a major threat.

Land-based biomass amounts to 1.8 trillion tons, corresponding to a 33000×10^{18} J of energy of (*Biomass Hand Book, 200*5). This is 80 times the annual energy consumption of the entire world. Biomass is a promising resource because products derived from it could possibly replace petroleum. Biomass consist of renewable resources that fix the energy from the sun. The energy from the sun is 620×10^{18} J per hour. An important point in the Kyoto Protocol is to encourage the development of energy production from renewable resources (Article 2.1. (a)[iv]).

The use of biomass contributes to reducing the amount of carbon dioxide in greenhouse gases. Methane and fluorocarbons, as well as carbon dioxide, are components of greenhouse gases. However, even the use of biomass may lead to environmental destruction if it is harvested at a greater rate than it is produced. The amount of energy that can be produced from biomass contributes to the control of carbon dioxide emissions in the short term, and poly (lactic acid), a form of plastic made from biomass, fixes and reduces carbon dioxide.[16] The Kyoto Protocol includes a mechanism called the clean development mechanism (CDM; Article 12). Under this mechanism, the amount of the greenhouse gases' emission reduction achieved by a developed country and a developing country in a jointly executed project is considered part of the reduction achieved by the advanced country. If a country that has biomass technology cooperates with a country where biomass is abundant (as it is in many Asian countries), the former is likely to achieve the target of the Kyoto Protocol whereas the latter would have to acquire the technology from the former country. It is necessary that Asian countries cooperate to work on carbon dioxide reduction, because unlike the USA, no Asian countries have both biomass technology and biomass reserves. Moreover, it is expected that the number of Asian countries on which the carbon dioxide allowance is imposed will be greater in the post-Kyoto Protocol. Then, the adoption of a mechanism (Article 12) whereby two or more countries can jointly achieve the target that the EU has set should also be able to come within the range.

Paradigm Shift

Chemists are advocating a new chemistry that originated from problems arising in the twentieth century. Green chemistry[17] is a new paradigm in chemistry that has spread around the USA.[18] In the field of plastics, during the twentieth century chemists and managers sought to make high-performance plastic products at minimal cost. For example, melamine resin, a thermosetting resin produced by the polycondensation of melamine and formaldehyde has many uses in tableware and other goods used in daily life. However, it was reported that harmful formaldehyde is released when in use.[19] This is a concern being the example of the effect that a product can have on the human body while it is being used. Moreover, because polyvinylchloride is easy to produce at a low price, and despite being hard, it can be softened with plasticizers; over 30 million tons are produced each year in the world. However, dioxin may be generated when it is incinerated[20] and it is being withdrawn from use because of concern about the excessive amount being added to the environment after abandoning the plastics. Safety in the production process is also a problem. Polycarbonate, consisting of bisphenol. A moieties bonded by ester bonds, has many excellent properties, such as heat resistance, high impact strength, size stability, and high transparency, and is widely used as an engineering plastic to make DVDs, car parts, electronic devices, OA apparatus, and many other items. However, because phosgene, which is highly poisonous, is used in the production process, this process is no longer in use. A process not using the phosgene process has now been developed. In this new process, the raw material is dimethyl carbonate, which is produced from ethylene oxide and carbon dioxide.[21] In view of the emphasis on carbon dioxide emission control in recent years, there is now a move to use biomass rather than petroleum products as raw materials for plastics production. A large-scale plant for poly (lactic acid) production has been constructed in the USA, and it is expected that similar plants will also be constructed in Asian countries in the near future. However, it is not only the raw material but also the energy use of the production process that is a problem.[22] Even if biomass is used as the raw material for plastics, the effect of carbon dioxide cannot be controlled if a large amount of petroleum is used in the production process. Thus, it is the aim of green chemistry to minimize the environmental load from the raw material to end disposal.

