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Special Article

Technology for sustainable agriculture and agro-industry

Nobutaka Ito

Visiting Professor, Faculty of Engineering, Chiang Mai University, Thailand
E-mail: ito.nobutaka@gmail.com

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Abstract: As already well known, the two issues of energy and environment, including food issue, are the emerging and crucial problems that are closely related. In this paper, the technologies which seem to be hopeful and sustainable for agriculture and agro-industry are introduced and their possibilities are also discussed together with the future aspect of global agriculture. Some collaborative research program is also introduced considering the university reform to autonomy and globalisation of the world.

Keywords: sustainable agriculture, agro-industry, environment

Introduction

What is happening currently in the world? The price of petroleum is going up day by day. Carbon dioxide gas is produced as a result of petroleum combustion thus becoming one of the main causes of global warming problem. As far as total petroleum dependence is concerned, carbon dioxide production continuously increases and the situation is neither improved nor becomes better. That is the reason why the energy issue is deeply related to the environmental problem besides having petroleum consumption almost directly proportional to the carbon dioxide production causing a serious problem of global warming. Recently the success story of Brazil in bio-ethanol production from sugarcane has encouraged researchers. Many kinds of research projects are now looking for the possibility of utilising various kinds of biomass resources. The possibility of bio-ethanol production from food crops is also being proposed and considered. Sugar beet, cassava, corn, rice and wheat are major candidates, in addition to palm oil, jatrofa oil, eucalyptus oil, tangerine orange oil and so on. However, some of the people worry that bio-ethanol production from food crops may bring up the price of food, and then

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people in developing countries may find it hard and difficult to get food and would be facing hunger and poverty. The food and energy issues must be discussed especially for energy production derived from them.

Global Tetralemma

In Figure 1, the author pointed out the four global issues which seem to have become important and serious problems to be assessed sooner toward the future [1-7]. Because of the drastic increase in world population that require more food production, more energy (mainly petroleum) must be correspondingly consumed for more production of food. A big amount of energy consumption jeopardises the environment due to carbon dioxide produced by petroleum combustion, which consequently brings global warming. The author believes that the above-mentioned four issues are closely related to one another and must be solved simultaneously, not one by one. In addition, he showed one of the solutions that could be found by proposing one of the key resources which can cover the three issues of food, energy and environment. For example, rice is one of them because it is a food plant from which bio-ethanol can possibly be produced and which absorbs a lot of carbon dioxide while growing in the paddy field. Almost fifteen years since the author has proposed this, it is really surprising to see how drastically the world has been changing and what kinds of problems it is facing now in these issues. The following are the four issues the author has previously picked up as global tetralemma. Needless to say, the problem has mainly started from the drastic increase of human population in the world. If this situation had not been encountered, the rest of the three issues might not have been seriously discussed. Let us see how these issues are now.

