# Realization of a Sustainable Society -- Zero-Emission Approaches

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## INTRODUCTION

There is no doubt about the necessity of improving our societies to sustainable ones in the coming century. Limits of the resources available on the earth and the capacity of the natural ecosystem to cope with the damages imposed upon by the human activities are getting more and more clarified in details. Nonetheless, anthropogenic activities are expected to become more and more intensified and population explosion especially in the developing countries is anticipated to add further burden to the global natural ecosystems. Natural ecosystems are based upon hierarchical combination of fragile unit processes of various natures and various time constants and this is the reason why the once-destructed ecosystems are hardly recovered to the original forms.

Sustainability came into a focus of environmental issues since UNCED was held at Rio in 1992. Prior to that, World Commission on Environment and Development (1987) defined sustainable development, as the development which satisfy the needs of current generations without suppressing the possible needs of the future generations. As stated before, the need for sustainability arose from the increase of the impact of human activities on the natural environment. Thus it is needed to show how we should modify our activities in a clear and concrete manner. The way to achieve sustainable society might be quite different in developing countries and in industrialized countries since the states of development and thus the problems they have are different. Never the less, the conceptual part should be in line together, since all the countries must be in the last, responsible for the future of the single planet, the earth.

Recently, several movements on finding concrete and constructive ways to achieve sustainable societies have been proposed and promoted. The purpose of this symposium is to examine the cases of industrialized countries in the endeavor to establish sustainable societies. Through the presentations and discussions on prominent ideas and best practices, it is desirable to seek for the plans for future collaboration worldwide in order to have a clear picture on a sustainable human activity in the industrialized society.

## CONCEPT OF SUSTAINABILITY

There have been many discussions on the definition of “sustainability” so far. The fundamental problem clearly derives from the excess intensification of the anthropogenic activities compared with the finite limit of the natural ecosystems on the earth. Thus a practical definition of “sustainability” might be “Optimization of economic level of human activity within the limit of renewable resources supply and the acceptance capacity of natural ecosystems."

In order to achieve this state, the working principle should be:

- To maximize resources productivity (product generated per unit resources) and to minimize material/energy load to the environment

Besides, in line with this definition, all the approaches should be of holistic nature. A systematic approach is especially important in order to clarify interlinkage of unit acts in the anthropogenic sphere.

Also, as necessary conditions to be considered, three equities should be emphasized:

- Equity among regions, especially between North and South
- Equity among living species
- Equity throughout generations

These conditions implies that we should try to limit human activities within a well defined system that can be proved not to impose any burden to outside the anthropogenic sphere and to the future generations.