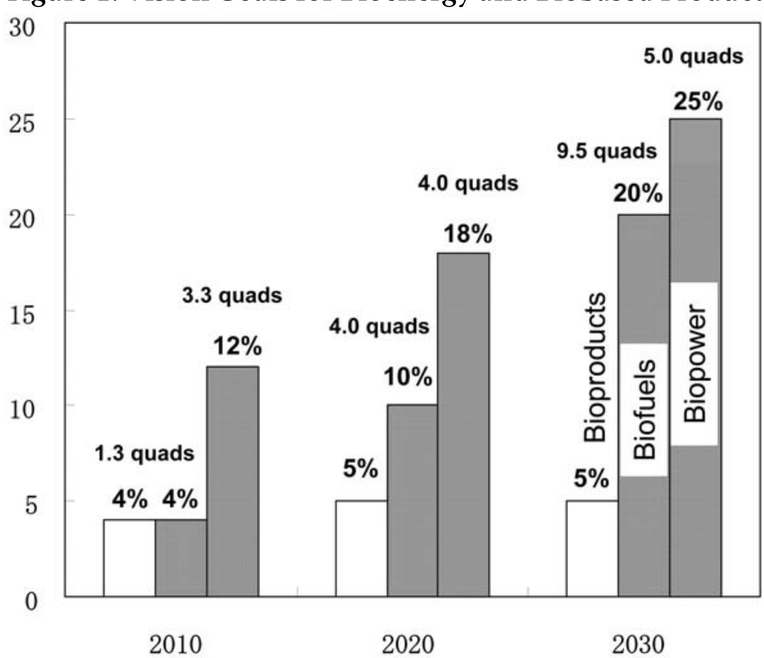
Sustainable chemistry is an environment policy advocated by the Organization for Economic Co-operation and Development (OECD), which has proposed an ideal way for industry to continue to grow while saving resources by recycling and by considering the influence of chemical products on the ecosystem. Furthermore, green chemistry does not include the concept of recycling. The European Chemical Industry Council (CEFIC) and the European Association for Bioindustries (EuropaBio), which receive the support of the Commission of the European Communities, together constitute an organization called the European Technology Platform for Sustainable Chemistry (SusChem), which started in 2004. SusChem facilitates long-term cooperation between governments and the private sector to promote technical improvements for use by governments, industry, the research community, and investors, through advances in three fields: industrial biotechnology, including the search for new enzymes and microorganisms; materials technology; and reaction and process design.[23]

Biotechnology is symbolized by three colours in Europe: red, green, and white. Red, the colour of blood, indicates biotechnology applied to medicine; green, the colour of plant, biotechnology in agriculture; and white, the colour of innocence, is technology as applied to the industry. White biotechnology is also called industrial biotechnology, and has been used since ancient times for making wine, cheese, etc. The term 'white biotechnology' has recently come to be applied more widely, to include the development of genetic techniques. Market analysts predict that white biotechnology will have an economic effect of 11–22 billion euros per year in the chemical industry by 2010, create new employment in many fields, and will stimulate economic activity, and will decrease the load on the environment.[24]

Biorefinery in the USA

Industrial processes using biomass as a raw material are also in the USA. An official announcement was made in August 1999 by President Bill Clinton in an Executive Order[5] for developing and promoting biobased products and bioenergy through biotechnological means to be documented in a report on methods of tripling the use of biomass in the USA by 2010. President Bush applied the idea (Figure 1) to industrial production using biorefineries in October, 2002[25] (Abraham, 2004). Moreover, the US Department of Energy (DOE)[26] in deciding the start of a biomass programme announced that 12 chemicals would become the key compounds (building blocks) of a biorefinery (Table 1). The US Department of Agriculture (USDA) assumes that production of ethanol from corn fibre or corn stover will be the first model of biorefinery. Biobased platform intermediate chemicals can be competitively produced by fermentation, the two most well known examples being lactic acid and succinic acid. A third building block, 3-hydroxypropionic acid, a platform intermediate (Figure 2) that can be produced at a theoretical yield of 100 per cent from glucose is being developed.[27] The US Department of Energy's. National Renewable Energy Laboratory (NREL) has teamed up with a commercial partner to design a biorefinery that will use corn or other renewable resources to produce fuels and chemicals such as 1,3 -propanediol that can be used in place of petroleum in the manufacture of textiles, carpeting, and packaging materials.