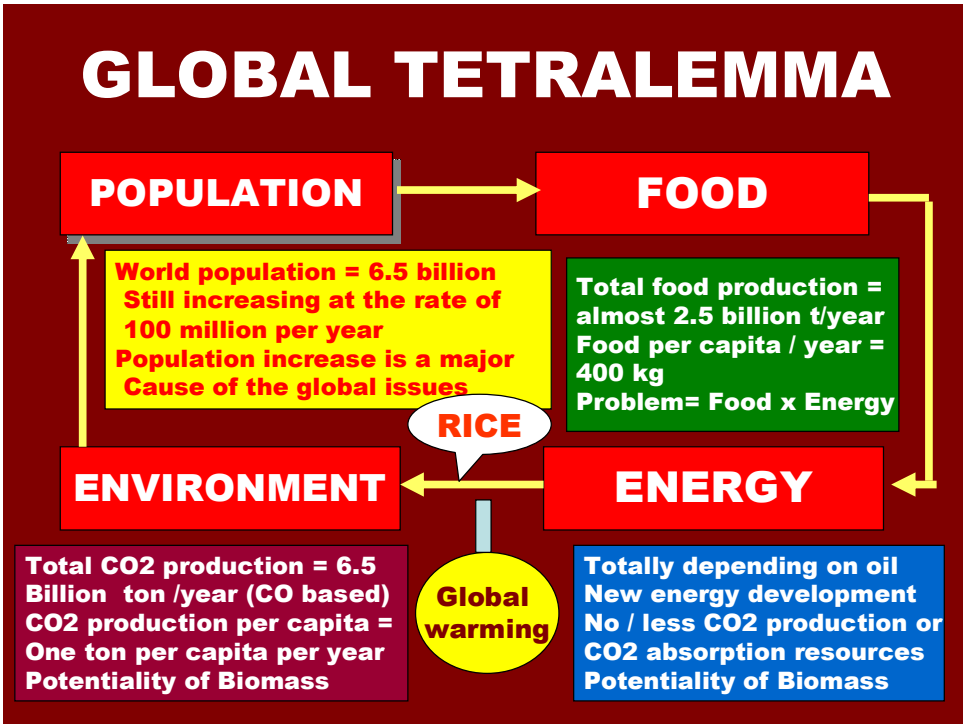

Figure 1. The concept of global tetralemma

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Population

The world population has recently become almost 6.5 billion and it is still drastically increasing at a rate of nearly one hundred million per year. It will become almost 9.3 billion in the year 2050, as shown in Figure 2, based on the assumption that it is continuously increasing at the same rate as today. The potential rated capacity of human population acceptable for the planet earth can be estimated simply by considering the total energy available from the sun, although the result of the calculation may become different depending on the assumption of what and which factors should be taken into consideration. According to the result of the simple calculation, though, it can be estimated to reach a maximum of 24 billion, as shown below:

- (1) Solar energy coming to earth = 170J/m^2.sec = 1.5×107J/m^2.day
- (2) Cultivated area = [5.1×1014 m^2] x 3.0%=1.5×1013 m^2
- (3) Photosynthesis efficiency = 0.1 %
- (4) Required energy per capita per day = 9.2×106 J/capita/day = 2200 kcal/capita/day
- Available maximum capacity of earth = [(1) x (2) x (3)]/(4) = 2.4×10^{10} capita
  = 24 billion capita

Hence, assuming that the world population will increase at the same rate as of today, it will be almost over the estimated maximum capacity of the earth in the year 2130 [8].

