Development of a Method of Associatively Estimating Technology and Environmental Actions toward the Design of Green Society

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Abstract

The saving-energy in household is a key point to achieve a sustainable society with reduced emission of carbon. To promote this activity, a proper estimation methodology is necessary for judging the values of saving-energy industrial products and our environmental actions at same level both in terms of CO_2 emission and cost. From this viewpoint, we presented a new estimation method by chart of CO_2 emission and expenses profiles during life cycle based on a new index, the environmental space life. Using the proposed chart, the effects of new eco-product introduction and our environmental action using old product were quantitatively compared. Several equations are defined, and the costs of our environmental actions were evaluated in contrast with the reduction of CO_2 emission by new product introduction based on this chart. It was found that energy-saving action is very valuable for the use of TV and air conditioner, and that the replacement with hybrid car is very valuable for automobile. Thus, the proposed method can be used for the proper selection of new eco-product and the determination of environmental action target in our low carbon emission life.

1. Introduction

Many local societies in Japan have recently been paying much attention to their sustainable development with reduced emission of carbon while local governments have been promoting various actions to introduce green technologies, which mean renewable energy and energy-saving industrial products, to mitigate emission of CO_2. It is, however, difficult to say that all of such actions have been in success. Impact of introducing green technologies, if just in a manner of retrofitting, has a limitation. Rather, effective combinations of technological innovation with local policy and action are desired. In leading the introduction of green technologies properly, one or more non-conventional indices in light of both energy and cost efficiencies are necessary. On the other hand, implementation of green technologies is successful only in maturated communities with environmental friendliness, in each of which the resident, i.e., the stakeholder, has a proper understanding of the impact/significance of such technologies. Promotion of sustainable development by the resident is thus indispensable in construction of a green society, in which the residents act can act happy to take full advantage of green technologies. In this sense, the green technology is no more than one of the tools. Studies on the assessment and/or design of green society are therefore required to integrate technologies and social acceptance. Such integration needs at least an appropriate and quantitative scale for considering uniformly both effects of green technologies and environmental action of residents on the reduction of carbon emission, according to which the policy maker can decide optimum institutional design.

From this viewpoint, we proposed a concept to design green local society. We adopt fossil energy consumption density or CO_2 emission

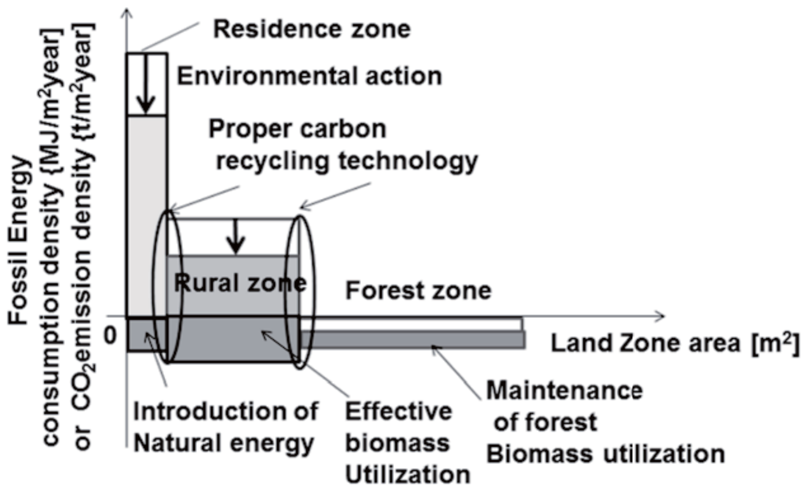

Fig.1 Basic concept of local green society

density as a quantitative logical scale. This index is defined as the amount of the fossil energy consumption or the CO_2 emission divided by the area of land. **Figure 1** shows the density map of fossil energy consumption or CO_2 emission against the area of land zone in local society. The area of rectangle bar for each land zone represents the amounts of fossil energy consumption or CO_2 emission in the land zone. In this figure, the consumption density of natural energy (solar, wind, and small hydro powers) and biomass energy resources utilized draw toward minus direction. Based on Fig.1, the green local society will be achieved by reducing the slope from residential zone to forest zone. Various strategies to reduce the slope are considerable. For example, the introduction of natural energy and environmental actions are effective in resident zone because of the number of people. Recently, several indices for eco-products such as eco-efficiency are presented [1]. In addition to this, the value (for example cost) of environmental action is needed to promote reduce the energy consumption in residence zone.

