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Title	ソフトエネルギーパスに基づく地域エネルギーの経済的・環境的評価
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Citation	環境科学 : 北海道大学大学院環境科学研究科紀要, 6(1), 27-41
Issue Date	1983-12-20
Doc URL	https://hdl.handle.net/2115/37150
Type	departmental bulletin paper
File Information	6(1)_27-41.pdf



Economic and Environmental Evaluation of Regional Energy Arising from a Soft Energy Path

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ソフトエネルギーパスに基づく地域エネルギーの 経済的・環境的評価

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1. Introduction

A new and widespread crisis resulting from the reduction in oil supply has made its impact not only upon regional energy demand but also on regional economic structures.¹⁾ A greater volume of new energy demand is expected in the coming years. The strongest possibility for meeting such demands is by energy conservation through a Soft Energy Path adopting the practical uses of regional energy: natural energy and biomass.²⁾

The objective of the study is to develop a regional planning model for energy conservation by the practical use of regional energy: natural energy and biomass. It will also cover an economic and environmental evaluation of the regional energy obtained from a Soft Energy.

We will attempt to apply this new regional planning model to the Tokachi Region of Hokkaido in Japan. This region has not only an abundant degree of potential energy of natural energy and biomass, but also good prospects for regional development.

The framework of the study involves firstly, the clarification of the social, economic and industrial structures and the degree of potential regional energy of

natural energy and biomass. Secondly, the relationships between the social, economic and industrial structures and regional energy flow will be discussed. And thirdly, a regional energy model arising from the Soft Energy Path will be constructed, and finally the economic and environmental impacts of the Soft Energy Path will be evaluated.

2. Introduction to the Tokachi Region in Hokkaido

Hokkaido,³⁾ the northernmost island of the Japanese archipelago, has an area of approximately 84,000 km² and has a population of about 5.6 million in 1980.

