Environ. Sci., Hokkaido	8 (1)	47~59	June 1985

A Study on Analysis of Regional Energy Utilization with Consideration of Public Opinion

Masaaki Iwasa

Department of Civil Engineering, Faculty of Engineering, Iwate University, Morioka, 020, Japan

Etsuo Yamamura

Department of Regional Planning, Division of Environmental Planning, Graduate School of Environmental Science, Hokkaido University, Sapporo, 060, Japan

Abstract

The paper, at first deals with an analysis of public opinion about the introduction of soft energy as the energy for home use, next makes a model of the household energy based on it and makes a scenario analysis of the effect, given by public opinion about the introduction upon the regional energy.

The main result is that the reduction rate of household energy will be over 80% under the influence of introducing soft energy, and the expenses will be smaller with the present rising rate of energy costs, when the farmers have high possibility of energy conservation by means of the improvements of residential houses and the wide use of adiabatic materials.

Key Words: Regional Energy, Public opinion, Latent class analysis, Scenario analysis.

1. Introduction

As has been considered in the previous paper, it becomes clear that the utilization of the soft energy used in the Tokachi region can be useful in this area, especially in farming area. In order to make use of these investigations, therefore, it is necessary to analyze the regional energy demand with the consideration of public opinion with making clear the possibility of the soft energy utilization.

This paper, with an example of a farming area in Tokachi, at first deals with an analysis of public opinion about the introduction of soft energy as the energy for home use, next makes a model of the household energy based on it and makes a scenario analysis of the effect, given by public opinion about the introduction upon the regional energy, and then considers the possibility of utilizing effectively regional energy in the future.

2. The Investigated Region and the Regional Energy

Otofuke-cho, Shimizu-cho, Sarabetsu-mura are the objects of the survey of public opinion, and as Otofuke is in the middle of the plain of Tokachi, Shimizu

in the outskirts of the west, Sarabetsu in the southwest of the middle.

Otofuke is the largest town of the 19 towns of Tokachi. Recently, it has turned to be a bedroom town of the city named Obihiro, and its population is growing rapidly, so the pure farming area is changing greatly. The population increases from 24,118 in 1970 to 31,135 in 1980. It is because the Kino section in the south has grown into a bedroom town of Obihiro, and at the same time, a rate of the farming household is decreasing from 28% in 1970 to 14% in 1980. In the case of stock raising, the total number of milchs and beef cattles in 1980 is 11,458, and the number in each house increases rapidly from 9 in 1970 to 33 in 1980.

People at Shimizu decrease from 16,162 in 1970 to 13,352 in 1980, but recently the reduction rates becomes slower. A rate of farming household does not decrease so rapidly as that of Otofuke, and changes from 27% in 1970 to 21% in 1980. The total number of milchs and beef cattles is 19,402 in 1980, and the number of cows per house increases from 11 in 1970 to 36 in 1980.

At Sarabetsu, the population decreases rapidly from 4,324 in 1970 to 3,624 in 1980, but recently the reduction rates become slower. The village is the pure farming village, and the rate of farm houses in 1970 is 48%, and that in 1980 is 40%. The total number of milchs and beef cattles in 1980 is 8,550, and the number per house increases from 12 in 1970 to 79 in 1980, showing a more rapid increase than in Otofuke or Shimizu.

The future rates of farm houses in this area can be estimated as follows. At Otofuke, it will decrease from 14% in 1980 to 6% in 1990, at Shimizu, from 21% to 16%, but at Sarabetsu, it will increase slightly from 40% in 1980 to 44% in 1990, and will show the highest rate.

The distribution ratio of the regional energy of the investigated area is as shown in Figure 1. It shows that the energy demand rate for home use is 40.9% high at Otofuke, 33.3% at Shimizu, and 40.2% at Sarabetsu. Here, the energy 'for industry use' almost means the energy 'for farming'.

The kinds of soft energy which farmers can use are for example, solar energy, wastes of livestock, and power of wind.

In the case of the introduction of solar energy, it is possible to heat rooms and water in winter, because hours of sunlight per year at Otofuke, Sarabetsu, and Shimizu are 2,400-2,600, 2,600 and 2,200-2,400, and moreover the hours of sunlight in winter are longer than that in summer. The introduction of soft energy given by the wastes of livestock is suitable in this area because the number of livestock is great. In this case, there are two possible ways of fermenting methane: the way at the medium temperature of 30°C-35°C, and the way at the high temperature of 50°C-55°C, and the fermenting way at the medium temperature is more useful for the energy conservation, because the way at the high temperature needs more calorie consumptions.

The utilization of wind power as the soft energy is not useful, for the wind is not strong in this area.