The management of forest is also effective to increase the amount of minus region. Based on Fig.1, the environmental action, the introduction of new technologies, and the management of forest are discussed by same index, and these effects can be compared quantitatively. To do so, a new additional quantitative method to estimate the value of environmental actions is required. On the other hand, the biomass in local society is a meaningful carbon circulation media. To reduce the slope between residence zone and rural zone, biomass utilization scheme of rural and forest zone reasonable in both cost and energy is required. The previous methods such as LCA [2] are useful to evaluate a presented technologies or process, but do not give us the optimum process deductively. So, a now methodology to design the optimum path and process of biomass conversion is desired in both aspect of energy and cost.

From the above viewpoint, we have been investigated the following items: 1) Estimation method for determining the value of organic waste and waste heat, 2) Exergy pass diagram for determining biomass conversion, 3) Estimation method for the value of environmental action based on a new environmental index, and 4) Analysis of the formed factor of familiarity in the Internet community, and discussion of its effect for promoting environmental action. In this paper, I introduced the details of the item 3).

2. Proposed Estimation Method

2.1 An index for estimating environmental action

We presented a new index environmental space life, to represent the consumption time of products per a certain space as defined by eq. (1) [3].

$$\text{Environmental space life} = \frac{\text{Consumption time of product [year]}}{\text{Space}} \tag{1}$$

The index represents life time of products utilized in a certain space. The space and time in the index can be selected flexibly based on the way of products use. The definition of space in the eq. (1) is broad, and we can select the number of person etc. as a dimension of space. The index can be defined at several levels, elemental level, compound level, product level etc. The advantageous feature of the proposed index is summarized as follows: (a) Easy and fair comparison of CO_2 load among various product utilizations, (b) A proper space to suppress the consumption rate is suggested, and (c) The quantitative target of environmentally friendly action is indicated. Especially, items (b) and (c) are significant. For example, we can reduce large amount of CO_2 per time derived from a certain product by considering the utilization space. Also, the introduction of proposed index gives us the effective connection between technology and policy making. Furthermore, the index can be applied to natural green resources such as wood and plant, and the CO_2 absorption life time and space can be estimated. In this paper, we try to estimate the effects of technological innovation and environmental actions using this index.

2.2 Chart for estimationg technological Innovation effect

Figure 2 shows the outline of the proposed chart for designing environmental actions. The chart is plotted by the accumulated amounts of CO_2 emitted or total expenses during the use of product against the consumption time. The CO_2 emission values of vertical axis are calculated by LCA, and total expenses are calculated by initial cost of target product and running energy cost. On the other hand, the abscissa is the value which multiplied the environmental space life defined above by a certain space. Using this chart, we can draw the CO_2 emission or the expense profiles of product. As shown in Fig.1, the amounts of

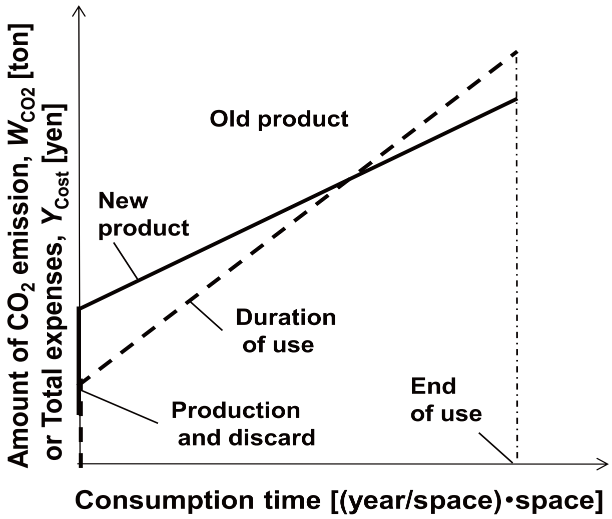

Fig.2 Schematic of proposed chart for estimation of CO_2 emission and total expenses