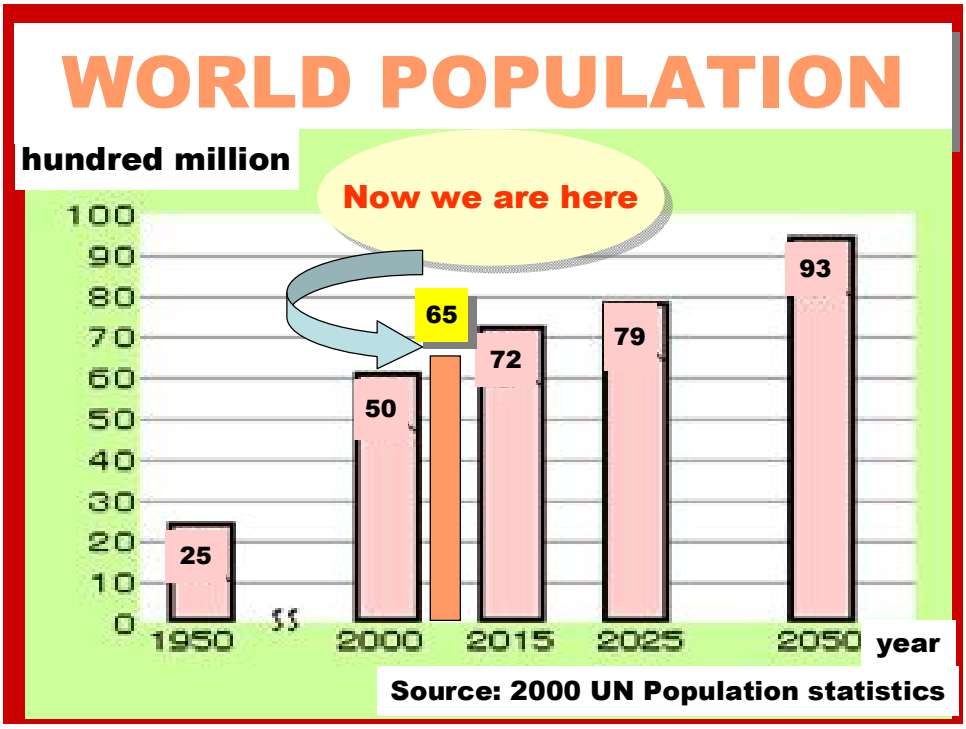

Figure 2. Estimated world population change

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Food

The total food production in the world is now almost 2.5 billion tons per year, consisting mainly of 2 billion tons of cereals that include rice, wheat, corn and soybean, and 0.5 billion tons of vegetables, meats and fruits. The amount of food per capita per year can be calculated by simply dividing this figure (2.5 billion), by the world population (6.5 billion), becoming almost 400 kg per capita per year. It looks good enough now looking at this figure, although many people can still be seen unable to get sufficient food and still suffering from poverty and hunger. According to some statistics, there are almost 800 million such people in the world and only 20% of the population is engaged in food production. This means that one person who is engaged in food production must produce food for five persons including his own. So the rest (80%) of the population depend totally on the food they produce. The important role that agricultural engineers play for the production of enough food to feed all the people on our planet involves not only in the fields of agricultural machinery and mechanisation, but also in irrigation and water management. To exactly make sure that food production and its distribution function to meet the actual current conditions facing the problem of poverty and hunger, agricultural engineers are strongly urged to make action to change the direction to meet these conditions positively and actively. As already mentioned above, it was found that biomass has a lot of potentiality to solve the global problems of food, energy and environment. Bio-ethanol is currently much focused as one of the most hopeful energy resources replacing petroleum toward the future from the viewpoint of stopping the global warming because of its neutral carbon. However, even if food crops could be used successfully for producing bio-ethanol, another problem would be the increase in food price. It should be noted that the total potential of available farm land is limited and it should be discussed on how it should or could be managed from the global point of view. The world's cultivated farm land is currently almost 1.3 billion hectares and it is estimated that it can possibly be increased up to 1.5 billion hectares at the maximum because a certain amount of those cultivated farm lands is also changing into desert year by year (Figure 3). Even if more new farm lands are further developed for food or energy bio-resource production, they may bring more environmental jeopardy such as deforestation. Not only for the issue of food but also for energy that more additional farm lands are needed to meet the requirement for both production increase of food and energy. It seems almost impossible to newly develop and reclaim farm lands in two dimensions. A plant (green) factory may, however, provide some possibility to ease this problem if high-rise buildings or architecture are constructed for growing food crops or energy ones. In relation to the topic, a huge structure of 2000 metres high consisting of thousands of truss structural members was proposed as one of the possible future city plans (Figure 4) [9]. This green (plant) factory might play an important role in growing bio-resources used for food and energy in future. Figure 4 shows one of the possibilities of growing and producing food and energy resources in a very huge truss structure based on a technology innovation of the future.

Energy

It is obvious that so long as there is total dependence on petroleum energy, carbon dioxide will be continuously produced and, as a result, the environment will continue to be jeopardised with global warming. This means that sooner or later, we will be strongly forced to shift the energy resources from petroleum-based to biomass-based.

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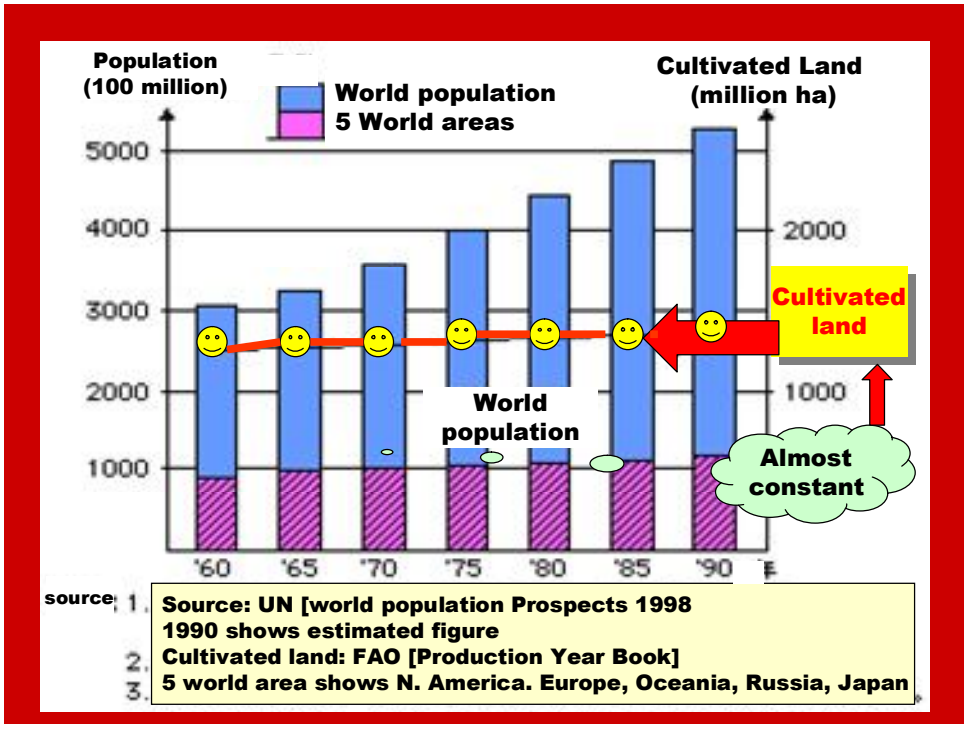

