A Practical Study For A Sustainable Wood-Based Energy Supply System : Case example for Heating Greenhouse Crops

A PRACTICAL STUDY FOR A SUSTAINABLE WOOD-BASED ENERGY SUPPLY SYSTEM
-Case example for Heating Greenhouse Crops-

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***ABSTRACT*:** This study was designed to construct a wood-based energy supply system that helps sustainable development of a local community as well as environmental conservation. The system would utilize local forests within a natural resource cycle and supply wood-based energy to heating greenhouse crops. To construct this system, we have been developing a combustion appliance which utilizes wood-based energy. In order to improve the combustion system, an experiment was conducted in 6a greenhouse. In the combustion appliance, downdraft system was adopted and it can produce the generating power of 60,000 kcal/h (if the moisture content is within 10%). In this experiment, we verified that the system was able to produce a stable combustion effect as well as minimized smoke and ash emissions. Also, we found out that the moisture content in wood-chips was reduced as low as 25% if the wood-chips were dried in the greenhouse. Meanwhile, a survey targeting local greenhouse farmers was conducted to determine the targeting price of the wood-based fuel. According to the survey, the maximum value that the farmers can afford for the A type heavy oil under a certain circumstance is around 45 yen/l, which is same as the price of 21.27 yen/kg for the wood-based fuel. The result of the survey indicated that it is important to break down the process flow from lumber to supply and make each process as efficient as possible in order to accomplish this supply cost for the energy needs.

KEYWORDS: sustainable development, sustainable energy, natural resource cycle

1. INTRODUCTION

The purpose of this study is to develop a sustainable wood-based energy supply system that will contribute to the sustainable development of a local community as well as promote global environmental and energy conservation. One of our objectives was to construct a model in which energy was produced and consumed in a local community. We experimented with energy conversion to wood-based energy from crude oil, which is an energy source for heating greenhouse crops.

Presuming that the global environment is conserved and sustained, we have to aim to construct a system that satisfies the following three conditions: (1) Use wood-based biomass which can be reproduced within a natural resource cycle (2) CO2 emissions within the limit of purification capacity in nature (3) Lower cost than crude oil market prices. Basically, the important tasks are: establishing the lumber to supply system that materially and economically functions; developing burners and machines that enable us to effectively and efficiently convert plants into energy.

2. BACKGROUND AND PURPOSE OF THE STUDY

In the late 20th century, an increasing world population and unbounded scientific and technological progress helped our global economy grow to incredible heights. However, such progress has come at a high cost as we have depleted our natural resources and irreparably degraded our planet. At present, most energy is imported from abroad, although only a century ago, our life system was mostly based on the wood-based energy source produced from forests in Japan. We have suitable conditions required for tree growth such as sunshine, precipitation and temperature, and 67% (25,120,000ha) of the nation's land is covered with forests. The ratio of artificial forests and natural forests are almost the same. The amount of the forests is approximately 3.5 billion m^3 [1] and the yearly growth reaches up to 80 million m^3 [1]. However, as a result of continuous forestation, which has been a state policy since the end of World War II, forest devastation due to poor replant maintenance has become a big problem. This situation is caused by the depreciation of converted timbers, disadvantaged business in forestry due to rising production costs, and a decrease in the labor population due to an aging society coupled with a record low birthrate.

In agricultural production, the food self-sufficiency ratio in Japan is approximately 40% (about 20% if include animal feed). This ratio is remarkably low compared to other developed countries. Most grains, except rice, are imported from abroad and in recent years, even fresh food such as vegetables have been more and more imported. If the situation continues, young people working in agriculture may disappear as it was in forestry because of the competition between domestic production costs and import prices.

Concentration of population in urban areas causes one-way labor absorption from local areas as well as creates economic disparity and this has become a key factor in preventing sustainable development in local communities. From the global environmental point view, this leads to the concentration of energy consumption and creates an enormous emission of environmental load substances. In the end, the situation worsens until the clean up capacity in nature is no longer effective enough.

While an upward trend on crude oil price is expected to continue in the future (Figure-1), sustainable development of local communities and reduction of environmental load are the fundamental challenges to our society.

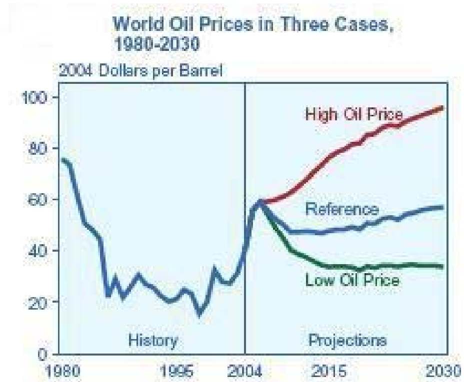

Figure 1 World oil price in three cases, 2980-2030
Source *International Energy Outlook 2006*, Energy Information Administration, Japan, 32 p, 2006.