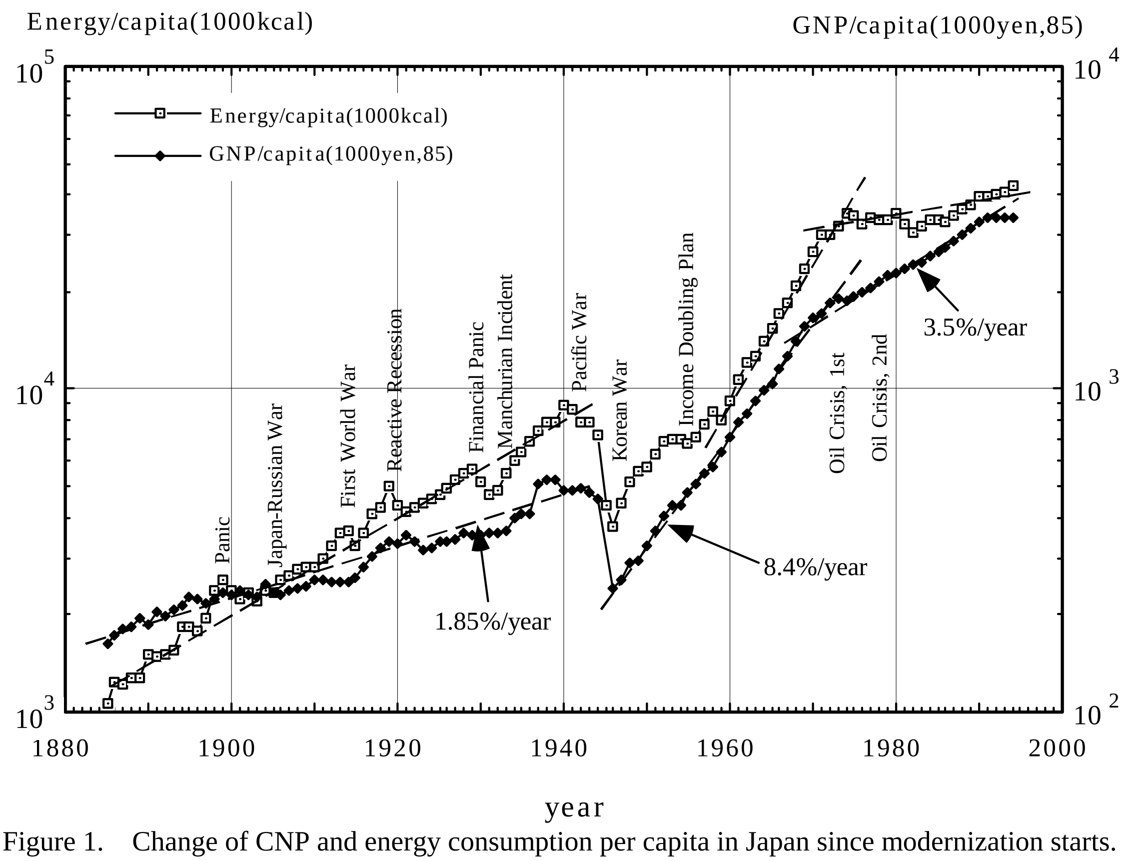


Figure 1. Change of CNP and energy consumption per capita in Japan since modernization starts.

PROBLEMS OF INDUSTRIALIZED COUNTRIES—JAPANESE EXPERIENCES

Japan experienced the remarkable growth of economy since the modernization started at late 19C. Figure 1 shows the long-term trends of gross national product (GNP) and energy consumption after the modern revolution of Japan. GNP figures are normalized on the basis of 1985 currency value. Almost a constant growth rate of 1.85%/year had been observed until the start-up of the Second World War. The situation changed after Japan was defeated at the WWII. The recovery of GNP and energy consumption were so rapid (8.4%/year), which looked as "the miraculous high growth of economy”. At 1970s Japan experienced the energy crisis twice, which leveled down the growth rate of energy consumption and at 1990s the bubble economy corruption greatly contributed to the slowing down of the GNP growth.

As illustrated in Figure 2, all the biological growths found in nature start from a logarithmic growth stage. Logarithmic growth implies that an intrinsic growth rate of the system is realized without any restricting conditions. The growth gradually becomes limited by supply of feeds/nutrients, spatial limitations, adverse interactions among components of various natures, etc. At simple systems such as a continuous monoculture in biological reactors, limiting factors of growth can be easily fed back to the growth rate of species. In these cases, stable steady state are rather easily found and achieved by taking a path shown as Soft Landing (I) in Figure 2. In more complicated systems such as biological predator-prey systems which involve plural species, growth of predators can easily eat up preys and extinction of prey species occurs, which eventually affects the existence of predator species.

In complex systems, such as economic growth of a country and transition of natural ecosystems, limiting conditions of growth or external boundary conditions are sometime difficult to be fed back because of its complex structural natures and its larger time constants of the systems. Also inertial movement of systems often causes a delay in realization of the limit. This causes an overshoot in growth, which may result in chaotic behavior or eventual extinction of the system. The current growth situation of industrialized countries might correspond to these cases. To approach the stable steady state, concrete working principles that are completely different from the working principles in the logarithmic growth period should be identified and employed.