Figure 3. Relationship between world population and cultivated area

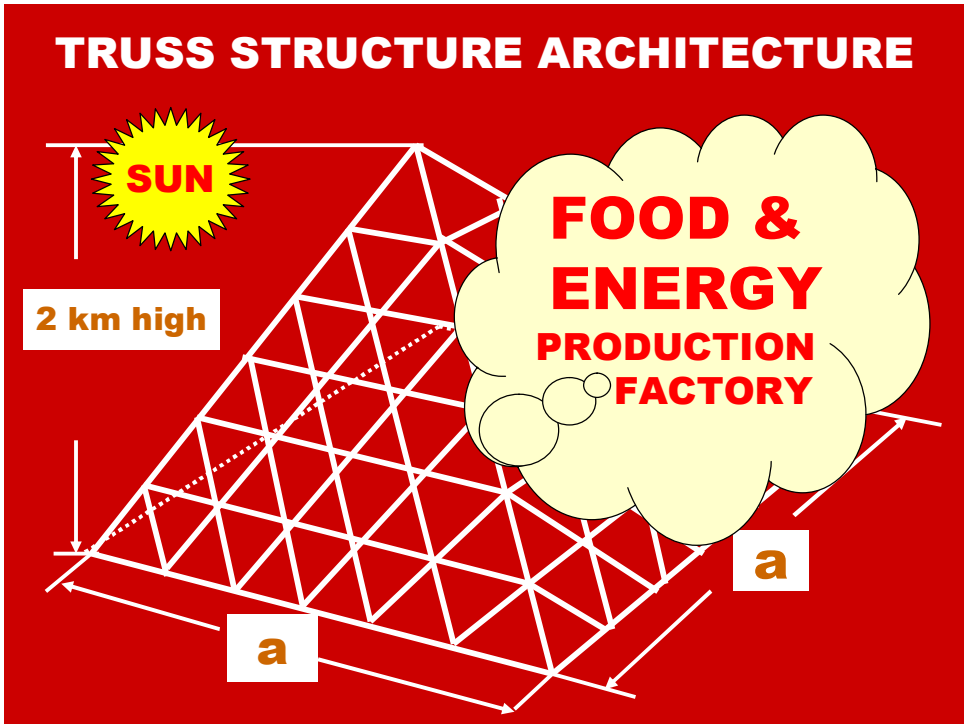

Figure 4. Green factory concept for food and energy production

In order to develop a new type of energy, therefore, the following two conditions must be prioritised, viz. less or zero carbon dioxide production (carbon neutral) to be environment friendly, and less cost to assure a constant stable supply of the energy as well as safety in handling. Renewable energy

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resources may be strongly recommended and, considering this background and conditions, the energy from biomass will be one of the most promising possibilities. Currently, a hybrid car that can be operated with two prime movers has already been commercialised. Electric-powered vehicle is also under research or development for commercialisation. Hydrogen car is also under the process of research and development but it will take some more time for hydrogen car to be commercialised by technological innovation. Global warming must be stopped as soon as possible. Meanwhile, hydrogen can possibly be produced from biomass, which will also be an additional merit of biomass utilisation. Thus, biomass can be used to cover the time gap until new energy resources can be found for the society.

Environment

Currently, the total carbon dioxide production in the world is almost 6.5 billion tons (carbon based), which is almost the same as the world population. As per a rough calculation, it can be considered that on an average one person is producing one ton of carbon dioxide per year worldwide, as shown in Figure 5.