CO_2 emitted from resource mining to production and discard or initial cost is plotted as a value of interception of vertical axis. Next, the space (occasionally the number of person) is set, the CO_2 emission rate or running cost is calculated by the LCA data or energy cost, and drawing the line to the durable time of the product. Thus, the chart is merely refined LCA data to the space velocity of product consumption, but this treatment gives us the indication of the environmental action and its quantitative effect. Furthermore, since the chart suggests the amount of CO_2 emission rate per unit space and time, we can design the CO_2 emission by selecting a proper combination of space and time in contrast with cost estimation as described later.

3. Quatitative Esimation of Environmental Actions

3.1 Comparison between old and new products

In the present life style, automobile and electric products are inevitable items. As we know, the CO_2 emissions from public welfare section must be significantly reduced, but it is difficult to conduct end-of-pipe treatment such as CO_2 collection in the power plant. Therefore, we must try to minimize the consumption rate of energy in our house and office. To assist this action, various save energy products are supplied by technological innovation. Indeed, such products are effective to reduce the CO_2 emission in the life cycle, but we do not know the quantitative way to use these products properly for minimizing CO_2 emission. To overcome this situation, it is required to the comparison of the CO_2 emission rates between these products including the usage at same index.

First, we compared the CO_2 emissions of several representative electric products and automobile between old and new types listed in Table 1. Based on LCA analysis data, we drew the profiles of the CO_2 emission and the expense for each product by following the procedure shown in Fig.2. **Figure 3** shows the profiles of total CO_2 emission, W_{CO2}, and total expenses, Y_{cost}, between new and old models for 4 products. In this paper, we calculated and compared the total amount of CO_2 emitted and the total expenses paid during next life time after replacing a new eco-product or a low price previous product. The calculation and comparison base are various, but we set the above calculation condition to examine the validity the proposed method shown later by focusing on the quantitative comparison of effects of technological innovation and environmental action at same level. As compared with the profiles, the CO_2 emission and total expenses of automobile are significantly large. The air conditioner also influences on CO_2 emission and cost because we usually have several units in the home. From Fig.3 the profiles were classified into 3 types as follows:

I. $W_{CO2}(new)<W_{CO2}(old)$ and $Y_{cost}(new)<Y_{cost}(old)$
II. $W_{CO2}(new)<W_{CO2}(old)$ and $Y_{cost}(new)>Y_{cost}(old)$
III. $W_{CO2}(new)=W_{CO2}(old)$ and $Y_{cost}(new)>Y_{cost}(old)$

The refrigerator and the hybrid car (HV) belong to type I, suggesting that the technological innovation is very effective for the save of both

Table1: Products for investigation in this work

Television [4] (32wide 1unit, Usage: 8 years)	**Old: Panasonic 2005 Model (Braun tube)**
	New: Panasonic 2006 Model (Liquid crystal)
Refrigerator [5] (400L, 1unit, Usage: 8 years)	**Old: Sharp 2006 Model**
	New: Sharp 2010 Model
Air conditioner [5] (33m² type, 1unit, Usage: 11 years)	**Old: Sharp 2006 Model**
	New: Sharp 2008 Model
Automobile [6] (10000km/year, Usage: 10 years)	**Toyota Gasoline car (1800 cc) 15km/L**
	Hybrid car (Toyota Prius 1800 cc) 30km/L
	Electric car (average)