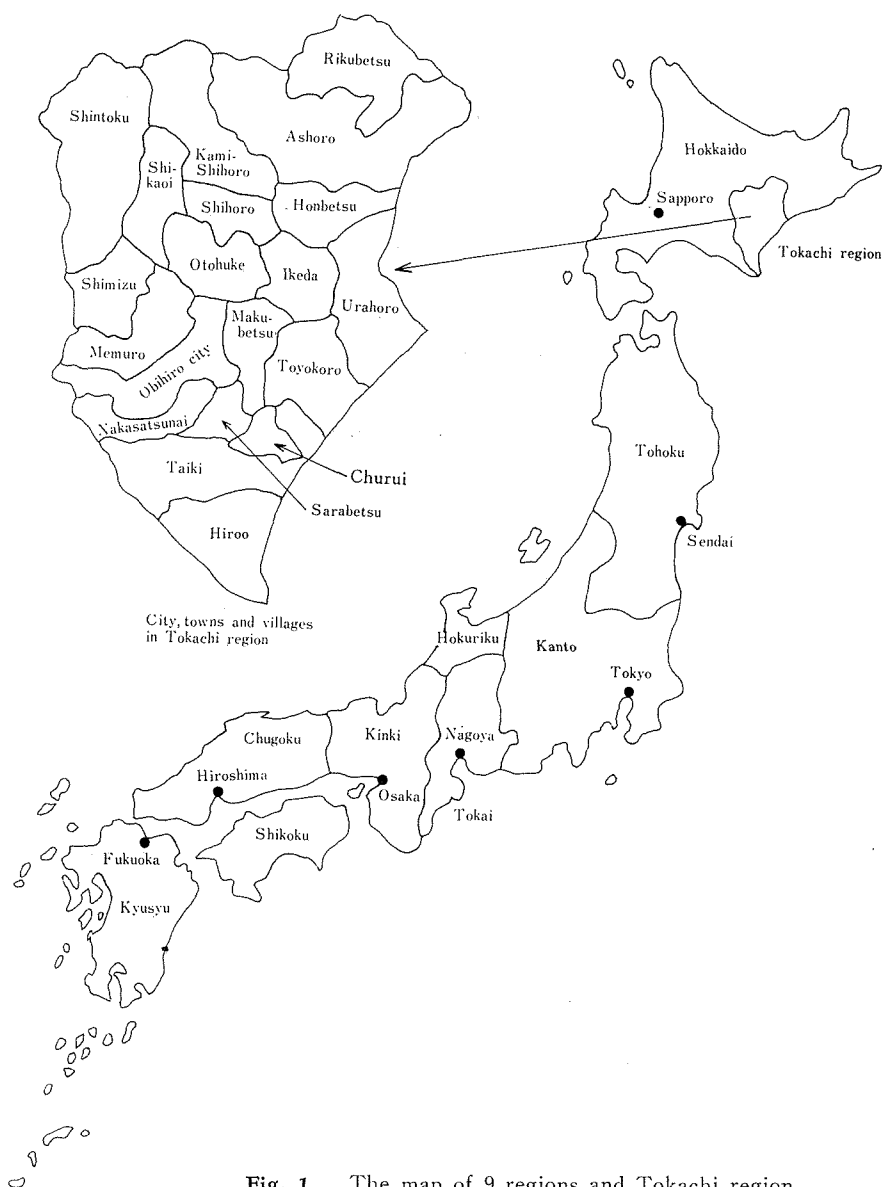


Fig. 1. The map of 9 regions and Tokachi region.

Its area is larger than that of Kyushu and Shikoku combined (approximately 63,000 km²) and alone accounts for about 21% of the total area of Japan as shown in Fig. 1. However, it contains only 5% of the total population of Japan.⁴⁾

The Tokachi Region, an eastern plain of Hokkaido has an area of approximately 10,831 km² and a population of about 0.36 million in 1979. The Tokachi Region is an independent geographic unit in many aspects. It stretches southeastward for 80 km, and has a width of about 50 km. It resembles the Kanto Plain in that it is chiefly composed of dissected fans that are pushed out from the west and north and valley floors that are entrenched below the level of the fans. Low hills and uplands which consist of either old diluvium or young Tertiary formation lie in the south and east of the plain, and is partly cut off from marine influence of the Pacific to the southeast.

The climate is continental without much snow, but the average winter temperature drops to -10°C with many fine weather days. Presently, 35,500 people of 105,000 families live in one city Obihiro and nineteen towns and villages in the Tokachi Region as shown in Fig. 1.

The Tokachi Region is the land of dry farms with mixed farming which is the combination of dairying and raising of such commercial crops as beans, sugar beet, and feed crops such as dent corn and hay.

Obihiro City is the center of the Tokachi Region, second to none. The city is a typical example of inland towns of Hokkaido that have been developed solely as the marketing centers of surrounding agricultural regions. Practically all the roads of Tokachi lead to this city. The planning of the city is modelled after that of Washington, D. C., and diagonal roads intersect with rectangular roads.

As regards to the present conditions of the energy consumption of the Tokachi Region, the distribution percentages of fuel oil consist of gasoline 19.7%, lamp-oil 40%, light oil 17.6% and heavy oil 22.7%, with lamp oil representing the highest. The consumption of LPG is mostly that of automobile and town gas. The distribution percentages of the consumption of electricity consist of electric light 41.7%, electricity for business 14.1%, small sum electricity 24.6%, large sum electricity 14.4% and others 5.2%. With the present condition of the degree of potential energy of natural energy and biomass of the Tokachi Region, solar energy is highly useful for heating during the winter season, with 2,200 sunshine hours a year. Windpower here is less useful for electricity due to the low average wind velocity. But biomass is highly useful for heating and as town gas, with the potential from the 67% of forests and fields in Tokachi and the percentage distribution of 23% of the cows in Hokkaido found in the Tokachi Region. Geothermal energy is also highly useful for electricity and heating as many hot springs are available. In addition, hydro-electricity can be usefully exploited from medium and small rivers made available by the many tributaries from the Tokachi River.

As mentioned above, the Tokachi Region has not only an abundant amount of potential energy : natural energy and biomass but also good prospects for regional development.

3. The Framework of the Regional Energy System Model

In this chapter, we will describe the framework of the regional energy system⁵⁾ model arising from the Soft Energy Path.