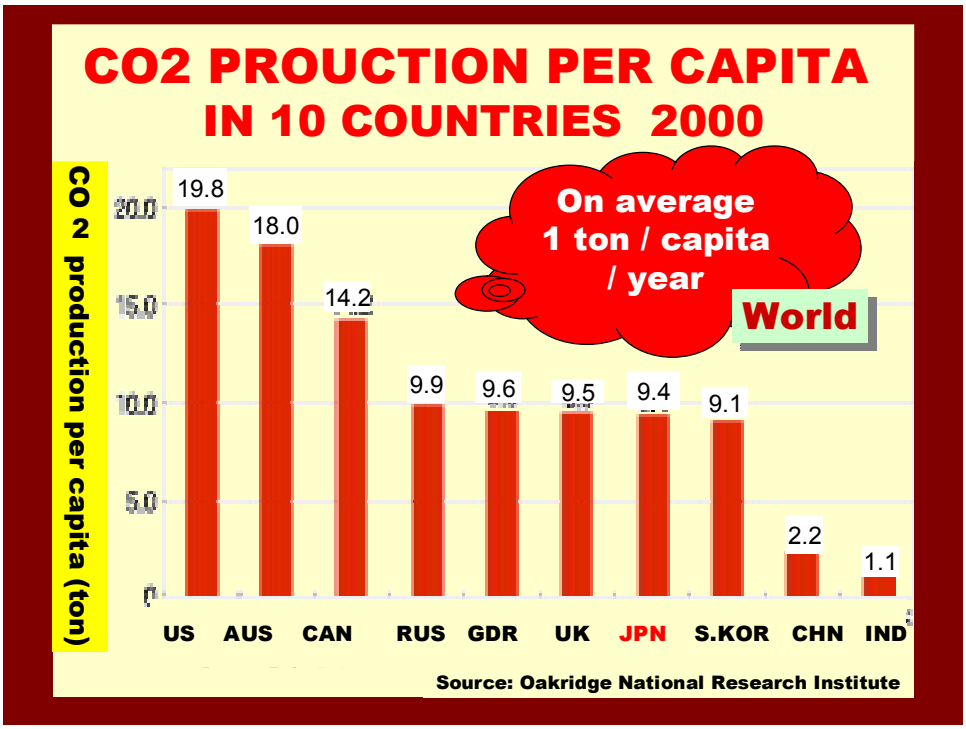

Figure 5. Carbon dioxide production per capita in ten countries

According to some estimated results of carbon dioxide production from car ownership, one car produces almost one ton per year including that produced during the car production process, assuming that it is owned for ten years with a total travelling distance of 150,000 km. This means that if one person owns one car, he produces another one ton of carbon dioxide. Thus the amount of carbon dioxide production is almost directly proportional to petroleum consumption. As already described, sooner or later the final decision on shifting from petroleum to biomass must be done. Technologically,

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as already noted, some of the low-emission cars, such as hybrid car, fuel-cell car and hydrogen car, are already under commercialisation trials, although it will take some time for these cars to be publically accepted due to obstacles such as high price and insufficient infrastructure for these new technology cars. Global warming does not wait for man though, so long as carbon dioxide production is not stopped. So before technology reaches that level, some of the social measure is needed to control carbon dioxide production, such as law and regulation legislation. Everybody wants to enjoy car driving, but few people know they are polluting the environment, or some people pretend they have no knowledge that they are polluting the air by driving their own car. Everybody has to be responsible for their commodity product and its subsequent production of carbon dioxide. The author has already written that economy makes some people hesitate to be responsible for what they are doing now because of the lack of evidence. If evidence is shown individually, everybody feels responsible, although information that just monitors actual carbon dioxide density does not make them feel responsible. The car is a very convenient and useful commodity. It works very well and is used not only in emergency situations, but also for enjoyment for those who enjoy driving. But it is difficult to clearly see who should be responsible for this kind of problem. Such being the case, the evaluation of the "Polluter Pays Principle" way of thinking would be conducted by the author. This idea is to force the polluter to be responsible for compensation in proportion to how much environmental pollution has been caused based on the evidence. Some countries have already introduced the carbon tax or other similar taxes although other countries have not done so due to reason of economy. The monitoring and recording equipment can be easily made considering the use of current technology with less expensive cost. Some industries, however, are not so keen to equip this kind of equipment and even have a negative reaction to this whole idea because sometimes the emission gas record may have an adverse effect of lowering the customer's acceptance of the products. It is obvious that more discussions and negotiations are needed to promote this activity to further improve the situation. Hence, the author would like to encourage people who really wish to improve the environment by introducing the idea of polluter pay principle. Through this principle, it is estimated that the introduction of some kind of tax related to the stopping of global warming may be possibly agreed upon in 2010 in Japan.

Sustainability

What is the meaning of sustainable development or simply sustainability? It may be understood in many ways depending on individuals. However, it can be simply explained by the following expression that the economic activity should be promoted without jeopardising the environment, as shown in Figure 6.

It must be kept in mind that the economy makes it difficult for some people to make decision for improving the crucial situation of the environment stemming from global warming. To have encountered the first energy crisis in early 1970s was the first experience that could never be forgotten as the author was traveling around the US. Even at ASAE meeting in 1975, many papers focusing on