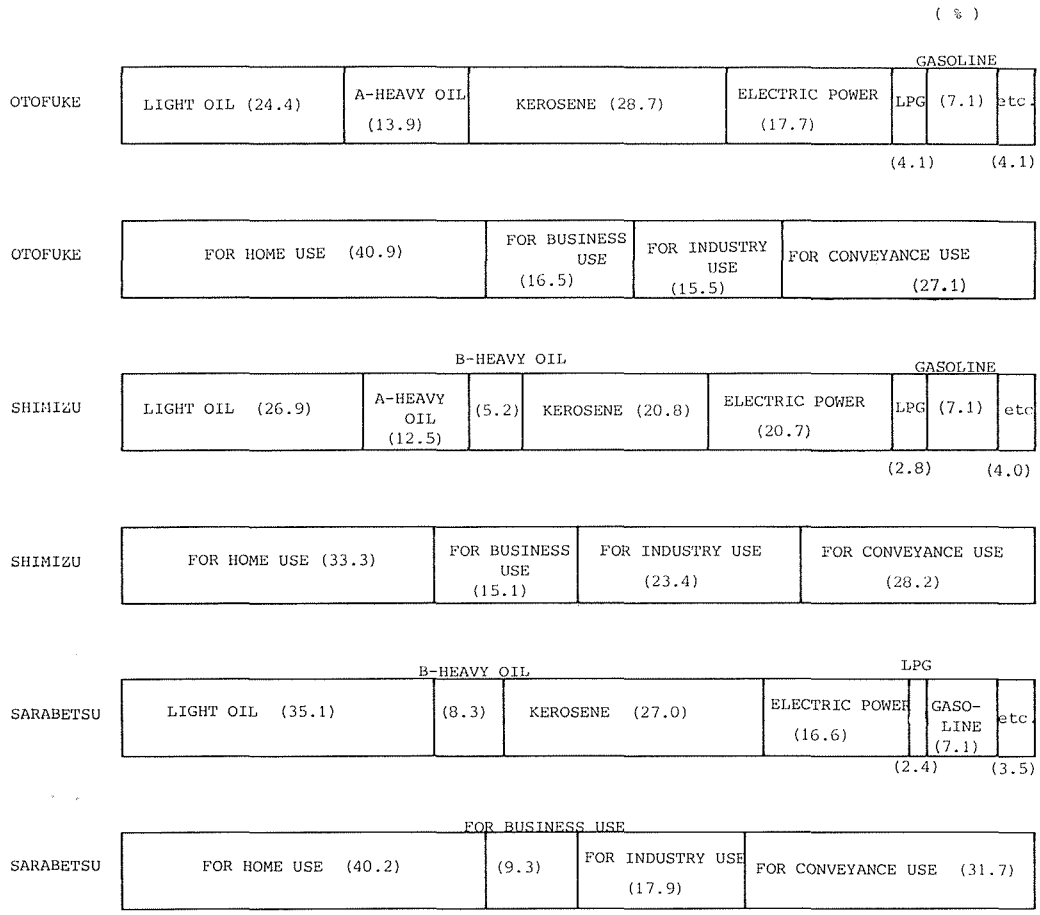


Figure 1. The distribution ratio of the regional energy in 1980.

3. An analysis of the Survey of Public Opinion

We conducted the survey of public opinions toward farming household in Otofuke, Shimizu and Sarabetsu. This is the survey of farmars' interest and concern, and utilizing two kinds of soft energy : sun energy and waste materials, their valuation of the validity and their will of the introduction. From its result, we estimate the rate of introduction of soft energy at every changing stage of energy costs. Further, we investigate the practice of saving energy, the consciousness of social behavior, and the degree of contentment with energy informations.

The ways of analysis are latent class analysis concerning region, age, cultivated acreage, and the number of breeding livestock, simple counting, and cross counting.

Latent class analysis

Latent class analysis finds an estimated probability of affirmative and negative class by consulting the attributes of farmars' interest and concern in soft energy, their valuation and their will of introduction. The way of analysis is as follows.

x_1 : Latent quantity which shows a reaction pattern of a group $(i=1, 2, \cdots, m)$
ν^i : Each probability of latent space $x_1, \cdots, x_m. \in X$.
π_i^a : The probability that an item with latent quantity x_a reacts with the attrib ute $r_i=1$ $\pi_i^a \equiv P_r(r_i=1|x_a)$ $(a=1, 2, \cdots, m,\ i=1, 2, \cdots, k)$

The probability P_i that the attribute r_i reacts with the whole $X=1$ is as follows.

$$P_i = \sum_{a=1}^{m} \nu^a \pi_i^a \tag{1}$$

The probability that latent quantity x_a reacts with an item both with an attribute $r_i=1$ and with $r_j=1$ is as follows.

$$\pi_{ij}^a = P_r(r_i=1,\ r_j=1|x_a), \qquad (i,\ j=1, 2, \cdots k) \tag{2}$$

Accordingly, the probability that the attribute r_i and r_j react with the whole $X=1$ is as follows.

$$P_{ij} = \sum_{a=1}^{m} \nu^a \pi_i^a \pi_j^a \qquad (i,\ j=1, 2, \cdots k) \tag{3}$$