The system model consists of six sectors, that is the energy demand sector, the energy supply sector, the regional environmental sector, the soft energy sector, the pollution sector and the evaluation sector.^{6,7)}

The energy demand sector^{8,9)} consists of four subsectors, namely the household subsector, the industrial and commercial subsector, the transportation subsector and the agricultural subsector. The household subsector deals with the direct purchase of fuels, electricity and gas used for space and water heating in homes as well as for cooking and running other domestic appliances.

The industrial and commercial subsector deals with the fuels, electricity and gas used for factories, building and machinery.^{10,11)} The transportation subsector

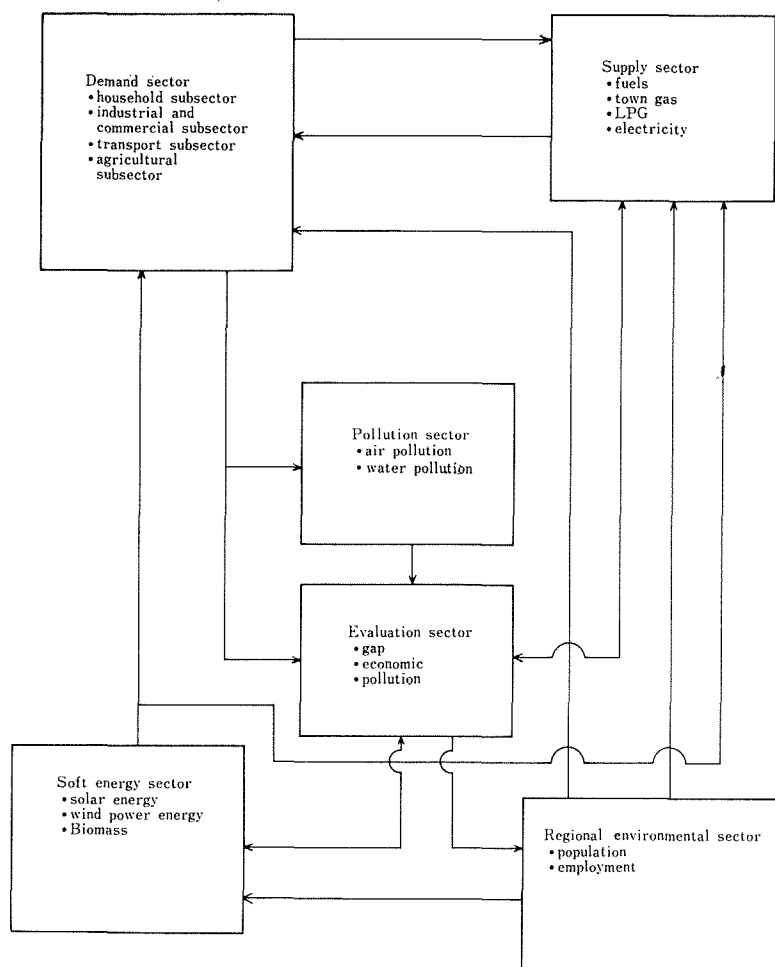


Fig. 2. Framework of the regional energy model.

(1) It is necessary to measure the regional employment opportunities by industries and scales.

(2) We can clarify the differences of the regional economic structures.

(3) It is necessary to measure the employment opportunities not only as the direct repercussive effects but also as indirect repercussive effects of industrial locations.

(4) We must measure the indirect repercussive employment opportunities not only of the industrial locational region but other regions as well.

The basic method of measurement of the employment opportunities has been presented by Isard and Miller.

Isard attempts to do an impact study on the direct and indirect repercussions of the location of the steel industry on the Greater New York — Philadelphia industrial region.¹⁸⁾ Miller also attempts to do the same impact study on the location of the aluminium industry in the Pacific Northwest.¹⁹⁾

However, in the studies, only a relatively small amount of research has been made on the four conditions made above.

We shall consider the detailed method of the measurement of regional employment opportunities arising from industrial locations of soft energy technology by the interregional input-output method.²⁰⁾

We will define the notations of the partitioned matrices as follows:—

A : interregional input coefficients matrix by regions.

I : identity matrix.

S : matrix having the values of inputs from other industries to locational in-

Table 1. The Classification of 25 Sectors.