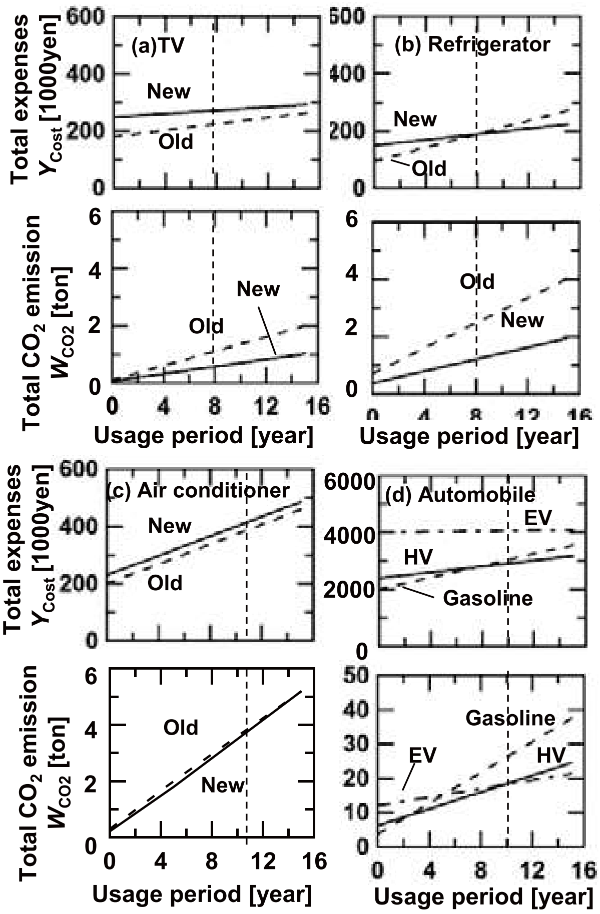

Fig. 3 Comparison of CO_2 emission and total expenses profiles between old and new products.

CO_2 emission and expenses. The CO_2 emission can be reduced from the beginning of usage by replacing refrigerator and total expenses is recovered at around 8 years. The automobiles profiles are somehow different by the kind of car.

Total CO_2 emissions of HV and electric car (EV) are suppressed over 2 years and 5 years, respectively, as compared with that of gasoline car. The EV is a good performance for the reduction of CO_2 during usage, but since the CO_2 emission at production stage is fairly large, it is necessary to use over 10 years to reduce under total CO_2 emission of HV. The total expenses of HV are recovered at 10 years, but it cannot be recovered within 15 years for the EV. Namely, the EV is categorized into Type II. From this results, the replacements with HV and EV are effective when we use them more than 10 years. On the other hand, television is categorized into type II. The effect of reduction of total CO_2 emission is excellent (CO_2 recover years is 1 year), but the expenses cannot be recovered within 10 years. The total expenses are now reduced year by year, so it will be categorized into type I within near future. Finally, the air conditioner is categorized into type 3. The technological innovation has been already attained to a good level, so the total expenses are almost equal and the CO_2 reduction effect is small. In this type, the environmental action is important to reduce the CO_2 emission furthermore. Thus, the proposed chart gives us the effect of technological innovation from the viewpoints of CO_2 emission and expenses.

3.2 Equations for estimating environmetal actions

Based on the above chart, we estimated the value of eco-product introduction and environmental action for the reduction of CO_2 emission. The estmation equations are listed from eqs.(2) to (6).