Similarly,

$$P_{ijk} = \sum_{a=1}^{m} \nu^a \pi_i^a \pi_j^a \pi_k^a \qquad (i, j, k=1, \cdots k) \tag{4}$$

The structure of the data is made clear by making a model from the results of (1), (3), (4) and $\sum_{a=1}^{m} \nu^a=1$, and by estimating the latent parameter ν^a, π_i^a $(i=1, 2, \cdots k,$ $a=1, 2, \cdots m)$ with estimates

$$P_i = \frac{1}{N}\sum_{\lambda=1}^{N} \delta_{\lambda i}, \qquad P_{ij} = \frac{1}{N}\sum_{\lambda=1}^{N} \delta_{\lambda i}\delta_{\lambda j}, \qquad P_{ijk} = \frac{1}{N}\sum_{\lambda=1}^{N} \delta_{\lambda i}\delta_{\lambda j}\delta_{\lambda k},$$

which are P_i, P_{ij}, $P_{ijk}\cdots$.

But

$$\delta_{\lambda i} = \begin{cases} 1 \text{ (In case that the individual } \lambda \text{ reacts to Yes on } r_i) \\ \qquad (\lambda=1, 2, \cdots N,\ i=1, 2, \cdots k) \\ 0 \text{ (In case that the individual } \lambda \text{ reacts to No on } r_i) \end{cases}$$

The analysis of this survey, with two classes and three attributes analyzed is as follows.

Models

$$\sum_{a=1}^{2} \nu^a = 1, \qquad P_i = \sum_{a=1}^{2} \nu^a \pi_i^a, \qquad P_{ij} = \sum_{a=1}^{2} \nu^a \pi_i^a \pi_j^a, \qquad P_{ijk} = \sum_{a=1}^{2} \nu^a \pi_i^a \pi_j^a \pi_k^a$$
$$(i \neq j \neq k) \qquad (i, j, k=1, 2, 3)$$

Matrices Π_1, Π_2, M, Δ_3, P, P^* are given as follows.

$$\Pi_1 = \begin{bmatrix} 1, & \pi_1^1 \\ 1 & \pi_1^2 \end{bmatrix}, \qquad \Pi_2 = \begin{bmatrix} 1, & \pi_2^1 \\ 1 & \pi_2^2 \end{bmatrix}, \qquad M = \begin{bmatrix} \nu^1 & o \\ o & \nu^2 \end{bmatrix}, \qquad \Delta_3 = \begin{bmatrix} \pi_3^1 & o \\ o & \pi_3^2 \end{bmatrix}$$

$$P=\begin{bmatrix}\hat{P}_3 & \hat{P}_{23}\\ \hat{P}_{13} & \hat{P}_{123}\end{bmatrix},\qquad P^*=\begin{bmatrix}1 & \hat{P}_2\\ \hat{P}_1 & \hat{P}_{12}\end{bmatrix}$$

Thus, the solution $\theta=\begin{pmatrix}\theta^1\\ \theta^2\end{pmatrix}$ of proper equation $\det(P-\theta P^*)=0$ is defined as $\Delta_3=\begin{bmatrix}\theta^1 & o\\ o & \theta^2\end{bmatrix}$. And then the parameters can be estimated at $\Pi_2=E_xX^{-1}$, $\Pi_1=E_yY^{-1}$, $M=\Pi_1^{t-1}P^*\Pi_2^{-1}$ by using the matrix X with vectors x^1 and x^2 (x^1 is a solution of $(P-\theta^1P^*)\ x^1=0$, and x^2, $(P-\theta^2P^*)\ x^2=0$), the matrix Y that with vectors y^1 and y^2 (y^1 is a solution of $(P^t-\theta^1P^{*t})\ y^1=0$, and y^2, $(P^t-\theta^2P^{*t})\ y^2=0$), the matrices E_x and E_y that have the reciprocals of the first lines as the opposite components.

Next, in regard to the samples of farming household, we need 262 houses at Otofuke, 68 houses at Sarabetsu, and 122 houses at Shimizu according to the sampling theory with 90% of trust and 3% of error area. And the valid samples are collected from 369 houses at Otofuke, 88 houses at Sarabetsu, and 141 houses at Shimizu. These numbers are sufficient and are about one-third of all farmhouses.

The main results of the simple counting are as follows. In Table 1, many farmhouses have from 1 to 20 breeding livestock and also have from 41 to 60. In Table 2, many farmhouses have from 21 ha. to 40 ha. of cultivated acreage.