Number	Sectors	Number	Sectors
01	Agriculture Forestry & Fisheries	14	Metal products
02	Coal & Lignite Mining	15	Machinery (n. e. c)
03	Mining (Excpt 02)	16	Electric Machinery
04	Food & Kindred products	17	Transportation Equipment
05	Textile products	18	Precision Machinery
06	Lumber & Wood products	19	Miscellaneous Manufacturing
07	Pulp, Paper & Paper products	20	Construction
08	Leather, Leather products & Rubber products	21	Electricity, Gas, Water & Sanitary Services
09	Chemicals	22	Wholesale & Retail Trade
10	Petroleum & Coal products	23	Finance, Real Estates & Other Service
11	Ceramic, Clay & Stone Products	24	Transportation & Warehousing
12	Primary Iron & Steel Manufacturing	25	Unallocated
13	Primary Nonferrous Metal Manufacturing		

dustry along the main diagonal (the diagonal running from upper left to lower right) and zeros elsewhere.

D : matrix having the values of inputs of locational industry along the column and zero elsewhere.

R : basic unit of employment opportunities.

N : number of regions.

M : number of industries as shown in Table 1.

X represents the matrix of the total repercussive employment opportunities and is satisfied by the following equations.

$$\begin{aligned} X &= D \otimes R + A \cdot S \otimes R + A^2 \cdot S \otimes R + \dots \\ &= D \otimes R + [I + A + \dots] \cdot A \cdot S \otimes R \\ &= D \otimes R + [I - A]^{-1} \cdot A \cdot S \otimes R \end{aligned} \quad (1)$$

Where, $D \otimes R$ is the direct repercussive employment opportunities and $[I - A]^{-1} \cdot A \cdot S \otimes R$ is the indirect one.

Let $[I - A]^{-1} \cdot A$, S , D , R be the following partitioned matrices.

$$[I - A]^{-1} \cdot A = \begin{bmatrix} \begin{array}{cc} a_{11}^{11} & a_{1N}^{11} \\ a_{N1}^{11} & a_{NN}^{11} \end{array} & \begin{array}{cc} a_{11}^{1M} & a_{1N}^{1M} \\ a_{N1}^{1M} & a_{NN}^{1M} \end{array} \\ \begin{array}{cc} a_{11}^{M1} & a_{1N}^{M1} \\ a_{N1}^{M1} & a_{NN}^{M1} \end{array} & \begin{array}{cc} a_{11}^{MM} & a_{1N}^{MM} \\ a_{N1}^{MM} & a_{NN}^{MM} \end{array} \end{bmatrix} \quad (2)$$

$$S = \begin{bmatrix} s_1^1 & & & \\ & s_N^1 & & \\ & & s_1^M & \\ & & & s_N^M \end{bmatrix} \quad (3)$$

Where, $s_j^k = 0$ ($k = k_0, j = j_0$)

$$D = \begin{bmatrix} \begin{array}{cc} d_{11}^{11} & d_{1N}^{11} \\ d_{N1}^{11} & d_{NN}^{11} \end{array} & \begin{array}{cc} d_{11}^{1M} & d_{1N}^{1M} \\ d_{N1}^{1M} & d_{NN}^{1M} \end{array} \\ \begin{array}{cc} d_{11}^{M1} & d_{1N}^{M1} \\ d_{N1}^{M1} & d_{NN}^{M1} \end{array} & \begin{array}{cc} d_{11}^{MM} & d_{1N}^{MM} \\ d_{N1}^{MM} & d_{NN}^{MM} \end{array} \end{bmatrix} \quad (4)$$

Where, the relation of matrices S and D is as follows,

$$\begin{aligned} d_{ij}^{k'k} &= s_j^k & (k = k_0, j = j_0) \\ d_{ij}^{k'k} &= 0 & \text{other} \end{aligned} \quad \begin{pmatrix} i = 1, 2, \dots, N \\ j = 1, 2, \dots, N \end{pmatrix} \quad (5)$$

The small k_0 is the locational industry and j_0 is the locational region.

$$R = \begin{pmatrix} r_1^1 \\ \vdots \\ r_N^1 \\ \vdots \\ r_1^M \\ \vdots \\ r_N^M \end{pmatrix} \quad (6)$$

Where, $\otimes$ multiplication represents the next operation.