We experimented to construct the energy supply system for heating greenhouse crops in G village in Kochi prefecture. G village is blessed with a mild climate and lots of sunshine, and it is where greenhouse crops originated in Japan.

3. SUSTAINABLE ENERGY SUPPLY SCHEME IN G VILLAGE

3.1 An overview of G village

G village is a small local community which faces the Pacific Ocean and has a population of 4,206 in an area of 3,963ha.

The forest area occupies 70% of the land, 2,813 ha, and the rest of 30% is the flatland. The acreage under cultivation is only 6% of the land, which is 237 ha. However, G village has the agricultural values of production (number of farm households: 332) of more than 3 billion yen and the values of production per farm household reaches approximately 10 million yen. The values of production per 10a rank in a high position in Japan. Especially, heating greenhouse crops has made a great contribution to the village above all other types of agriculture. Even in winter, they are able to ship fresh vegetables and flowers. The cultivated area of the heating greenhouse crops in G village is 70 ha and there are about 700 greenhouses. From the end of November to March, about 7,000 kl of heavy oil (type A) is used. However, because of an increase in the price of crude oil since 2005, the benefit of the heating greenhouse has been reduced and furthermore, there has been a tendency for the greenhouse framers to suffer their business due to the high production costs. On the other hand, though there are 140 households who own local forests, no families actually make their living working in the forest. Therefore, the value of the forest production is much smaller compared to agriculture. Planted trees have not been taken care of and the densely planted trees need to be thinned. Also, natural forests which are near town are barely cared for and those far from town are neglected.

3.2 Intra-regional cyclical energy supply scheme

In the present system, in which fossil fuel is used, energy is imported from outside regions and crops are exported to outer regions. Under this system, not only value creation is small in the region, but also the relationship between forests and agriculture is not reciprocally circulated.

By using wood-based energy produced from forests, CO_2 in the region is circulated and neutralized. (Figure-2)

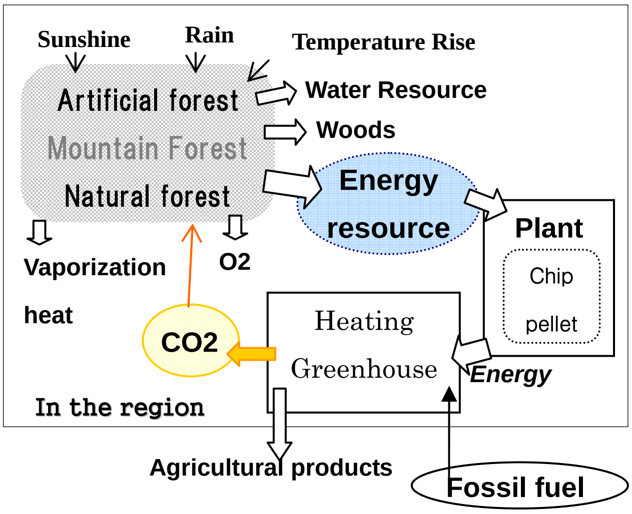

Figure 2 Intra-regional cycle

The management cycle of artificial forests differs from that of natural forests as shown in Figure-3, and natural forests hardly require care by man.

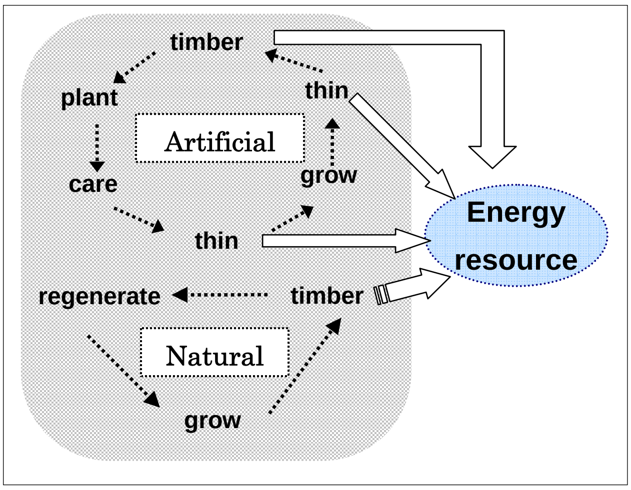

Figure 3 Resource cycle of artificial forests and natural forests in the mountains

3.3 Combustion and growth amount

	Combustion calorie (kcal/m^3)	40 years growth Amount (m^3/ha)
Coniferous tree (Cedar)	1,550,000	527
Broad leaf tree	2,050,000	490