In regard to age, in Table 3, the number of householders under 29 years old is small, but each age of the rest shows the average number. In regard to school career, many householders have low regular school careers. In regard to the reasons of introduction or non-introduction of the solar system in Figure 2, the more economical the solar system becomes as energy price rises, the higher the

Table 1. Number of breeding livestock

NUMBER OF LIVESTOCK	NUMBER OF HOUSE-HOLDERS	(%)
0	294	49.1
1-10	90	15.1
11-20	38	6.4
21-30	20	3.3
31-40	32	5.4
41-50	37	6.2
51-60	37	6.2
61-70	23	3.8
71-80	10	1.7
81-	17	2.8

Table 2. Cultivated acreage

ACRAGE (ha.)	NUMBER OF HOUSE-HOLDERS	(%)
UNDER 20	248	41.5
21-40	255	42.6
41-80	22	3.7
OVER 80	73	12.2

Table 3. Age

AGE	NUMBER OF FARMERS	(%)
-29	28	4.8
30-39	133	23.0
40-49	182	31.4
50-59	171	29.5
60-	65	11.3

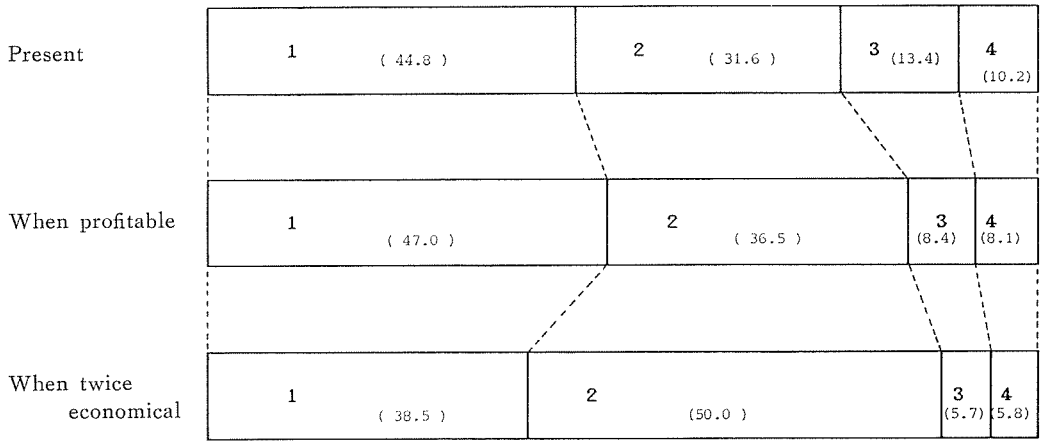
Table 4. School career

CAREER	NUMBER OF FARMERS	(%)
LOW CAREER	377	64.1
MIDDLE CAREER	177	30.1
HIGH CAREER	34	5.8

LOW CAREER: Elementary school. New-systemed junior high school.
MIDDLE CAREER: Old systemed junior high school. Miscellaneous school.
HIGH CAREER: Old-systemed high school. Junior college. College.

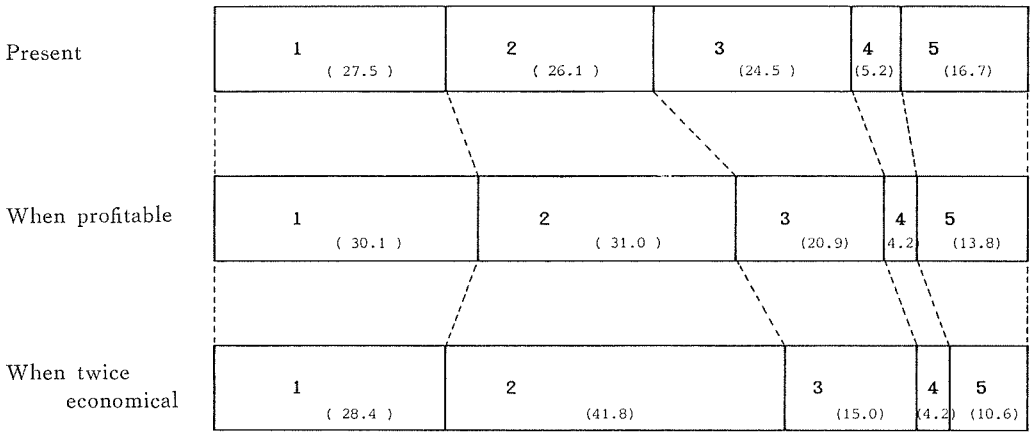
introduction rate becomes, and the more important the economical reason, and the weaker the reason of non-introduction because of troublesomeness and also the unknown reason.

Concerning the reason for the introduction of the utilization of waste materials, and that for the non-introduction, as in Figure 3, the more economical the utiliza-



1. Thinking about energy problem.
2. Thinking about costs.
3. Because details are unclear.
4. Because it is new and troublesome, other reasons, no answers.

Figure 2. The reansos of introduction or non-introduction of the solar system.



1. Thinking about energy problem.
2. Thinking about costs.
3. Because details are unclear.
4. Because it is troublesome.
5. Because it is new and its utility is unclear, other reasons ,no answers.

Figure 3. The reasons of introduction or non-introduction of the utilization of waste materials.

tion system becomes as energy price rises, the higher the introduction rate becomes though it is not so high as that of solar system, and the higher the economical reason becomes, and the weaker the unknown reason.