Figure 1: Vision Goals for Bioenergy and Biobased Products



Note: Bioproducts represents the proportion of target chemicals that are biobased. The column labeled Biofuels represents the proportion of demand for transportation fuels. Biopower represents the proportion of electricity and heat demand in utilities and industry that is supplied by biomass. The quad is an energy unit based on the British thermal unit (BTU, 1 kWh). 1 quad = 1 quadrillion BTU (10^{24} BTU).

Table 1: Top 12 Chemicals that can be Produced from Plant Sugars

Succinic acid	2,5-Furandicarboxylic acid
3-Hydroxypropionic acid	Aspartic acid
Glucaric acid	Glutamic acid
Itaconic acid	Levulinic acid
3-Hydroxybutyrolactone	Glycerol
Sorbitol	Xylitol

The production of ethanol and the addition of motor gasoline have accelerated. President George W. Bush announced a programme called "Twenty in Ten: Strengthening America's Energy Security" in his State of the Union Address in January, 2007.[28] This programme requires that the production of biomass energy from renewable resources should be increased to 35 billion gallons and that the amount of the gasoline used should be reduced by 20 per cent by the year 2017. As alternate fuels, ethanol, biodiesel, methanol, butanol, and hydrogen have been listed, amongst others. However, the effect of ethanol in reducing carbon dioxide emissions in the USA is low. The ratio of the amount of fossil energy used to the amount of produced ethanol energy is only 1.5 for the US compared with the corresponding ratio of 8 for ethanol production from sugarcane in Brazil. In the USA, the energy source is natural gas; in Brazil ethanol is distilled using the combustion heat of bagasse, the residue left after refining sugarcane.[29]

Moreover, in the corn belt of the USA 10 t/ha or more of soil continues to be lost each year as a result of erosion by the action of wind and rain.[30] In addition, there is concern that stable corn production might not be sustainable in the long term because of decreasing groundwater caused by too much irrigation. It seems that the aim of the biorefinery policy in the USA is to develop the use of corn and decrease dependency on oil from the Middle East. In the future, this policy may lead to a food crisis because of diversion of production towards fuel for cars in this advanced country.

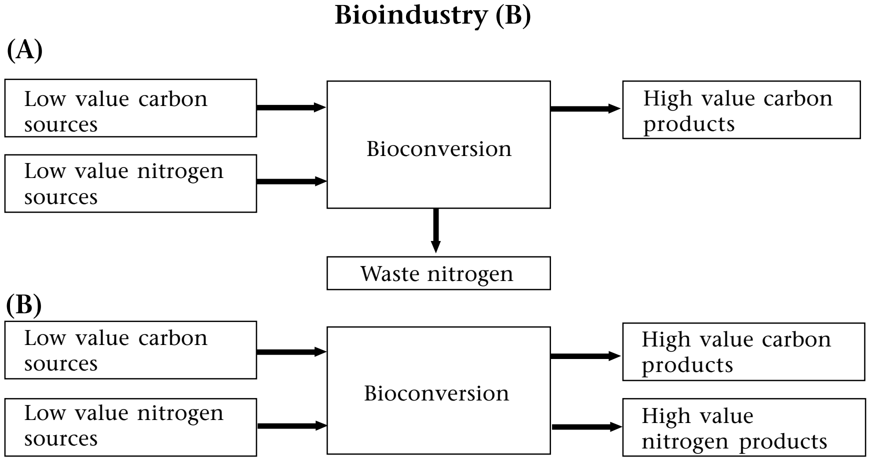
"Cycle C" and "Cycle N"