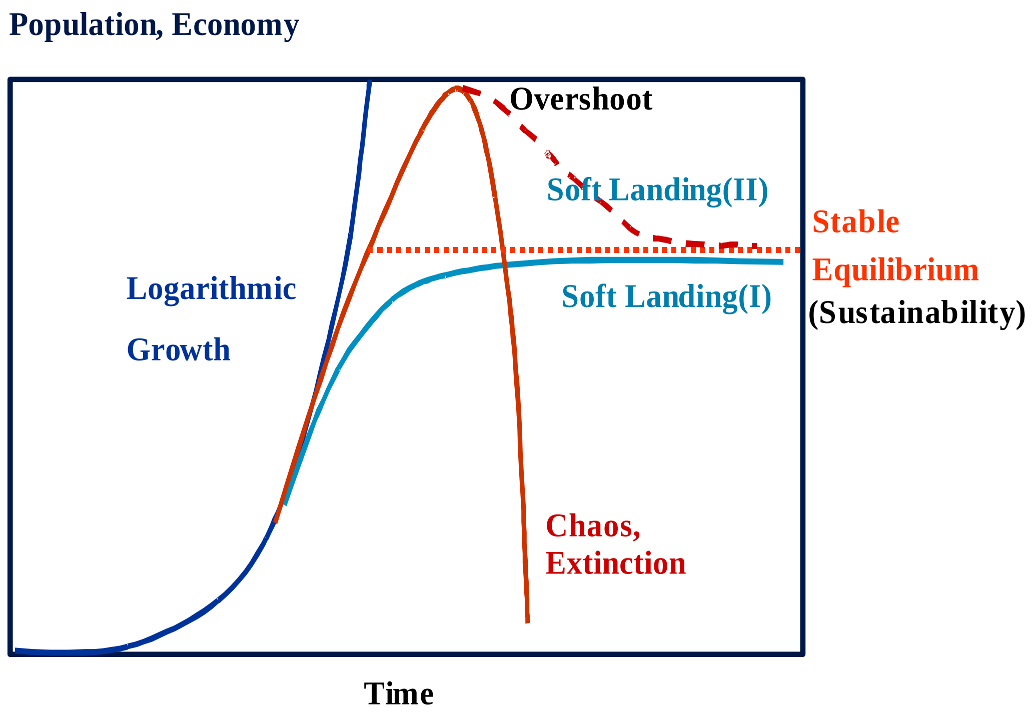

Figure 2. Typical growth patterns in complex systems

A first step in this direction is to make an estimation of a level of sustainable steady state. Establishment of a sound material balance system is the most important basis for the sustainable society. After a goal of growth is visualized, strategies for soft landing on the goal must be discussed in detail.

Environmental problems have been derived from the intensification of anthropogenic activities in many areas. Present situations of human activities in Japan are symbolized by the indices shown in Figure 3, where comparisons are made among the industrialized countries on energy consumption, gross national production and discharged amounts of industrial and municipal wastes per unit habitable area. Habitable area is defined as the area of flat land in each country.

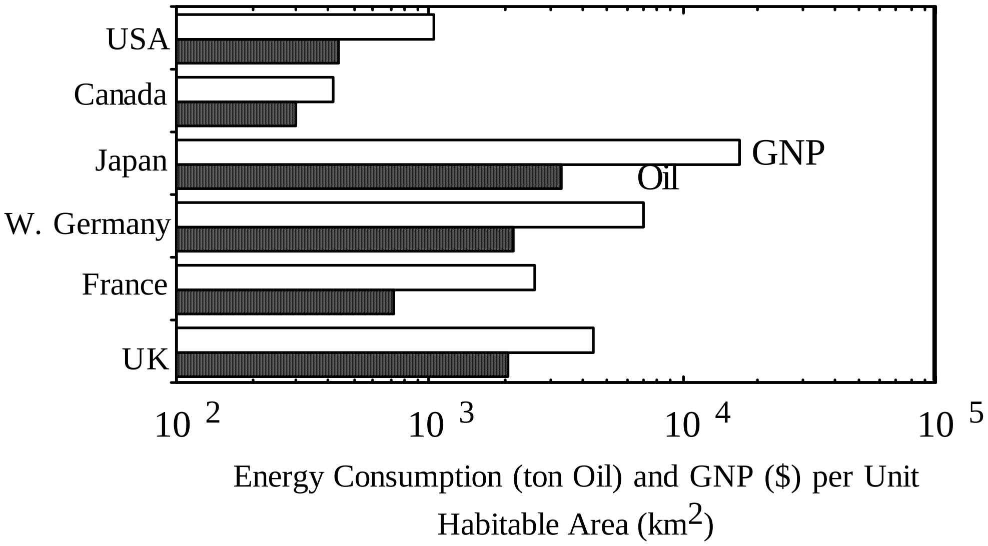


Figure 3. Comparison of the intensity of human activities in six industrialized countries: GNP and energy consumption per unit habitable area

It is clear that Japan is the highest of the listed countries in all the indices, reflecting the spatially intensive human activities. Waste generation per unit habitable area shows the same trend among six countries. Therefore, Japan has to find its own solution to establish a sustainable system independent of any previous examples.

Amount of wastes to be finally disposed in Japan is enormous and a serious problem has arisen to find a place to accept this amount. Material cycle management is thus an essential problem when sustainability is to be considered. In order to clarify the material flows in Japan, flows and stocks of all the materials should become under control. The current situation is far behind this goal and many attempts are needed to establish this system, which involves conceptual, methodological, technical and social systems research.