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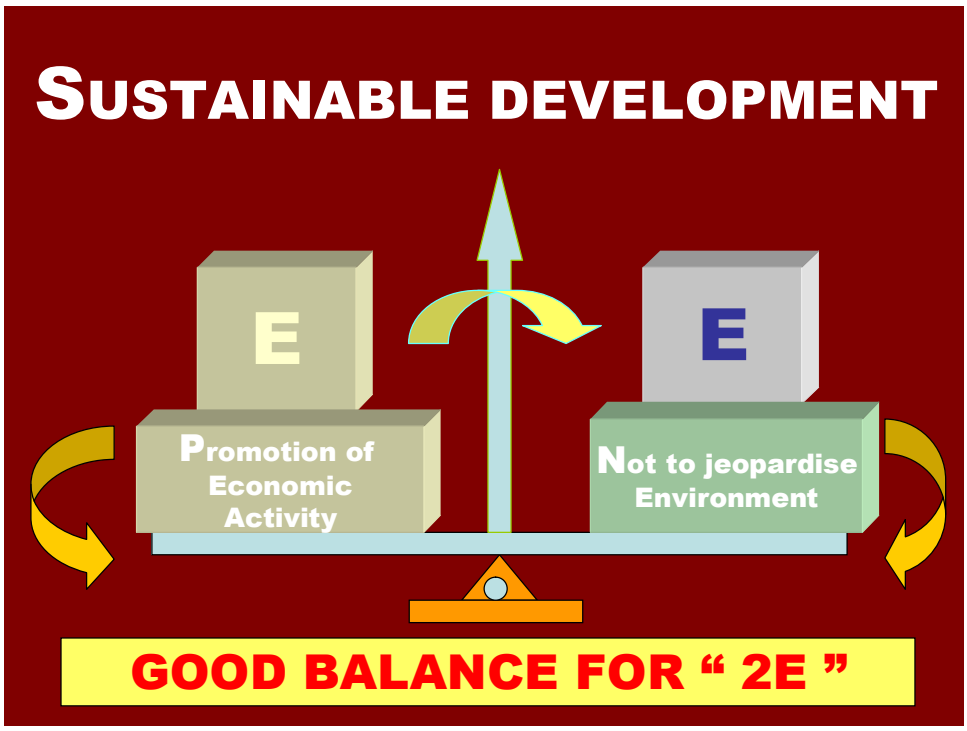

Figure 6. Meaning of "Sustainable Development"

the possibility of using natural energy and related topics were presented and discussed. One paper entitled "Energy forest……" proposed the idea of using trees in the forest with an area of 25 x 25 square miles. At the centre of the forest, an electric power generation plant was to be set up and certain number of trees in one part of the forest was to be cut down and used for electric generation at the power plant. The area where the trees were cut down was immediately recovered by reforestation. Almost the same amount of trees in the neighbouring area was used in the same way next year and around 20 years later such rotational usage of forest returns back to the first area. Upon intensive evaluation by the author, some problems, however, were pointed out, such as the energy balance between energy supply and consumption and how it could be balanced. In addition, the carbon dioxide production from the burning of trees was also one of the problems at that time. Currently, the carbon dioxide produced from plant is not accounted for because of the neutral carbon. This is one of the examples showing sustainable development. The term "sustainability" can be explained by the capability of a system and how it can maintain its function and performance under continuous operation without jeopardising the environment. One time in the past, carbon fixation was seriously discussed. Yet, whatever method is to be used, it must be treated again due to the capacity limitation for storage. The recirculated usage of produced carbon dioxide would be recommendable because no treatment is necessary as compared again to the fixed amount of carbon dioxide In the early days when carbon dioxide production problem was discussed, two countermeasures could be found. First was the control of carbon production and the other was the active use of produced carbon dioxide. The effort of non-production or control of the amount of carbon dioxide produced is necessary and has to be continued even though controlling is difficult once it is produced. The active use of produced carbon dioxide can be desirably recommendable.

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Biomass

Biomass is currently much focused specifically from the viewpoints of energy and environmental use due to the global warming issue. Food is one of the biomass resources and it has been simply for human consumption. However, due to the drastic increase of petroleum price and carbon dioxide production that cause global warming, the possibility of producing bio-ethanol from food crops is proposed. Biomass can be used for many purposes but its utilisation is mainly classified into two categories of material use and current energy use. Biomass production should be easily mechanised and automated in most of the operations such as harvesting, separation, fermentation, distillation and refinery, to assure the standardised quality of bio-products for commercialisation in addition to low production cost. The food versus energy crash problem in using food crops to produce bio-ethanol should be avoided if possible although other merits should be noted which are found positive for both government and producers (farmers). Due to the rising price of food crops, farmers can get more income and the government can reduce the subsidy for the assistance in agricultural sector. Inversely, the government can obtain income from taxes because farmers must pay this tax for increased production. Farm lands should be fully used for biomass production and no extra lands should be left abandoned due to the production control policy considering that people are facing hunger and poverty and are not easily able to get food. Other countermeasures can be found to save people such as by using financial funds coming into the government from the farmers as tax for increased production. Anyway, what is to be done towards the future is to fully use farm lands with high efficiency and grow bio-resources as much as possible whether they are used for food or energy resources. There should be no more extra lands for production control or similar political regulations. The next era of Asian Techno Farm (Research Centre or Institute) to cover these global issues in collaboration with Asian Community is thereby proposed by the author.