One of the problems faced by the bioindustry is that of dealing with microorganisms after they have been used in bioconversion. Unlike chemical catalysts, growing microorganisms are problematic and it is considered that microorganisms should not be allowed to grow indefinitely. Therefore, a technology has been developed to immobilize microorganisms and to control their growth.[31] Since refined raw materials are used in laboratories and in factories making products of high when added value such as medicines, a nitrogen source is necessary as a submaterial. However, if using a raw material in high purity for multipurpose bioplastics, the product cost may not be feasible compared with oil-based plastics. Moreover, if the raw material was refined the nitrogen source might be the waste during the refining process. This waste would pollute the environment. A good example is in alcohol fermentation from sugarcane wherein the nitrogen source in molasses is anabolized when the yeast is growing. In this reaction, the removal of the nitrogen source included in molasses and controlling the growth of yeast is not preceded, because the process cost increases.

Humans obtain their essential amino acids, which cannot be biosynthesised in the body, mainly from livestock. However, feeding grains to livestock is an inefficient means of producing essential amino acids. When the population increases and the supply of essential amino acids declines, a more efficient nitrogen circulation process will be required. The author proposes the commercialization of the microorganism used for bioconversion as a high-value-added nitrogen product in biorefinery (Fig. 2).

In conventional bioindustry, low-value carbon sources are converted to high-value carbon by bioconversion (microorganisms). As the microorganism becomes waste, the amount of nitrogen sources

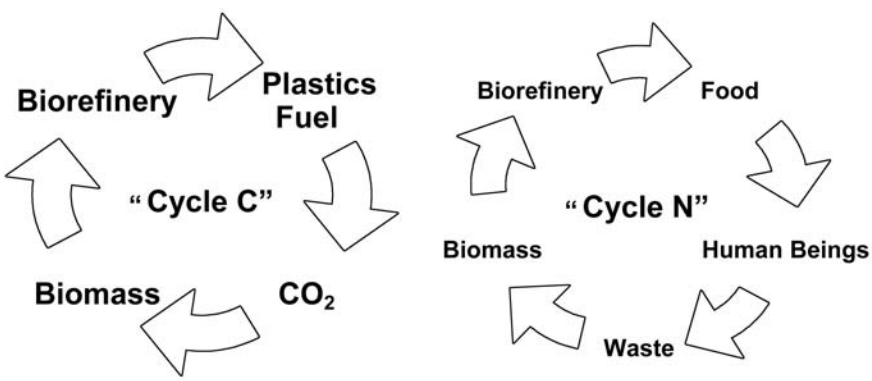
Figure 2: Concept for Conventional Bioindustry (A) and New Bioindustry (B)



should be minimal. However, it is adequate for such medicinal use, etc. that use refined raw materials. On the other hand, the new concept should be applied to produce fuel and plastics from biomass. These raw materials will not be highly purified, and the nitrogen source will be converted to high-value products.

Bioplastics and ethanol that are now being developed are countermeasures to increasing the carbon dioxide and the oil dryness. This is the plan for making a carbon cycle (“Cycle C”). Feeding grain to livestock is an inefficient means of generating essential amino acids, and as the population increases and essential amino acids run short, a more efficient nitrogen circulation process will be required. The microorganism used for bioconversion is a good source for quality protein wherein it is possible to build the “Cycle N” (Fig. 3).

Figure. 3 Carbon Cycle (“Cycle C”) and Nitrogen Cycle (“Cycle N”). Energy and Plastics come under “Cycle C”