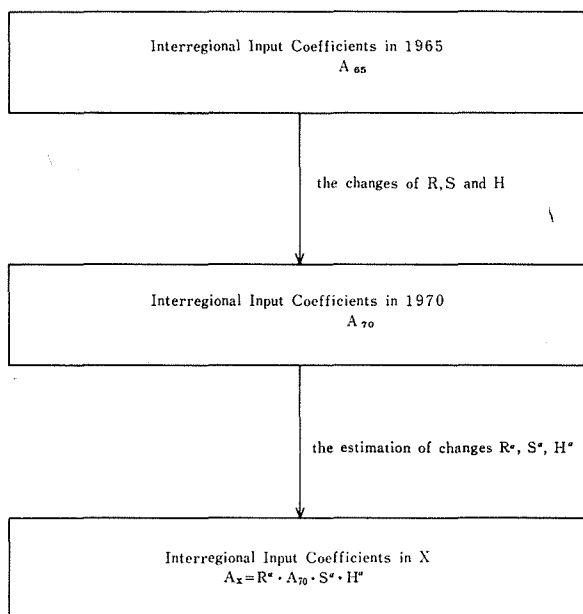
$$x_i^{k'} = \sum_{k=1}^N d_{ij}^{k'k} \cdot r_i^{k'} + \sum_{k=1}^N s_{ij}^{k'} \cdot a_{ij}^{k'k} \cdot r_i^{k'} \quad (7)$$

$$(i, j=1, 2, \dots, N, k'=1, 2, \dots, M)$$

To apply the new method, it is necessary to estimate the future target values of interregional input coefficients and the basic unit of employment opportunities.

Then, we represent the Improvement RAS method to estimate the future target values.

For example, Fig. 3 represents the flow to estimate the future target values by the interregional input coefficients in 1965 and 1970. The basic unit of employment opportunities is estimated by the similar method.



where,

R : substitute change coefficients

S : processing change coefficients

H : relative change coefficients

$\alpha = (X - 1970) / 5$

Fig. 3. The Improvement RAS Method.

4. The Estimate and Evaluation of Regional Energy Arising from the Soft Energy Path in the Tokachi Region

The estimate of the energy demand in the Tokachi Region is as follows.

The energy demand of electric light and electric power in 1985 is estimated to be 1.9 times greater than in 1975, with the energy demand of lamp oil 1.6 times, the energy demand of LPG 1.7 times, the energy demand of heavy oil 2.1 times and the energy demand of gasoline 1.9 times.

The estimate of the energy conservation rates in the Tokachi Region arising from the Soft Energy Path mentioned in chapter 3 is as follows.

The energy demand of electric light and electric power in 1985 is substituted by 6.0% with the Soft Energy, with lamp oil by 12.0%, LPG by 71.0% and the total energy by 7.3%.

Next, the estimate of the energy conservation rates in Obihiro City with the example of the town model arising from the Soft Energy Path is described as follows.