Bio-ethanol Production from Rice

Rice has been selected by the author as one of the most hopeful key resources because it can contribute as food, energy and environmental resources. As basic data, rice is grown almost worldwide with total production reaching almost 5.5 hundred million tons per year and more than 90 % of its production is in Asia. This is the reason why rice is called the main food crop in Asia. The production of bio-ethanol from rice gives almost 430 litres from one ton of rice, which is the biggest production amount among agricultural crops. Rice can absorb a lot of carbon dioxide while growing in the paddy field. Almost 17 to 19 tons of carbon dioxide (CO_2 based) is absorbed per hectare (equal to 4 to 5 tons carbon per hectare) and it should be noted that this figure is more than that obtained from trees. Rice can be used for many other purposes as mentioned already and this is its merit. If more rice is available, then it can be used for producing energy (bio-ethanol). On the other hand, when there is less food, rice can be consumed. Hence, rice can be used either way or both depending on the situation.

In talking about the new energy development, energy balance must be checked and discussed in detail. Japan accepted "E3", the bio-ethanol blended fuel on April 27, 2007. For that purpose, ethanol was imported from France and produced from wheat. The energy balance in bio-ethanol production is almost the same for both rice and wheat but the total amount of bio-ethanol production from rice is

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higher than from wheat. Incidentally, energy balance in bio-ethanol production can be defined as the ratio of output energy to input energy, which is 0.38 for rice (almost equal to wheat). By introducing the newly proposed rice production system by the author, this value can be improved a little. However, the system has to be discussed again for further improvement to increase the value (ratio of output energy to input energy) to more than 1.0. Being different from the rice for food, the rice for energy does not need the same process in the post-harvest stage. Rice husk should be removed and separated from brown rice although other processes such as drying and milling may not be necessary for bio-ethanol production. If it goes successfully, the energy balance may be much more improved. At the final stage of bio-ethanol production process, distillation is needed for further refining of the produced bio-ethanol. In this process, the possibility of applying the ultrasonic wave has recently been developed by one of the liquor shop master. Even though further details about this are not yet known, if ultrasonic wave can be applied in this stage, however, almost two thirds of the energy used in the existing distillation method can be saved, as shown in Figure 7. Thailand is one of the rice-producing countries but is not producing oil. If rice can be used for bio-ethanol production, it is not necessary to export rice to other countries. Rice will be a higher value-added agricultural product. Besides, the success of this

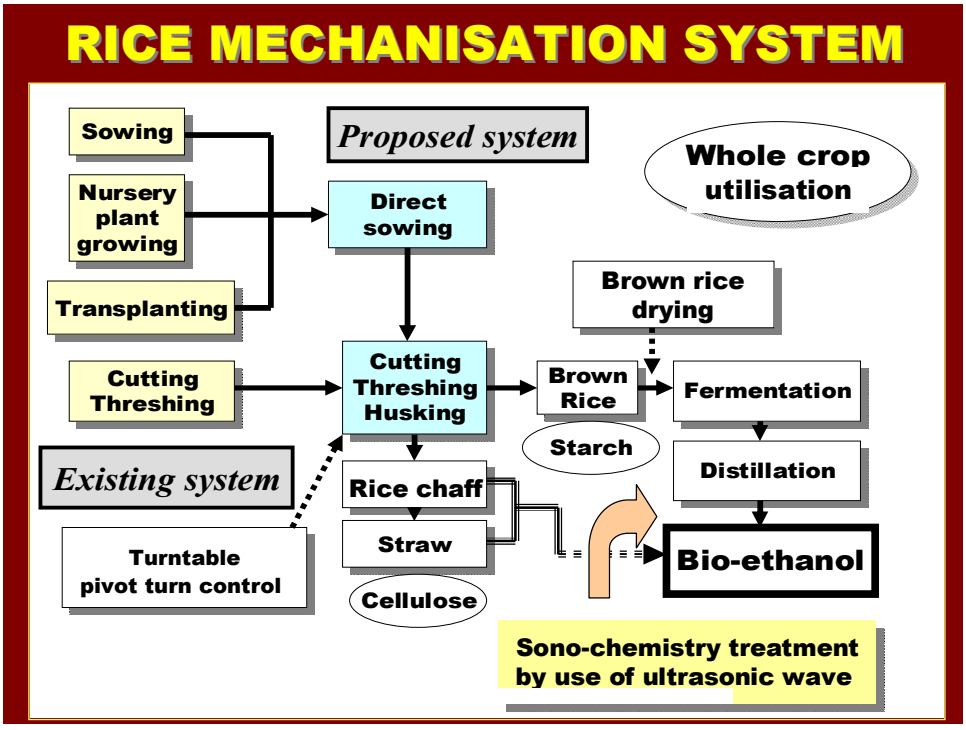

Figure 7. Rice mechanisation and bio-ethanol production system

program may lead to the development of a new market for energy not only in Thailand but also in other Asian countries considering that rice grown and produced in this area is almost more than 90% of the total world production. Which is then better: to use rice for food or energy? Which is better for farmers or government? In relation, Du Pont industries have currently successfully developed a new bio-based

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energy for the next era "bio-butanol" jointly with BP (British Petroleum). They are planning to a build new plant for its commercialisation [10].