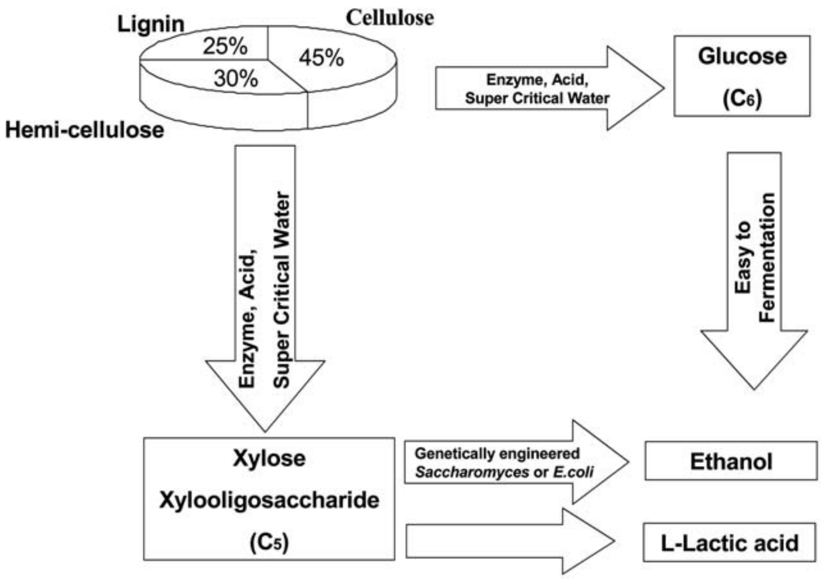
Four Types of Biorefineries

Biorefinery is classified according to the raw material used in whole-crop biorefinery, green biorefinery, and lignocellulose feedstock biorefinery.[32] In whole-crop biorefinery, the raw materials used are cereals such as rye, wheat, triticale, and maize. There are many biomass resources in Asia. Cassava, a kind of potato, contains 25–30 per cent starch. Its country of origin is South America but it now is produced in many countries; the annual world production is 176 million tons, and 50 million tons are produced per year in Asian countries such as

Thailand and Indonesia. The sago palm is another example being a perennial plant which accumulates a large amount of starch in the trunk. It grows in Indonesia and Malaysia, and other countries in Asia. It reaches 7–15 m in height and is 30–60 cm in diameter by about 10–15 years, and 500 kg of starch can obtained from one tree. Although there are no accurate statistics on total production, it is expected that in the near future, there will be 20 million tons or more of undeveloped resources. Because a plantation of sago palm has been developed and grown in Malaysia and Indonesia in recent years, it is considered as a stable biomass. World production of sugarcane further is huge—it was 290 million tons in 2002 in comparison to wheat production which was 570 million tons in the same year. Sugarcane contains about 12 per cent sucrose. Brazil accounts for 28.0 per cent of world sugarcane production, and production from Asian countries accounts for 43.5 per cent of the total.[33]

For green biorefineries, the raw materials are green biomass such as grass from the cultivation of permanent grassland; closure fields; nature reserves; and green crops such as lucerne, clover, and immature cereals from extensive land cultivation. For lignocellulose feedstock biorefinery, the raw material is mainly plant cell walls. The industry that is most advanced in the use of lignocellulose is the pulp and paper industry.[34] Recently, methods of resolving lignocelluloses into syngas and of converting them into sugars that can be fermented to useful chemicals have been developed.[35] Lignocellulose, the major source reservoir of fixed carbon in nature, has three major polymers: cellulose, hemicellulose, and lignin. Various pretreatment options for lignocellulose are now available to fractionate, solubilize, hydrolyze and separate cellulose, hemicelluloses, and lignin components. Hemicellulose includes glucans, mannans, and xylan. The amount of xylan varies in different plants, from as much as 35 per cent of the dry weight of birch wood to as little as 7 per cent in some gymnosperms.[36] Ethanol made from biomass by fermentation is already being used for automobile fuel. Because *Saccharomyces*, typical yeast, cannot utilize xylose, genetically engineered strains of *Saccharomyces*[37] and *Escherichia coli*[38] were developed for converting xylose contained in biomass to ethanol. On the other hand, L-lactic acid can be produced from lignincellulolytic biomass which is the raw material used in xylose fermentation (Fig. 4).[39] Lignocelluloses also can be used as an energy source in biorefinery.