$$\Delta W_{CO2} = W_{CO2}(old) - W_{CO2}(new) \tag{2}$$

$$\Delta Y_{Cost} = Y_{Cost}(new) - Y_{Cost}(old) \tag{3}$$

$$Y_{Cost,action} = Y_{Cost,initial}(old) + Y_{Cost,use}(old)[W_{CO2}(new)/W_{CO2}(old)] \tag{4}$$

$$\Delta Y_{Cost,action} = Y_{Cost}(new) - Y_{Cost,action} \tag{5}$$

$$V_{action} = \Delta Y_{Cost,action}/\Delta W_{CO2} \tag{6}$$

where,

ΔW_{CO2}: Amount of CO_2 reduced by introducing new product

ΔY_{Cost}: Total expenses gained by introducing new product

$Y_{Cost,\ action}$: Running expenses during use of the product

$Y_{Cost,\ action}$: Total expenses under environmetal action of old product

$\Delta Y_{Cost,action}$: The expenses recovered under environmetal action of old product as compared with introduction of new product

V_{action}: The unit value of environmetal action of old product in constract with introduction of new product

3.3 Effect of technological innovation

Using the above equations, we first estimated the effect of introduction of new product. In the following discussion, we compared the performance at the condition that a product is purchased after replacing life. **Figure 4** shows the relationship between ΔY_{Cost} and ΔW_{CO2}. The negative value means that the expensed by introducing a new product cannot be recovered by the end of use. The selections of TV and EV cause significantly large minus values, indicating that we had better do efforts for environmental actions of old products for these items. The ΔY_{Cost} of air conditiner, refrigenerater and HV were plus values, so the replacement with new products were meaningful. Especially, the replacement of gasoline car with HV is significantly effective for the redcution of CO_2

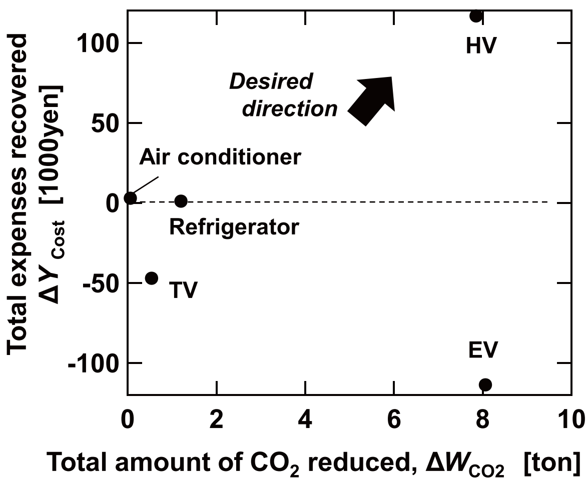

Fig.4 The value of new eco-product introduction

with high pay back of expenses. This estimation is changed by the decrese in initial cost or duration of usage. We must cosider carefully the selection of new product in the viewpoint of cost effectiveness. On the other hand, the function of product is an essential factor to select it. Since the reduction of CO_2 emission and expense recovery should be just considered totally by combination of several products used in our home, the proposed method is an useful one for designing the total utilization plan of home products by drwaing conbined lines using this chart.

3.4 Guidline for environmental action for each product

As mentioned above, our environmental action in the household is important to establish low carbon emission society, but we cannot recognized quantitatively the action effect. Using the proposed chart, we can estimate the cost effects of CO_2 reduction by the environmetal action or technological innovation. **Figure 5** shows its estimation procedure. First, the CO_2 emission profiles of old and new products are drawn at basic space condition such as one person and one room etc. If the W_{CO2}(new) < W_{CO2}(old), the line slope of old product shifts smaller to coincide the final CO_2 emission to new product at end of use (t0). After this work, we read the value of abscissa, t1, and consider the space to satisfy that value.