The result of cross counting shows nothing noticeable, but there is a tendency that the farmers with higher school careers prefer using soft energy.

Next, the result of latent class analysis with the analysis of friendliness concerning soft energy in each town and village is as follows. As regards public opinion on the solar system, the affirmative percentage is 80% at Otofuke, 83% at Shimizu, and 73% at Sarabetsu. As regards public opinion on the practice of energy conservation, the affirmative percentage is 82% at Otofuke, 88% at Shimizu, and 94% at Sarabetsu.

According to Figure 4, which represents public opinion, classified by age, on the solar system, the introduction rate shows high percentage on the whole, though it shows low percentage in residents over 60 years old. This is the same in the case of utilization of waste materials as is indicated in Figure 5.

According to Figure 6, which represents public opinion, by school careers, on the solar system, the higher school career becomes, the higher the introduction rate becomes. This is the same in the case of the utilization of waste materials as is indicated in Figure 7.

As regards public opinion, classified by cultivated acreage, on the solar system, as shown in Figure 8, there is no great difference in cultivated acreage. In regard to the utilization of waste materials, farmers with more than 41-ha. arable land have more positive attitude as shown in Figure 9.

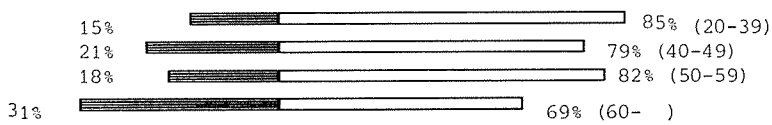


Figure 4. Residents' opinions on the solar system by age.

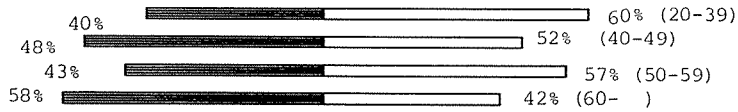


Figure 5. Residents' opinions on utilization of waste materials.

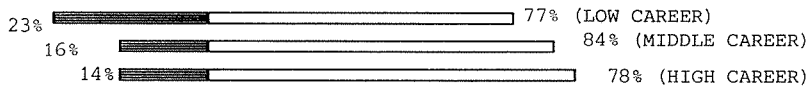


Figure 6. Residents' opinions on the solar system by school career.

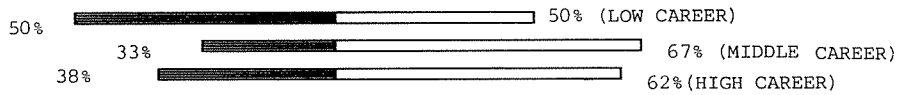


Figure 7. Residents' opinions on utilization of waste materials by school career.

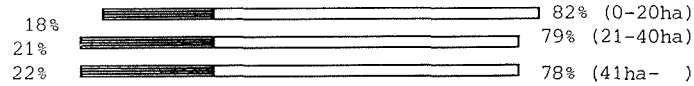


Figure 8. Residents' opinions on the solar system by cultivated acreage.

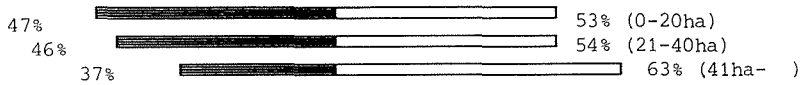


Figure 9. Residents' opinions on utilization of waste materials by cultivated acreage.

The above-mentioned analysis shows that public opinion on the solar system, the utilization of waste materials and energy conservation have almost the same tendency in two towns and one village, and the farmers' opinions in these regions are said to be nearly the same. The opinions on the solar system are very affirmative. Those on the utilization of waste materials are not so affirmative as that of the solar system. This is because the system of utilizing waste materials is not marketed so widely as the solar system and the system is difficult to operate. But the majority of the residents belong to the class favorable to the system and more residents will have affirmative attitude, if practical use of waste materials is promoted and the operation becomes easy in the future.