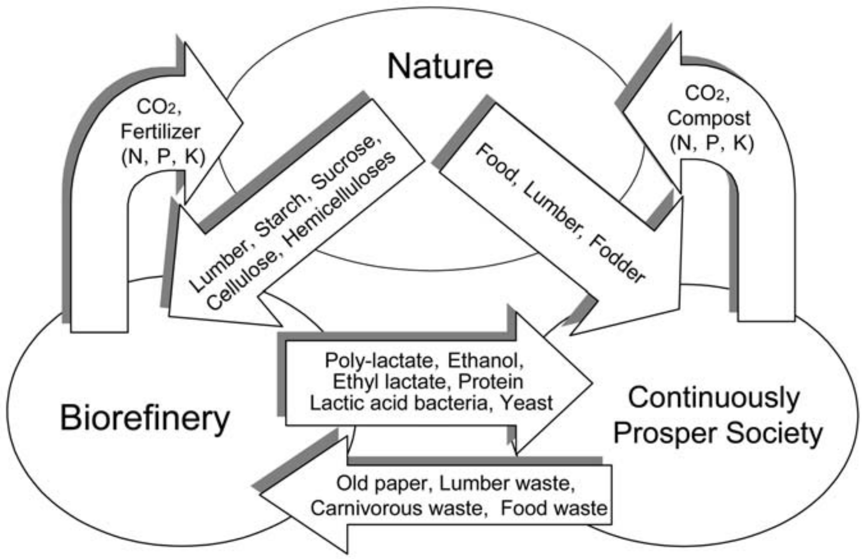
Figure 4: Effective Utilization of Wooden Biomass



The fourth type of biorefinery uses organic waste as a raw material.[40] The previous three types of biorefineries are used in countries where biomass is abundant. These countries are set to revive the industry by using agricultural products conforming to agricultural and industrial policies relating to biorefinery. On the other hand, Japan and some European countries lack space for garbage landfill, and have an insufficient area for compost and few agricultural products. Use of biorefinery serves two roles: that of refuse disposal, and, that of the production of useful products.[41] In these countries, refuse disposal and environmental pollution policies are interconnected. Old paper, lumber waste, and animal and food waste provide the raw material for fermentation and energy resources (Fig. 5).

In Japan, every year the food industry discharges six million tons of organic waste and ordinary families discharges 10 million tons of garbage. Although this garbage is incinerated or buried underground, organic waste contains excess water and cannot be incinerated. Moreover, when the waste is disposed off in landfills, it also generates methane gas which causes global warming.[42] Laws such as the Food Recycling Law [2001] and the Construction Materials Recycling Law

Figure 5: Relationships among Nature, a continuously Prospering Society and Biorefinery



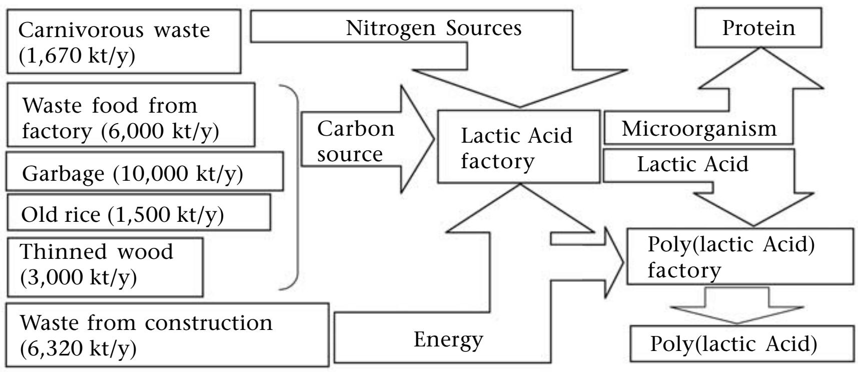
[2000] to recycle food and construction materials wastes (Figure 6) have already been enforced in Japan. Construction materials wastes are used raw materials for the manufacturing energy for production of poly(lactic acid) can be obtained.[43]

Old paper, lumber waste, animal waste, and food waste provide the raw material for fermentation and energy resources.