Material balance is estimated only for the total weight flow in Japan. This is given in Figure 4. In order to realize a sustainable material flow, it is essential to minimize the final disposal amount from anthropogenic spheres. Inputs to the anthropogenic sphere are about 12 tons of domestic resources, 10.4 tons of which is virgin materials, and about 5 tons of imported resources, each of which is based on capita per year. With 10.4 tons of virgin materials, it is estimated that 40 tons of destruction of natural environment is accompanied. Wastes from industrial processes, 3.2 tons, and domestic activities, 0.7 tons, are partly recycles and treated for minimization of volume and finally 0.8 tons matters is to be disposed for landfill. Serious lack of landfill sites in near future is expected in Japan.

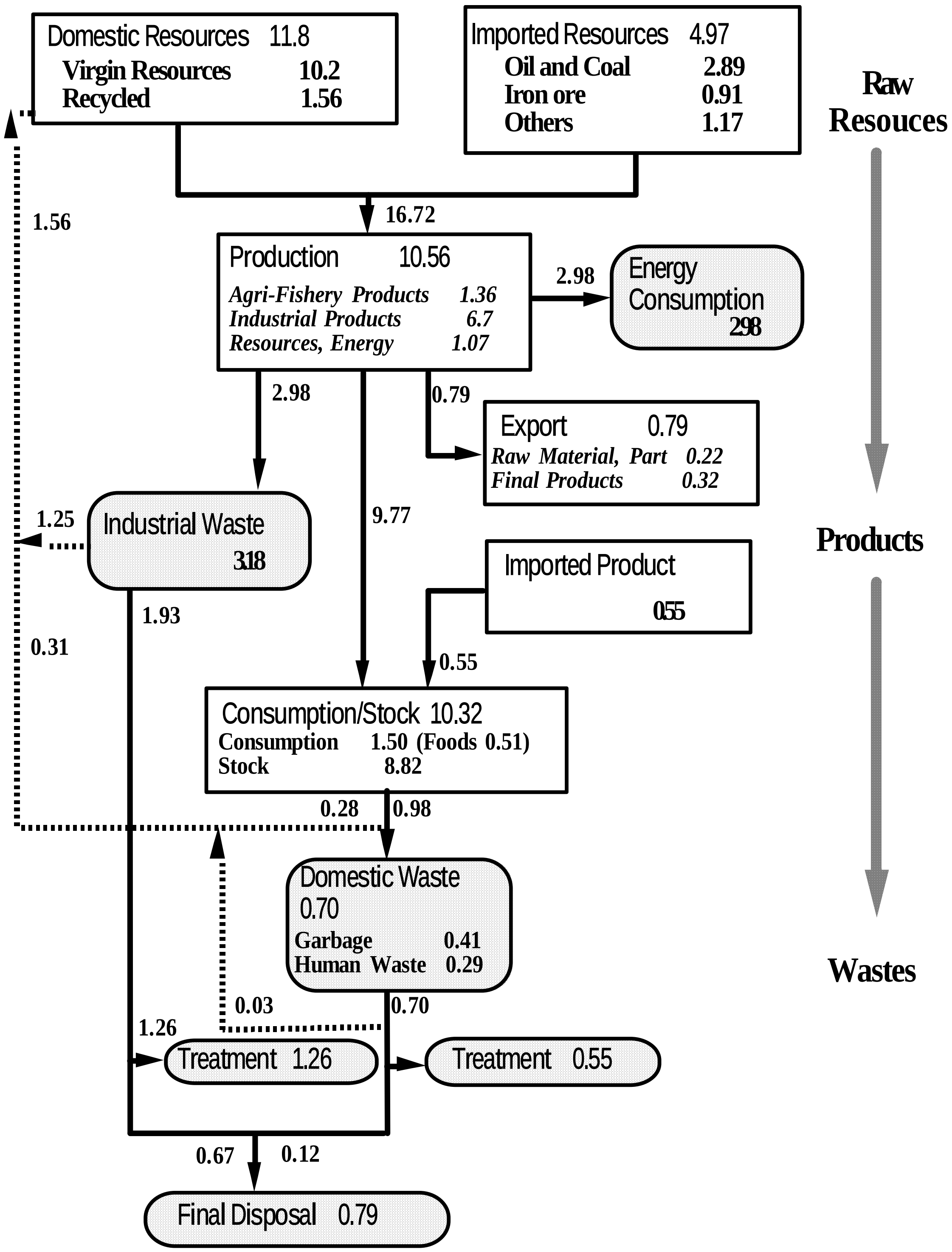


Figure 4. Total material balance in Japan, 1993 Fiscal Year (ton/capita yr), source: Clean Japan Center