Precision Farming

Precision farming or precision agriculture [11-13] has been proposed for the purpose of saving energy, material, time and labour based on more accurate and precise control in agricultural operation for growing crops. The necessary amount of fertilisers and chemicals can be more timely and precisely applied just on the exact spot where those materials are just needed as compared to the existing operation. The operations can be done under automatic control by machine. The high technology system functions much better in huge scale farming. It is said that precision farming can be effectively introduced to a large scale of farming areas of more than 50 hectares. It seems almost impossible to introduce precision farming in Asian agriculture. But is this true? The author does not think so since, considering the situation human beings are facing, this farming method should be introduced for efficient food and energy production. Needless to say, it does not fit the individual farmer's farming operations. However, sooner or later, any possibility must be considered in establishing a regional or global level farming for solving the issues of food, energy and environment towards the future. Asian agriculture is characterised by small-scale farming, rice-growing family labour forces, and so on. It is predicted by the author that rapid globalisation may not allow this type of farming. Even for the food and energy production, it will become more difficult to totally depend on the individual farmer's production. It should be managed internationally or globally apart from individual farmer's production. Considering the background being faced right now, global partnership is extremely needed for promoting the projects. The above-mentioned Techno Centre is also one of them. Precision farming can make it possible to manage the farm project at the national level with initial focus on food and energy production. Precision farming can be characterised by the following keywords: huge-scale farming, application of space technology such as GPS and GIS, autonomous guidance control of agricultural machinery, bio-technology and genetic engineering application for higher-yield production. Various engineers are required, e.g. mechanical, electric-electronic including tele-communication, chemical, civil, material science, agricultural, genetic and biological engineers. Areas of post-harvest technology, especially in fermentation, distillation and bio-refinery, will be really needed. Through the activities in research and development based on this organisation, the technology transfer and human resource development can be promoted including the training program and education for environmental preservation.

University Autonomy

All Japanese universities were forced to become autonomous within 2003. One of the biggest changes arising therefrom was the total amount of budget coming to the university from the central government. In the first year, the same amount of budget was provided but was reduced by one per cent after a year and the next. If this amount is continually decreased, sooner or later the university will be encountering the difficult conditions of maintaining a healthy management. Therefore, the university is requested to make an effort to get more external funding for research projects based on its collaboration

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with industries. The main budget provided for the university does not usually go to the faculties but is distributed based on proposals from individuals or groups of first priority especially if the proposal had high evaluation and approval. Normally, an individual faculty gets a very small amount of budget, just enough to cover the costs for correspondence, telephone, fax, copying, water and electricity. Thus, if the faculty wants to receive budget for conducting research, a proposal has to be made and submitted to the relevant section, otherwise the budget cannot be relayed sufficiently to the individual faculty to conduct research under this competitive condition. The Ministry of Education and Science has prepared a lot of research funds for universities to offer unique and original programs in research and education, which are called COE (Centre of Excellence). These funds can be provided for three to five years once the research proposal has been approved and accepted, hence they function not only for the promotion of research and education, but also in making the difference among universities from the viewpoint of financial management and quality of research and education. Some senior high school students may refer to these factors for their evaluation in making decision for selecting the university to enter. Through the past three years of experience, one conclusion can be derived, and that is, the strong leadership by the university head is extremely required and requested. Once a university has decided to go autonomous, new projects and programs must be continually proposed and implemented for a healthy and sustainable university management and maintenance of the high quality level. These projects and programs must be original and should be filled with unique ideas that cannot be imitated or purchased. In the case of the same or similar contents being involved in the program, new and original ideas and how the university could create them are requested to be shown. Some examples may include: 1) university campus clean-up operation program, and 2) university goods-manufacturing program (as being proposed by the author). Both are combined with engineering education. Similar to the industry, several universities have already got approval for ISO 14001. Kyoto University has already decided to introduce the carbon taxation system in the university campus, which is the first trial in Japanese universities [14]. These are some of the examples done by leading universities, which show how people in universities are thinking seriously about the environment especially global warming. The author has always emphasised the importance of the originality of ideas and the time for program completion. Incidentally, the use of agriculture in academic areas is disappearing and the reformed faculties and departments are putting new names focusing on bio-based academic areas that are increasing worldwide. It is very difficult to find departments or faculties in Japan still keeping the name of "agriculture". Most of them have already changed into bio-oriented or environment-based organisations. However, we agricultural engineers should always keep asking ourselves what we should do for agriculture and what role we are to play for agriculture.

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