Ethanol-Poly (lactic acid)-Based Biorefinery

The concept behind biorefineries is the same irrespective of the kind of raw material used. Environmental destruction is the end result of contemporary science based on reductionism. We need to develop holistic science and technology, if we are to achieve a society that strikes a balance between the intricate systems of nature. This is an important proposition for all scientists and engineers. Reductionism assumes that the sum total of the maximization of a partial profit is equal to the maximization of the total profit that caused the environmental destruction; therefore, in this century it is necessary to develop a chemistry that considers influences on the global environment in a holistic way. Nature has been considered as not a reduced system but as

Figure 6: Japanese-type Biorefinery



an overall system. That is, it is necessary to adopt the idea of using waste (by-products) in the process of producing target compounds, and for this purpose to choose some key materials and produce them efficiently. The problem with industry of the twentieth century was not simply that it relied too much on oil. It is because industry used production systems that were based on such reductionism.

First, alcohol as a fuel for cars is produced using biomass that would globally replace oil. In Japan, about 40 per cent of oil is used in thermal power plants, 40 per cent for transportation, such as cars, and 20 per cent for the manufacture of raw materials and plastics, etc. Then, proposed here is an ecosystem based on a holistic view.[44] The lactic acid fermentation and ethanol fermentation would be the based of this biorefinery. Ethanol produced by ethanol fermentation is used as fuel for cars, etc. Lactic acid produced by lactic acid fermentation is polymerized to form poly(lactic acid), which is used to make plastics. Lactic acid and ethanol are esterified to produce ethyl lactate, which is used as a biodegradable solvent. The demand for ethyl lactate has expanded to provide a replacement for chlorofluorocarbons as the washing solvent for semiconductors. Poly(lactic acid) is produced from L-lactic acid, since available as a food product. However, D-lactic acid will also be produced as a stereo complex polymer.[45] Unlike in chemical synthesis, in this biorefinery microorganisms can easily produce the L- or D-isomer at high optical purity. Although a lactic acid bacterium is usually used[46], *Rhizopus oryzae*[47] and a Bacillus sp.[48] produce lactic acid which is usually produced through the use of lactic acid bacteria. Whether the L- or D-isomer is used, lactic acid at high optical purity is required to produce crystalline poly(lactic acid) that is to be used to make fibre or film materials. In polymerization and the chemical recycling processes, lactic acid is racemized by a heating process. Ethyl lactate production is an effective use of the racemized lactic acid. These products play a role in circulating carbon. The yeast and lactic acid bacteria used for the fermentation of ethanol and lactic acid are excellent protein resources for humans. Heterolactic acid bacteria, which can produce lactic acid and ethanol simultaneously, will attract attention in the future. Yeast extract is a good medium component for lactic acid fermentation. These microbes have a high degree of safety since they have long been used in fermented food products. In other words, this process plays a role in circulating nitrogen. In addition, enzymes, probiotics, lactic acid bacterial inocula for silage and useful physiologically active materials such as bacteriocin can be produced from lactic acid bacteria.[49] When a *Bacillus* species is used, an insect pathogen can also be made simultaneously with lactic acid.[50] Since many useful products are obtained in this way in the production process, poly(lactic acid) is suitable for use in a biorefinery. Fermentation cultures using ethanol, lactic acid, and microorganisms are applied to fields as fertilizer, and the phosphorous and potash are then circulated. In this way, not only does wastewater treatment become unnecessary but also fermentation waste can be sold as a product. Poly (3-hydroxybutyric acid), biodiesel oil from rapeseed oil or palm oil, hydrogen, and methane from biomass are other potential biorefinery products.

From the point of view of business feasibility, many products form the so-called product portfolio and profits from fast-growing products can be invested in the development of the next products to show promise.[51] Markets for food additives, lactic acid and brewing ethanol are already established, and yeast and lactic acid bacteria are used as feeds. Although expansion of these markets has stopped, markets for fuel ethanol and for ethyl lactate, which is used as a solvent, are expanding rapidly, and poly(lactic acid) also has a large potential market. As high-value products, physiologically active materials contribute to the stability of enterprises, and microbial proteins are a promising future profit source. Since establishing a biorefinery is a large undertaking, the participation of many companies and national cooperation are required.