Source: *Forest biomass energy*, National Forestry Extension Association in Japan, 2001

3.4 Timber cycle

The mountain forests in G village comprise 2,813 ha, which includes an area of coniferous tree forest of 1,285 ha, an area of broad leaf tree forest of 1,447 ha, and a region of bamboo trees of 81 ha. Most of the coniferous trees are in artificial forests and 3,000 to 4,000 cedar trees and Japanese cypress per hectare were planted there. Regarding the economic value of coniferous trees, Japanese cypress older than 100 years and cedars older than 80 years are more marketable. The ideal number of those older trees to be timbered is 100 to 200 per hectare. By the time those older trees are timbered, approximately 95% of the whole trees need to be thinned. If we assume that timbered cycle of coniferous trees is 40 years (1,285 ha/40), we are able to acquire the trees from an area of 32 ha yearly. On the other hand, it is known that broad leaf trees in this area can be recovered to its original in 30 years after timbering. Assuming that the timbered cycle is 40 years (1,447 ha/40), we can collect the broad leaf trees from an area of 36 ha yearly. As for bamboo, since the growth of bamboo is complete in 2 years, it is possible to be timbered in a 3 year cycle from an area of 27 ha yearly.

3.5 Necessary calorie and supply calorie

The amount of type A heavy oil (8600 kcal/l) used by greenhouse farmers in this village is 7000 kl yearly and the necessary combustion calories are approximately 600 million kcal. As described in 3-3 and 3-4, sustainable supply calories from the mountain forests in G village are 894 million kcal. Therefore, it is physically feasible to supply energy produced in the local mountain forests for heating greenhouse crops.

4. TASKS TO BE SOLVED

One of the primary tasks in this paper is to reduce the energy supply cost despite the type A heavy oil market prices. Secondary, to develop an appliance that burns trees efficiently is also an important task to be solved. Finally, it is so important to gain understanding from the public regarding this project in which mountain trees are timbered and used for energy, because there are some stereotyped opinions in public that timbering trees can only lead to environmental destruction.

4.1 Supply cost

According to the survey of farmhouses conducted in May 2006, most of the houses requested around 40 yen/l, which was the standard price in 2004, as the type A heavy oil price to properly sustain their greenhouse crops. Moreover, an energy cost of 45-50 yen/l is the maximum value farmers can afford if it is not expected that there will be an increase in the price of the products. Presently, the market price of 70 yen/l has remained constant for two years and it is considered that there is only a little possibility of a price reduction in the future. In addition, they answered the amount of money that they could invest for the combustion appliance and it would be approximately 500 thousand yen for a 10a sized greenhouse.

The amount of combustion energy is inversely proportional to the moisture content of a combustible body. The combustion energy of type A heavy oil /l

is 8,600 kcal, and 2.15 kg of dried material with a 5% moisture is required in order to secure the same amount of energy by using wood-based energy.
The supply cost of wood-based energy needed to satisfy the needs of farmers is 45 yen / 2.15 kg. In other words, 21.27 yen/kg is the target price that supply side should be aiming for.

To accomplish the supply cost for the energy needs, it is important to break down the process flow from mountain forests that supply wood-based fuel (Figure-4) and reduce the cost by striving to make each process from (1) to (8) as efficient as possible.

There are certain elements that promote efficiency such as improving workers' skills, utilizing natural power, maximizing the utilization of materials, equitable work distribution throughout the year, and the overall effectiveness of machines. It is necessary to set up and implement targets for each element to reduce the overall cost.

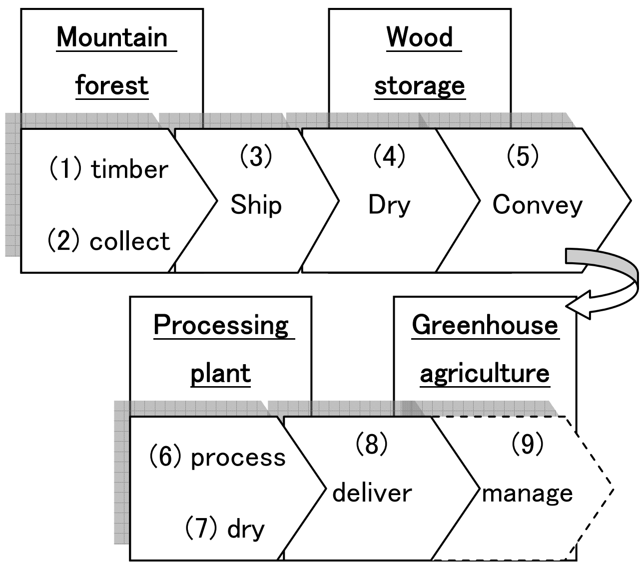

Figure 4 Process breakdown

4.2 Development of a combustion appliance

In recent years, nationally supported projects utilizing wood-based biomass have been promoted, focusing on biomass power generation, home heating, and the use of this energy in plants, with a national objective to reduce CO2 emissions based on the Kyoto Protocol. Our case study is one of the few projects involving heating greenhouse crops.