The energy demand of electric light and electric power in 1985 is substituted

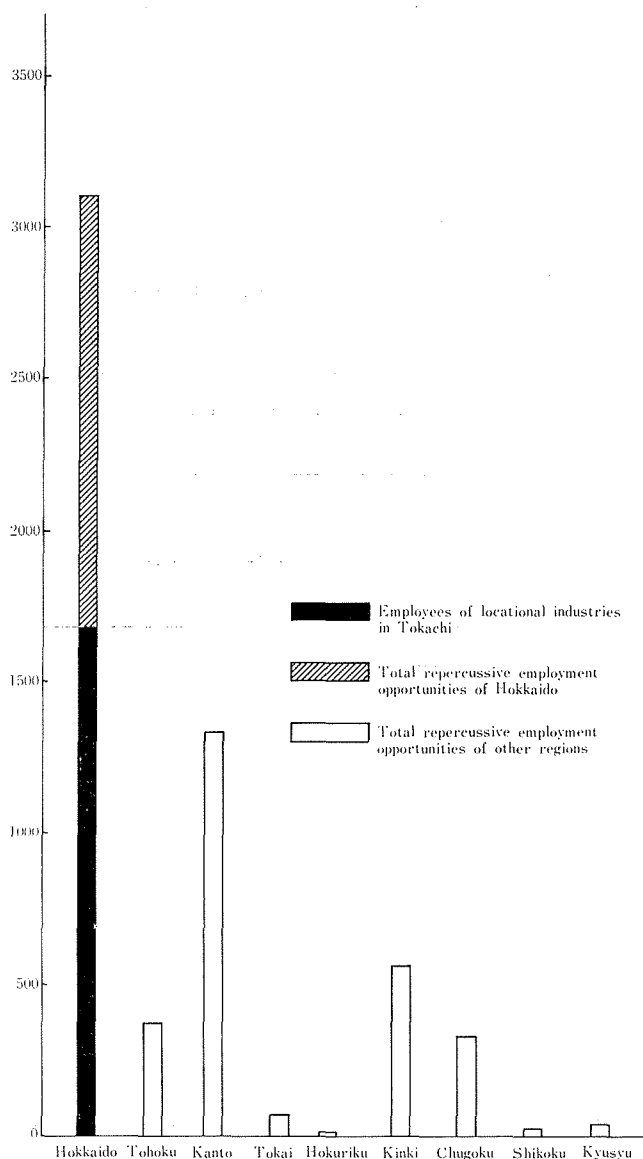


Fig. 4. The regional employment opportunities.