Conclusion

Nobody would object to the opinion that the first half of this century constitutes an age of environmental science. Chemistry that uses biomass as its raw material will develop in this century, unlike the twentieth century, when industry was able to use oil in abundance. Plant genetics, biochemistry, biotechnology, biomass chemistry, and separation and process engineering synergize each other.[52] In the twentieth century we began to turn our focus away from the limited fossil resources. However, if depletion is faster than the production, it is clear that it will completely be used, despite the biomass being a renewable resource. Developing Asian countries should not repeat the mistakes made by Europe and the USA in the twentieth century. There is a philosophical problem underlying environmental problems. There is a Western concept of trying to deal with nature on the basis of the science of the twentieth century. If an attempt is made to maximize the accumulation of partial happiness, the negative part generated by the process will be rounded down. We should learn from nature that it is a complex system. There is no wastage in nature—everything circulates. Nature has a food chain and a circulation system, and no specific product is treated as waste. The control of the system works even in the case of an imbalance by generating a large volume of a specific product, following which the system assumes a constant environment. This idea is familiar in the many Asian countries where harmony with nature has always been respected. Biorefineries based on this thought will become part of nature. Thus, the final goal should be to construct biorefineries that would integrate with the nature

Endnotes

1 The Intergovernmental Panel on Climate Change (IPCC) has been established by WMO and UNEP in 1988 to assess scientific, technical and socio-economic information relevant for the understanding of climate change, its potential impacts and options for adaptation and mitigation. The IPCC does not carry out research nor does it monitor climate related data or other relevant parameters.
2 Climate Change, (2007).
3 Climate Change (2007a).
4 Ministry of Environment, Japan (1994).
5 Godoy (2006).
6 Kluger (2005).
7 Schrug and Alley (2004).
8 Cuffey (2004).
9 Heinberg (2005).
10 Henderson (1996).
11 *Oil and Gas Journal* (2005).

[12] Third Session of the Conference of the Parties (COP3) to the U.N. Framework Convention on Climate Change, December 1-10, 1997, Kyoto, Japan.
- Tenth Session of the Conference of the Parties (COP10) to the U.N. Framework Convention on Climate Change, December 6-17, 2004 Buenos Aires, Argentina.
- Documents concerning all COP sessions could be obtained from the UNFCCC Secretariat (http://unfccc.int/secretariat/items/1629.php)

[13] The United Nations Framework Convention on Climate Change (UNFCCC) sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. The Convention enjoys near universal membership with 191 countries having ratified it. Under the Convention, governments:
- gather and share information on greenhouse gas emissions, national policies and best practices,
- launch national strategies for addressing greenhouse gas emissions and adapting to expected impacts, including the provision of financial and technological support to developing countries,
- cooperate in preparing for adaptation to the impacts of climate change. The Convention entered into force on 21 March 1994.

[14] The Kyoto Protocol! The 1997 Kyoto Protocol shares the Convention's objective, principles and institutions, but significantly strengthens the Convention by committing Annex I Parties to individual, legally-binding targets to limit or reduce their greenhouse gas emissions. Only Parties to the Convention that have also become Parties to the Protocol (i.e. by ratifying, accepting, approving, or acceding to it) will be bound by the Protocol's commitments. 173 Parties have ratified the Protocol to date. Of these, 35 countries and the EEC are required to reduce greenhouse gas emissions below levels specified for each of them in the treaty. The individual targets for Annex I Parties are listed in the Kyoto Protocol's Annex B. These add up to a total cut in greenhouse-gas emissions of at least 5 per cent from 1990 levels in the commitment period 2008-2012. The Kyoto Protocol entered into force on 16 February 2005.

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- Tenth Session of the Conference of the Parties (COP10) to the U.N. Framework Convention on Climate Change, December 6-17, 2004 Buenos Aires, Argentina.
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