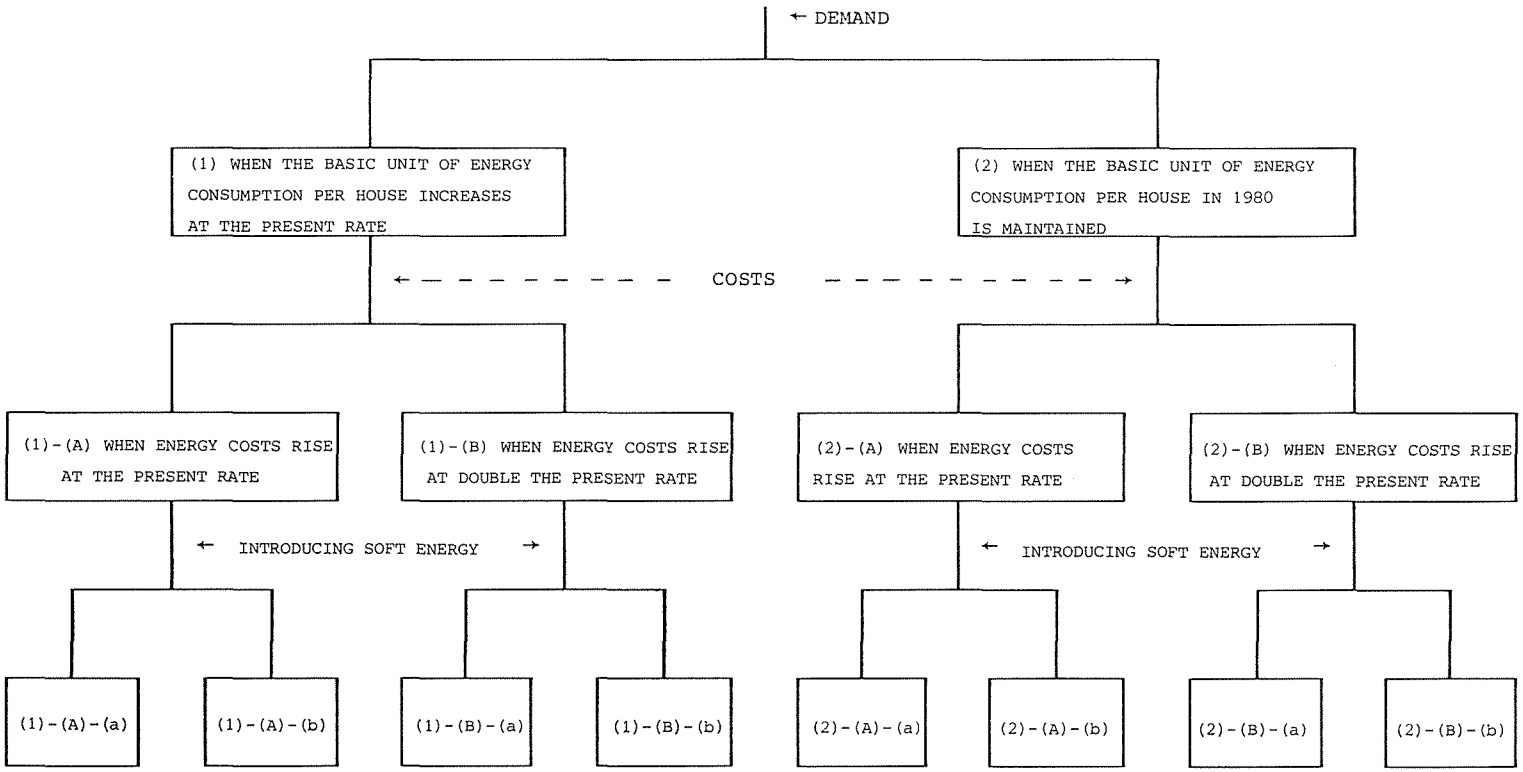
4. The Introduction of the Soft Energy Introduction Rate Based on the Survey of Public Opinion

The soft energy introduction rate of the soft energy supply sectors in the regional energy models is considered as follows. First, we compare energy costs per 1000 kcal estimated by the household energy demand sector, with the price of the soft energy system and soft energy costs per 1000 kcal calculated on the basis of the energy generated by the soft energy system of each region, and then we set up the year in which both energy costs per 1000 kcal will rise to the same level and the year in which soft energy costs per 1000 kcal will be twice as economical as in 1980.

Next, farmers who are favorable to soft energy and have an will to introduce it are selected from the result of the latent class analysis, given in 3, on soft energy in each town and village and are regarded as those who introduce soft energy in the same situation.

Moreover, since the costs of heating by means of the solar system are much higher than those of hot water supply, the farmers with more than 21-ha. arable land of a medium scale are regarded as those who introduce the solar system. With regard to the utilization of waste materials, only the farmers with plenty of waste materials—in case that they have more than 20 head of cattle in terms of cows—are regarded as those who introduce the utilization.

On these conditions we set up the introduction rate at each stage. The period from the year set up to the time when the farmeres introduce the system depends on the delay of exponential functions. Since the utilization of waste materials is



a) When the estimated introduction rate is used.
b) When only the farmers who have more than 21-ha. arable land introduce the solar system for heating, and only the farmers who have more than 20 cattles introduce the utilization of the waste materials.

Figure 10. Scenario analysis

still developing, we suppose that the supply of soft energy by utilizing waste materials will start in 1990.

In respect to the basic unit of the amount used, we suppose that potentiality of the energy conservation is high among the farmers who are well disposed toward the energy conservation and who have experienced it, we set up the case that the basic unit of the amount used will rise after 1980.

As the result, we have the analysis with eight scenarios as shown in Figure 10.