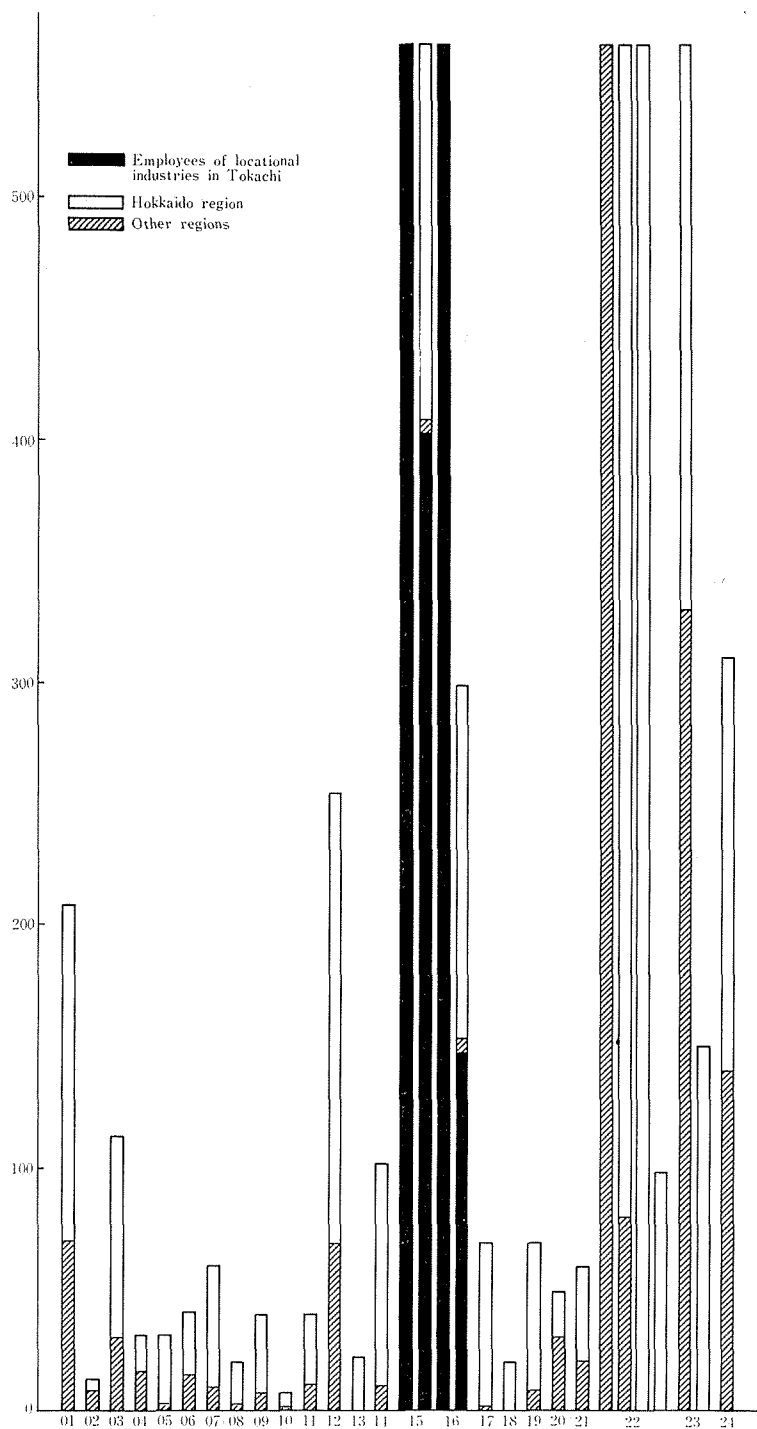


Fig. 5. The regional employment opportunities by industries.

by 4.1% with soft energy, with lamp oil by 8.0%, LPG by 21.2% and the total by 5.2%.

Furthermore, the estimate of the energy conservation rates in Urahoro village with the example of the farm village model arising from the Soft Energy Path is described as follows.

The energy demand of electric light and electric power in 1985 is substituted by 9.0% with soft energy, with lamp oil by 26%, LPG by 100% and the total energy by 25%. As mentioned above, the substitution rate of farm village represents a higher figure than of town.

The analytical results of the evaluation of environmental and economic factors are as follows:

(1) The reduction rates of air pollution and water pollution arising from soft energy in the Tokachi Region are 6.7% and 40% respectively. The reduction rate of water pollution represents a higher figure than that of air pollution.

(2) In comparing the direct costs of alternative energy systems, the present values of payments with the annuity loan of solar system is \$0.11 per 1,000 kcal, making the wind power as \$0.10 per 1,000 kcal and the biomass as \$0.05 per 1,000 kcal. The biomass is cheaper than other alternative energy systems.

(3) The accumulated alternative investments of the soft energy locational industries in the Tokachi Region are as follows.

The solar energy investment is \$220 million, the wind power investment \$250 million, the biomass \$260 million and the total \$730 million. If the total investment of \$730 million is allocated for five years from 1981 to 1985, then the average investment per year becomes about \$146 million.

Furthermore, the benefit from compost per year is \$52 million and the reduction cost of lamp oil import per year in the Tokachi Region is \$15 million, and the reduction cost of LPG import per year in the Tokachi Region is \$17 million. As mentioned above, the economic impact is estimated at a high level.

(4) The accumulated regional total employment opportunities arising from the annual output of the soft energy industries located in the Tokachi Region in 1985 are shown in Fig. 4. From the facts presented in Fig. 4, the sum of the regional total employment opportunities in other regions is equal to the one in Hokkaido. The remarkable feature is the expansion of the regional total employment opportunities in the Kanto Region which advanced industrially.

(5) The regional total employment opportunities by industries in 1985 are shown in Fig. 5.

The regional total secondary industry employment opportunities arising from the soft energy industries is 7.3% of the secondary industry employment in the Tokachi Region. This results in influences on the manufacturing industries with a lower level than the national level in a favourable way. In addition, the remarkable feature is that the expansion of the regional total employment opportunities of tertiary industries in Hokkaido is 40% of the total ones. This is the main cause which is the indirect repercussive impact of the locational industries of the soft energy industries.

5. Conclusion

To summarise, we have investigated a regional planning model for energy conservation by the practical use of regional energy: natural energy and biomass, and also covered an economic and environmental evaluation of the regional energy obtained from the soft energy. As for the analytical results of the model, the reduction rate of pollution and the reduction cost of oil and gas import with the substitution of soft energy represents a high value. Besides this, the economic direct and indirect impact of alternative investments of the soft energy industries is estimated at a high level in the Tokachi Region. Then, this study indicates many useful informations to the developing countries without fossil fuels.

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Summary

A new and widespread crisis resulting from the reduction in oil supply has made its impact not only upon regional energy demand but also on regional economic structures. A greater volume of new energy demand is expected in the coming years. The strongest possibility for meeting such demands is by energy conservation through a Soft Energy Path adopting the practical uses of regional energy: natural energy and biomass.