In this study, involving farmhouses, the objective was to improve the efficiency of the burner section of a combustion boiler in order to provide an efficient, inexpensive supply. To construct such an appliance, we stipulated some conditions for the appliance that the structure has to be simple, and it would enable to maximize combustion efficiency and minimize smoke and ash emissions at the same time.

Using a downdraft system on the burner, it has successfully produced a stable combustion effect. The method's effectiveness has been demonstrated in an experiment conducted in a 6a experimental greenhouse.

4.3 Public involvement

To gain the public's understanding, it is necessary to state that the project is designed to conserve the environment.

- Timbering within the growth range of mountain forests is a resource cycle.
- Burning wood is carbon neutral.
- Planted artificial forests need to be thinned.
- High temperature combustion has no discharge of hazardous substances.
- Participation in CO2 emission trading.

It is important to inform people of these points in a logical and an easy-to-understand way.

5. EXPERIMENT TO VERIFY EFFECTIVENESS

Generally, greenhouses are heated during the night from November to March. During the day, the temperature in the greenhouses is higher than 20 ℃ due to the solar energy. Required temperature may vary depending on the crops. For example, an eggplant requires 12 to 16℃ and a green pepper requires 16 to18℃.

In our experiment using a 6a experimental greenhouse, 16,000 Russell prairie gentian seedlings were planted and grown. The temperature required to grow Russell prairie gentian should be higher than 15 ℃ and in the test, a burner using wood chips with 60,000 kcal/h generating power (if the moisture content is within 10 %) was installed.

The minimum temperature in the greenhouse was set at 15℃ and by measuring the variation of the outside temperature, inside temperature (temperature sensors were installed in 6 points), and underground temperature (temperature sensors were installed 10 cm below the ground in 2 points), the relationship between the amount of chips sent to the combustion room and the supply interval (g/min) was calculated in order to develop an automatic chip supply program. (In the experiment, the amount of wood chips per time was 700g and the average moisture content was 25%).

Wood chips as fuel were processed from the woods timbered in the scrub bush and artificial forests in the village, and waste wood discharged from a sawmill, which was purchased and processed with a chipper. Moreover, natural drying was performed to dry the chips as much as possible. We found out that if wood chips were dried in a greenhouse where there was no cultivation after sun drying, the moisture content fell off until around 25%.

6. CONCLUSION

We consider greenhouse crops using fossil fuels to be unnatural and unreasonable in terms of the environment, energy, and economy. Half a century ago, greenhouses were developed by combining the blessings of nature and a plastic sheet, which was an industrial product. We can imagine how surprised and impressed people were when out of season vegetables were grown in a plastic house and served on the table. As time went by, heating greenhouse agriculture became more and more popular, satisfying many people’s wants. As a result, various kinds of vegetables can be sold in the markets regardless of the season. We are convinced that this is not what truly society needs.

However, this agriculture has been rooted in our society as part of the giant social system as well as created many layers of markets involving many stakeholders. It is not realistic to change this system drastically. Actually, we have heard from farmers that they are pressed to make their decision if they continue to run greenhouse farming due to the rise in the price of crude oil. Moreover, trees planted on mountains are left untouched, and if they are not taken care of them, devastation of the mountain forests will be the result. In short, solving these problems has been a big motive for our study.

We found that the flow of timbering trees from mountains, gathering, and conveying to a plant, and processing them in the plant is physically feasible according to our experiment. However, another task, economical efficiency of the system has not yet been validated at this point. Especially, because our country has a complicated geographical formation as well as steep mountain forests, it is expected that the process of timbering, gathering, and conveying wood is going to be expensive. There are two tasks specific to combustion in this study. The first task, development of a wood-chip burner is almost completed and we have the prospect of starting mass production. The other task, which is to make drying wood chips more efficient and economical, is still left unsolved.

It is necessary for our society to demonstrate that circulation of the resources and energy helps environmental conservation, to prove that environmental conservation creates economical benefits, and to establish the wood-based energy supply system for heating greenhouse crops as a contribution to the sustainable development in a local community. We believe that this is the first step toward the innovation based on both environment and economic points of view.

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