5. The Results of the Analysis

The estimation of energy components in each town and village in 1990 is shown in Figure 11. The household energy accounts for 42.8% of the whold amount of energy used at Otofuke, 29.8% at Shimizu and 37.5% at Sarabetsu. These rates still represent high figures. As regards the amount of the household energy used at each house, it is estimated that the amount in 1990 will be 1.37 times as great as in 1980, 1.45 times at Shimizu and 1.41 times at Sarabetsu. If shown in terms of money, it is estimated that the expenditure in 1980 will be

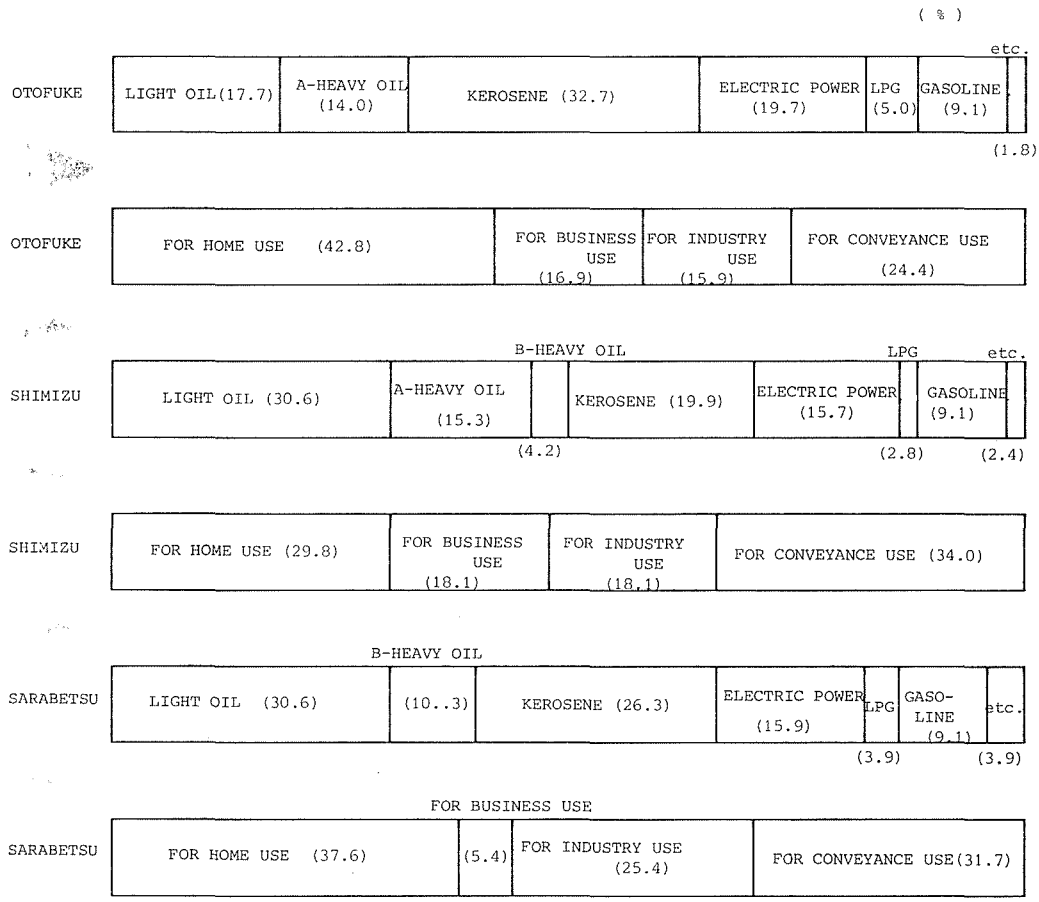


Figure 11. The distribution ratio of the regional energy in 1990.

2.52 times as much as in 1990 at Otofuke, 2.77 times at Shimizu, and 2.72 times at Sarabetsu. In case that the costs of energy in 1990 will rise twice as high as in 1980, it is estimated that the costs will be 3.83 times as great as in 1980 at Otofuke, 4.26 times at Shimizu and 4.19 times at Sarabetsu.

As regards the influence of soft energy introduced by farmers' will upon the household energy of the whole town or village, it is estimated that the reduction rate of the household energy at Otofuke in 1990 will show an increase of 2.2%, in case that the energy costs maintain the present rising rate and with the requirements set on the utilizers, and 2.4% in case that the rising rate of the energy costs is twice, 11.0% and 12.3% respectively at Shimizu and 26.5% and 27.0% respectively at Sarabetsu.

Next, the influence of soft energy introduced by farmers and of the energy conservation upon the household energy of the whole farmhouses is as follows.

The Effect of Introduction of Soft Energy

If the present rising rate of energy costs will be maintained till 1990, the reduction of (non-soft) energy demand can be estimated as follows. The reduction rate is 41.0% without the requirements set on the utilizers of soft energy and 21.5% with those requirements at Otofuke, 57% and 38.1% at Shimizu, 59.6% and 32.3% at Sarabetsu. If the present rising rate of energy costs will become twice as high, the rate is 43.9% and 21.5%, 74.4% and 40.9%, 60.9% and 32.3%.