WASTE MANAGEMENT IN INDUSTRIAL SYSTEMS

Industrial waste management policies have been changed from “end-of-pipe” approach, to “cleaner production.” Reduction, recycle, and reuse of wastes have been pursued so far and in fact this has been in success in some area. However, at the same time, it has been realized that a modification of a single production process is not enough for the minimization of generation of wastes. Minimization of exploitation of natural resources and total wastes from anthropogenic sphere is accomplished only through holistic understanding, holistic restructuring and holistic management of material flow of anthropogenic systems. Structures of industries as well as social systems are to be reformed so that the sustainable relation between the human activities and natural environment can be established. The efforts of minimization of wastes as a first step will lead to the total utilization of resources or the increase of total productivity of the system. This idea will be symbolically called “Zero Emissions”. Comparison of the concepts involved in the End-of-pipe, the Cleaner Production and the Zero Emissions is made in Table 1. Cleaner Production emphasizes minimization of emission at the exit of the industrial processes and proposes the reduction, recycle and reuse of the wastes, which then is called “end-of -pipe” approach. The Zero Emission concepts will require industries to re-engineer their manufacturing systems so that they can fully utilize the resources within the industries. Zero Emissions, therefore, is expected to create new jobs and revenues and then is considered to follow the industrial breakthroughs in the past, such as zero defects (Total Quality Management) and zero inventory (just in time production).

Table 1. Comparison of Cleaner Production and Zero Emissions

| End-of-Pipe | Cleaner Production (Reduce, Recycle, Reuse) | Zero Emissions (Total Productivity) |
|---|---|---|
| Minimize effects on downstream | Same as left | New industries at upper stream |
| Minimize waste | Same as left | Value added |
| Cost minimum | Same as left | Increase revenue |
| Existent production processes | Modification of unit processes | Clustering of industries |
| Countermeasure at the outlet | Input-output analysis | Output-input connection |
| Individual problems: Water, energy, wastes,.. | Waste minimization by modification of production process | Integral approach, Job creation |
| Starting point | Transit | Final goal |

Gunter Pauli initiated Zero Emission Research Initiatives (ZERI) first at UNU in 1994 and then is continuing activities to realize these ideas in practices and some examples of Zero Emissions approach are given in the Fiji Islands, Namibia and Columbia (Las Gaviotas). George Chan has designed the integrated biomass system at the Fiji Island, which is composed of mushroom cultivation on beer brewery wastes, pig farming by using spent mushroom beds, methane gas production from pig wastes digestion, and aquaculture (plant and fish) from digestion effluent.

Detailed material balance studies are now conducted on this system.

In industrial systems, the approach to the Zero Emissions seems more difficult since eco-restructuring needs to start from the existent industries which have been highly intensified and fully optimized locally based on the open market economy system of the country.

The same concept of Zero Emissions, however, should be applied also in the industrialized countries. Namely, thorough material balances are to be identified in each industry and the database or the inventory sheets should be established. The possibilities of utilizing a waste from an industry as a raw material in itself or in another industry should be studied to establish a completely closed material balance and to achieve the total utilization of resources. During this analysis, identification of key technologies to realize the industrial networks should be made. Also, assessment methodology to judge which of the alternatives is more suitable to the concept of Zero Emissions. Technologies and systems thus selected should fit the area needs, so that material balances and local activities should be first made clear.

In order to achieve Zero Emission industrial systems, the items summarized in Table 2 should be developed. Especially development of methodologies for establishing a cluster of industries including proposals of new components to complete clustering and for assessment of alternative combinations of industrial networks are the most essential part of the study.

Table 2. Research topics needed for constructing Zero Emission industrial networks

| Category | Need for research |
|---|---|
| 1. Wastes to resources | Identification of key technologies |
| 2. Unit industrial processes | Clarification of complete material balances |
| 3. Clustering of industries | Output-input analysis, Methodology for clustering |
| 4. Regional optimization | Characterization of the region |
| 5. Assessment method for alternatives | Total resources productivity |