Based on this procedure, we estimated the space of usage. **Figure 6** shows the increse of environmental action space for old product equivalent to keep CO_2 emission by new product, r_{space} (= t1/t0), The increasing ratios of usage space for liquid crystal television and air conditioner were within 1.3. This means that the easy environmental action such as approx 25% reducing of usage times and 2 degree increasing setting of temperature, etc. These environmental actions have a merit of no initial expenses. The increasing ratio of usage space for refrigerator was

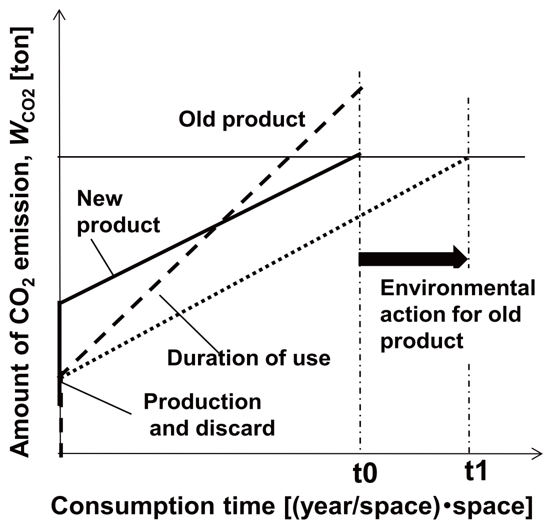

Fig. 5 Estimation of increasing ratio of space for environmental action

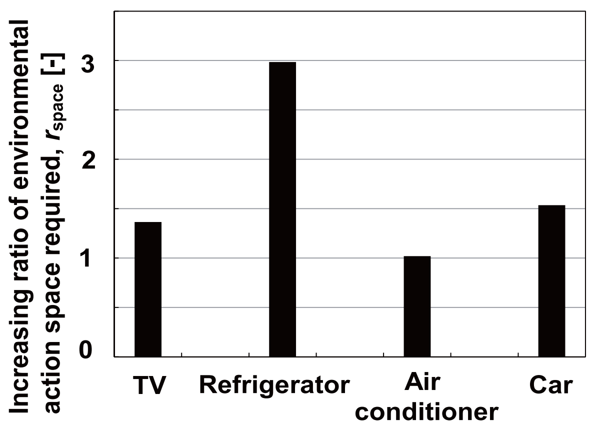

Fig.6 Comparison of r_{action} value among products

3. However, refrigerator is always acted, so an environmental action is a small effect as compared with the replacement with a new eco-product. Since the total expenses is also suppressed using a new eco-refrigerator, the technological innovation of refrigerator contributes effectively to reduce the CO_2 emission. The increasing ratio of usage space for automobile was 1.5. This means that the replacement with HV is equivalent to the environmental actions by gasoline car of 2/3 usage frequency, 1.5 times increase in total number of passenger per 1 ride, etc. Thus, this estimation clealy indicates quantitatively the environmental actions in constract with introduction of new eco-products.

Based on thus estimeted data, we find the targets of environmental action quantitatibely. **Table 2** lists the examples of environmental actions for the usage of each industrial product in home to keep the same effect by introducing eco-product with saving expenses. Thus, the estimation method gives us the clear targets for our environmental actions and we can select easy one by the quantitative information to reduce CO_2 and enegy consumption in home.

3.5 Value estimation of environmental action

Finally, we estimated the value of environmental action in constract with

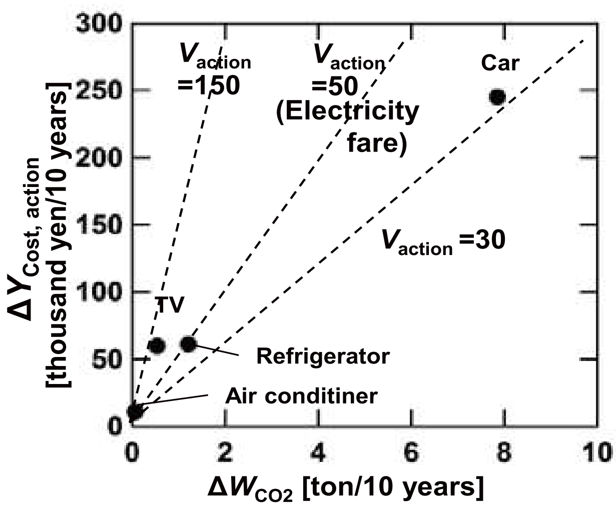

Fig.7 Values of enviromental actions in contast with introduction of new eco-product