The costs can be estimated as follows. If the present rising rate of energy costs will be maintained till 1990, the utilizer's expenditure for energy will show 28.7% increase without the requirements set on the utilizers of soft energy and 5.2% increase with the equirements at Otofuke, 30.2% increase and 12.8% increase at Shimizu, 14.8% increase and 1.9% decrease at Sarabetsu. If the present rising rate of energy costs will become twice as high, the utilizers' expenditures for energy will show 1.3% increase and 6.8% decrease, 14.7% decrease and 12.7% decrease, and 13.5% decrease and 14.4% decrease.

The influence given by maintaining the basic unit of consumption in 1980, and by practicing energy conservation

At Otofuke, it is estimated that the reduction rate of both energy demand and energy cost in 1990 is 20.9%. It is estimated that they will be reduced at the rate of 25.2% at Shimizu, and 25.4% at Sarabetsu.

The influence given by maintaining the basic unit of consumption in 1980, and by introducing soft energy

If the present rising rate of energy costs will be maintained till 1990, the reduction of (the non-soft) energy demand can be estimated as follows. The reduction rate is 61.9% without the requirements set on the utilizers and 42.4% with the requirements at Otofuke, 81.4% and 63.4% at Shimizu, 84.1 and 57.7% at Sarabetsu. And if the present rising rate of energy costs will become twice as high, the reduction rate is 64.7% without the requirements at Otofuke, 81.4% and 66.3% at Shimizu, 84.1% and 67.7% at Sarabetsu.

If the present rising rate of energy costs will be maintained till 1990, the utilizers' expenditures for energy can be estimated as follows. It is estimated that the increase of expenditure will be 7.8% without requirements at Otofuke, 5.0% at Shimizu. It is estimated that the decrease of Expenditure will be 15.5% with requirements at Otofuke, 12.4% at Shimizu. And if the present rising rate of energy costs will become twice as high, it is estimated that the decrease of expenditures will be 19.6% without requirements and 27.7% with requirements at Otofuke, 39.9% and 37.9% at Shimizu.

If the present rising rate of energy costs is maintained till 1990, it is estimated that the expenditure will be reduced at the rate of 10.6% without the requirements set on utilizers of soft energy, and 2.73% with requirements set on utilizers of soft energy, and 2.73% with the requirements. If the present rising rate of energy costs becomes twice as high, it is estimated that the expenditure will be reduced at the rate of 38.9% without the requirements set on utilizers and 39.8% with the requirements.

Thus, it is estimated that the amount of the household energy used at one house in these regions in 1990 will be 1.3-1.4 times as great as in 1980. It is also estimated that the expenditure will increase 2.5-2.8 times as high, if the rising rate of energy costs is maintained and that 3.8-4.3 times, if the present rising rate of costs becomes twice as high. Under these circumstances, the expenditure for household energy will be much greater in the future. In these regions, the proportion of household energy to the total energy will be very great and the importance of household energy will not change here in the future.

As regards the influence of the farmers' will to introduce soft energy into the whole regions, their will is reflected in energy utilization of the whole regions, especially in the pure farming regions such as Sarabetsu. This indicates the promising utilization of soft energy in the pure farming area where the residents are under the favorable conditions in making use of soft energy.

Next, the influence of the introduction of soft energy and energy conservation into household energy of the whole farmhouses is as follows.

As regards the influence of the introduction of soft energy for home use, some places will show that the reduction rate of household energy of the whole farmhouses is over 50% with the present rising rate of energy costs. On the other hand, the introduction of soft energy causes the farmers to bear more expenses than before. If the present rising rate of energy costs becomes twice as high, some places will show that the reduction rate of household energy of the whole farmhouses is over 70% and so, in regard to the costs, the farmers' conditions will be favorable in 1990.

6. Conclution

It is clear that the reduction rate of household energy will be over 80% under the influence of introducing soft energy and the expenses will be smaller, with the present rising rate of energy costs, when the farmers have high possibility of

energy conservation by means of the improvements of residental houses and the wide use of adiabactic materials.

References

Yamamura, E. (1977): Regional Balance Growth. TAIMEIDO.

Yamamura, E. (1979): Regional Planning I. GIHODO.

Caldwell, S. Greene, W. Mount, T. Saltzman, S. and Brock, R. (1979): Forecasting Regional Energy Demand with Linked Macro, Micro models. *PAPERS, The Regional Science Associa tion* **43**, 1979.

Yamamura, E. and Kagaya, S. (1983): Regional Energy Planning Arising from Soft Energy Path. *Energy Developments in JAPAN,* Vol. **6**, No. 2, RUMFORD PUBLISHING COMPANY, INC.

Yamamura, E., Kagaya, S. and Iwasa, M. (1983): Economic and Environmental Evaluation of Regional Energy Arising from a Soft Energy Path. *Environmental Science, Hokkaido, Journal of the Graduate School of Environmental Science,* Vol. **6**, No. 1.

(*Received 19 February 1985*)