The objective of the study is to develop a regional planning model for energy conservation by the practical use of regional energy: natural energy and biomass. It will also cover an economic and environmental evaluation of the regional energy obtained from the Soft Energy.

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The framework of the study involves firstly, the clarification of the social, economic and industrial structures and the degree of potential regional energy of natural energy and biomass. Secondly, the relationships between the social, economic and industrial structures and regional energy flow will be discussed. And thirdly, a regional energy model arising from the Soft Energy Path will be constructed, and finally the economic and environmental impacts of the Soft Energy Path will be evaluated.

The main results of estimates and evaluations arising from the soft energy path in the Tokachi Region are as follows.

- (1) The estimates of the energy demand in the Tokachi Region is as follows. The energy demand of electric light and electric power in 1985 is estimated to be 1.9 times greater than in 1975, with the energy demand of lamp oil 1.6 times, the energy demand and of LPG 1.7 times, the energy demand of heavy oil 2.1 times and the energy demand of gasoline 1.9 times.
- (2) The estimates of the energy conservation rates in the Tokachi Region arising from the Soft Energy Path are as follows. The energy demand of electric light and electric power in 1985 is substituted by 6.0% with the Soft Energy, with lamp oil by 12.0%, LPG by 71.0% and the total energy by 7.3%.
- (3) The estimates of the energy conservation rates in Obihiro City with the example of the town model arising from the Soft Energy Path are described as follows. The energy demand of electric light and electric power in 1985 is substituted by 4.1% with the Soft Energy, with lamp oil by 8.0%, LPG by 21.2% and the total by 5.2%.
- (4) The estimates of the energy conservation rates in Urahoro village with the example of the farm village model arising from the Soft Energy Path are described as follows. The energy demand of electric light and electric power in 1985 is substituted by 9.0% with the Soft Energy, with lamp oil by 26%, LPG by 100% and the total energy by 25%. As mentioned above, the substitution rate of farm village represents a higher figure than that of town.
- (5) The estimates of introductive rates of solar energy and biomass based on attitudinal survey on settlers in Otohuke, Shimizu and Sarabetsu villages are as follows. The estimates of introductive rates of solar energy of Otohuke, Shimizu and Sarabetsu represent high values such as 80%, 83% and 73%. The estimates of introductive rates of biomass represent half values such as 52%, 57% and 52%. It was most efficient method to reduce the energy costs that the energy conservation method added to the soft energy introductive system.

(6) The reduction rates of air pollution and water pollution arising from the Soft Energy in the Tokachi Region are 6.7% and 40% respectively. The reduction rate of water pollution represents a higher figure than that of air pollution.

(7) In comparing the direct costs of alternative energy systems, the present values of payments with the annuity loan of solar system is \$0.11 per 1,000 kcal, making the wind power as \$0.10 per 1,000 kcal and the biomass as \$0.05 per 1,000 kcal. The biomass is cheaper than other alternative energy systems.

(8) The accumulated alternative investments of the soft energy locational industries in the Tokachi Region are as follows. The solar energy investment is \$220 million, the wind power investment \$250 million, the biomass \$260 million and the total \$730 million. If the total investment of \$730 million is allocated for five years from 1981 to 1985, then the average investment per year becomes about \$146 million. Furthermore, the benefits from compost per year is \$32 million and the reduction cost of lamp oil import per year in the Tokachi Region is \$15 million, and the reduction cost of LPG import per year in the Tokachi Region is \$17 million. As mentioned above, the economic impact is estimated at a high level.

(9) The accumulated regional total employment opportunities arising from the annual output of the soft energy industries located in the Tokachi Region in 1985 are as follows. The sum of the regional total employment opportunities in other regions is equal to the one in Hokkaido. The remarkable feature is the expansion of the regional total employment opportunities in the Kanto Region which advanced industrially.

(10) The regional total employment opportunities by industries in 1985 are as follows. The regional total secondary industry employment opportunities arising from the soft energy industries are 7.3% of the secondary industry employment in the Tokachi Region. This results in influences on the manufacturing industries with a lower level than the national level in a favourable way. In addition, the remarkable feature is that the expansion of the regional total employment opportunities of tertiary industries in Hokkaido is 40% of total ones. This is the main cause which is the indirect repercussive impact of the locational industries of the soft energy industries.