technological innovation. In general, we do not know which environmental worth actions have. If their values are clarified as quantitaive prices, our motivation for the actions is promoted with fruitful sense of accomplishment. From the above results, we can estimate this value by Eqs. (4)-(6). Thus calculated value of each product plots in **Fig.7**. In the figure, the slopes of dashed lines represent the V_{action} values. The line of V_{action} = 48 and 65 yen/kg-CO_2 correspond to electricity fare and gasoline fare, respectively. The V_{action} values for old TV and air conditioner were more than 50 yen/kg-CO_2. For these products, the value of environmental actions (=save energy actions) of old products increase severl times larger than that by introducing new products. Namely, the effect of environmental action is several times valuable as compared with that of technological innovation for these products. On the other hand, the value was ca.30 for HV, which is about half of gasoline fare based on 1kg-CO_2 emission. This means the replacement with HV is more advantageous than the environmental actions, and that the technological innovation of HV reaches a superior level. From the results, we can select an option which consists of introduction of HV and refrigenerater

Table 2 Examples of environmental actions equivalent to intoduction of eco-prooducts

Degree of suppression by new eco-product	Environmental actions using old product	Degree of supppesion by environmental action
Air conditiner: 8.99 kg-CO_2	1 ℃ lower setting of heater	31 kg-CO_2
	1 hr saving of heater use	19 kg-CO_2
Television: 110.8 kWh	100 min saving of waching time	102 kWh
Automobile: 800 kg-CO_2	15 min saving per day of driving	837 kg-CO_2
	3500 km milage saving per year	788 kg-CO_2

with save energy of old type TV and air conditioner. As mentioned above, the values shown here based on the data at some year, so its values continuously change by renewal of spec and cost of product. If we change the point of view, the chart gives us a clue of the target for reasonable cost and spec of new eco-product. The detailed analyses using much data are necessary, but it is considered that the presented method can be one of the estimation method to combine technological innovation and environmental action.

4. Conclusion

Our environmental action with proper target is significant to achieve a low carbon emission society. To assist it, a new estimation method of environmental action was presented, in which we can estimate quantitatively the effects of both new eco-product introduction and our environmental action. The values of environmental actions varied with the product type. From the estimation results by relatively old data, the values of environmental action for air conditioner and TV are high; on the contrary, the replacement with HV is preferable for automobile. The analyses results also lead to the degree of environmental action using a new index presented, an environmental space life. We just show the methodology to evaluate the value of environmental action in contrast with the introduction of a new eco-product in this paper, but it is expected that the environmental harmonized life is designed with taking cost performance into account by applying the usage of various industrial products in future work.

Acknowledgment

I give sincere thanks to Profs. Takeshi Katsumi, Toru Inui, and Kazuhiro Mae for their useful discussions.

Reference

[1] L.D. Desimone, F. Popoff, "Eco-Efficiency: The Busi-ness Link to Sustainable Development", World Business Council for Sustainable Development, MIT Press, 1997.

[2] M.A.Curran, "Life-cycle Assessment: Inventory Guide-lines and Principles, 1st edition, CRC-Press, USA, 1994

[3] N. Mae, K. Mae, T. Katsumi, A New Diagram for Evaluating Relationship between Technological and Environmental Actions Ecodesign2011, Kyoto, 2011, page No. G1-06 (CD-ROM).

[4]<http://panasonic.jp/support/product/tv/03/TH-32D65.html>, <http://panasonic.jp/support/product/tv/02/TH-32LX60.html>, (Accessed 12.07.2012)

[5] Sharp CSR report 2010, 2010/06, P.44. Sharp CSR report 2011, 2011/07, P.45.

[6]<http://www.env.go.jp/air/car/comm_erv-dm/21-03.html>, (Accessed 18.04.2012).

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