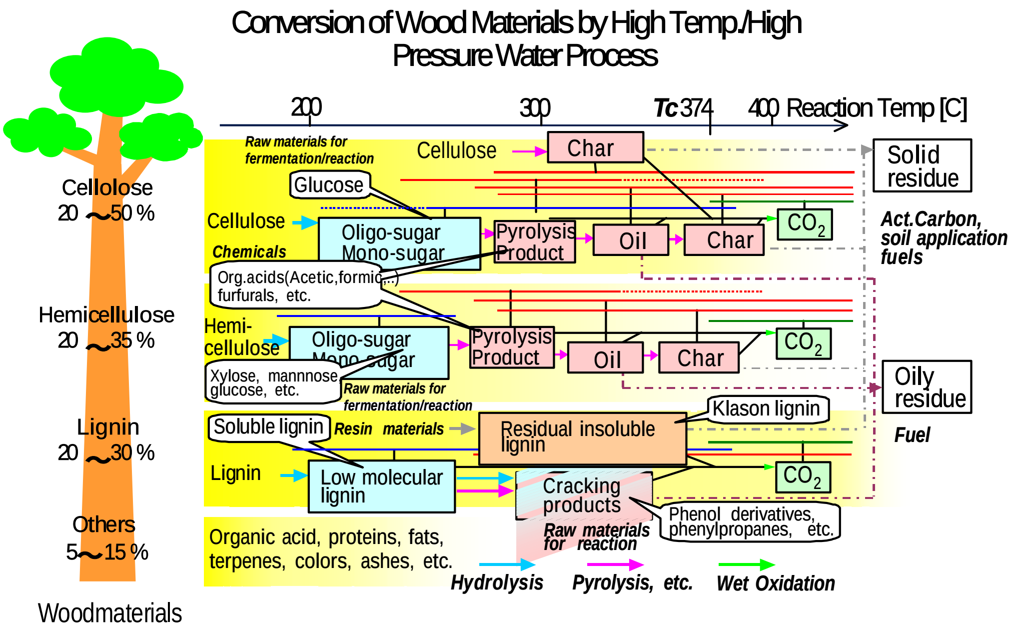


Figure 5. Example of the high temperature/high pressure treatment of biomass for complete material utilization (Source: Sakoda, 1999)

RESEARCH PROJECTS ON ZERO EMISSIONS IN JAPAN

A project was implemented from April 1997 in Japanese universities by the support on Ministry of Education. "Formulation of Material Cycles Oriented for Zero Emission" project (ca 240,000,000yen/year for 1997-2000 FY) as one of the Specific Area Researches in Grant-in-Aid for Scientific Research consists of a steering committee and three prearranged research groups together with 60 individual research groups selected from 250 proposals (as of 1999). The three prearranged research groups are:

(1) Analysis of Material Flows in Industrial Processes (Head of the group: Tadashi Hano, Oita University),
(2) Construction of Closed Material Cycles Within Industrial Clusters (Head of the group: Hiroyuki Yoshida, Osaka Prefectural University), and
(3) Mathematical Modeling for Complete Material Cycles in Area Units (Head of the group: Koichi Fujie, Toyohashi University of Science and Technology).

Each of these prearranged research groups consists of 6 to 8 members. The first group aims to clarify all the materials flows in steel, metal, chemicals, foods, brewery and power industries including wastes streams from component processes and to establish the inventory database for each industry. At the same time possibility of minimizing and recycling of wastes and utilization of wastes as resources for other processes should be investigated. Technology development to convert unused byproducts (wastes) to value added products is also emphasized in this group. One example is illustrated in Figure 5. High temperature and high pressure water treatment of biomass based wastes shows a possibility of producing valuable organics, proteins, chemical agents, and functional materials. The second group focuses in networking industries of different categories so that material cycles within the network become more complete. The concept to formulate industrial clusters should be established so that an appropriate combination of industries should be easily proposed. Input-output databases for various industries and available technology database are prepared and computer simulation software to examine possible networking of industries is developed. The third group, on the other hand, aims to establish a methodology to clarify total material balance in the area unit, such as municipality, islands, nations and so on. Input-output analysis in the field of product analysis is to be extended to the actual material flows.

## CONCLUSION

Sustainability is the important requirement for all the future human activities to be based on. Though the actual paths to achieve sustainable relations between anthropogenic activities and natural ecosystems are still under development, the anthropogenic sphere should be designed carefully and in details so that we do not leave any excess load to natural ecosystem, other countries and future generations. Zero Emissions is one of the trials in this direction and construction of complete material cycles in anthropogenic sphere is emphasized here. Many other important components in the establishment of sound relations with the ecosystems, such as energy, climates, agriculture, etc. are to be included in the future development of a holistic management system for anthropogenic activities.

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