Reduction of CO_2 Emission in Yoshida Campus by Using Environmental-Friendly Energy Sources and Saving Energy

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1. Introduction

It is not exaggerating to say that one of the most serious global problems in the 21st century is global warming caused by greenhouse effect gases, especially CO_2, emitted by our daily activities depend on fossil fuels. While we have been developed our scientific civilization without conscious about global climate, the ecosystem in nature has been destroyed, which is now terrifying our safety of life. The proofs are all around. Drought in Africa causes more serious poverty. Rise of sea level decreases coastal area where about 60% of metropolises locate and quarter human beings live conveniently. It is definitely true that using much amount of energy is as a two-edged blade; convenient city life comes at the expense of human life. Before exhausting the expense, we must try to create sustainable society broken free of the environmental sacrifices. It is factual that presently citizens in the world are aware of these crises though most of them still tend to waste energy unconsciously, *e.g.* overuse of air conditioners and idle of lamps. It seems to be a human common nature that we cannot immediately take actions to accomplish something troublesome. But, we know that the future situation without any actions will become more serious and it will be too late even to take actions. In order to hinder such a worst situation, people who are interested in and studying the issue in universities should firstly begin to tackle it and contribute to reduce CO_2 emission from such a small-scale society as a university, prior to others.

From this context, our research was purposed to show how meaningful our challenges are, to reduce CO_2 emission in Yoshida campus, Kyoto University. Our first question was how much amount of CO_2 emission is possibly reduced in fact. We estimated the possibility from two aspects: (1) energy supply with less or without CO_2 emission inside the campus and (2) energy conservation by consumers. Focused on the former side, introduction of environmental-friendly new energy sources was assumed and their abilities were inspected. On the other hand, concerning to the energy consumption side, the estimated result[1] published by Kyoto University in 2007 was used to get the information about the amount of CO_2 emission reduced by our individual efforts such as turning off unused electrical appliances. In light of these results, we conducted a questionnaire survey to know the motivation of staffs and students in Yoshida campus for reducing CO_2 emission, because our title issue cannot be solved without our all corporation.

These results were considered to be helpful for design of policies. Finally we supposed some recommendations which may be able to help in the reduction of CO_2 in Kyoto University, please check it out.

2. Feasibility for reduction of CO_2 emission in Yoshida campus

2-1 Energy supply

In this part, we assumed introduction of alternative energy sources which we supposed to be applicable in Yoshida campus. Solar cells, a biomass plant and fuel cells were chosen and their feasibilities were estimated from the data shown in following sections.

2-1-1Solar cell

Our attention as energy supplier is directed to solar energy due to its inexhaustibility. Even fossil fuels (e.g. petroleum, coal, and natural gas) which the principal energy sources at present can also be regarded as solar energy because they are derived from ancient plants which received solar energy in those days. However, since they emit CO_2 when they burn, solar energy is now designed to be used directly. Furthermore, solar energy can be received everywhere in the world, which is essential for ubiquitous energy use of mobile appliances and energy security especially for Japan that has few underground resources. Based on the above information, the solar photovoltaic energy converted by silicon solar cells is one of the most promising and attractive energy sources. Here, the estimated amount of the electricity generated by silicon solar cells on whole roof area of all buildings in Yoshida campus could compensate the electricity consumed in Yoshida campus in 2008. The detail of the estimation method is shown below.

Solar photovoltaic energy can be directly converted to electricity by means of the photovoltaic (PV) cells. It is beneficial to make the most of the roofs of all the buildings in Yoshida campus placed by PV cells on. Thus, we estimated how much electricity can be generated by PV cells on the condition. For our estimation, the following values were utilized. The total area of the building's roofs in Yoshida campus is 724,565 m^2, the energy consumed in Yoshida campus, Kyoto University at 2008 is about 128,000,000 kW/year, which corresponding to the cost of about 30,000,000,000 yen/year. The amount of the above energy consumption is equivalent to the CO_2 emission of about 97,300 tons/year. Polycrystalline silicon PV cell is widely used at the present, were assumed to be employed. The specifications of this type are listed in table 1. It is reported that the annual power production by a 3kW PV cell in Kansai region is 3,424kWh/year, this value includes the effect of latitude of Japan and change of sunshine conditions.

Table1 PV cell specifications

Item	Specification
Type	ND-191AV (Sharp Corp.)
Size	1318x1004x46 mm^3
Energy conversion efficiency	14,4 %
Maximum power	191 W
Price	72,470 yen
Weight	16 kg
Life time	25 year

If the PV cells are placed on the roofs without inclination, the electricity generated by PV cells is expected to be around 110,000,000 kWh/year. If the PV cells are placed with appropriately inclined at angle of 50°, the expected electricity generation increases up to 170,000,000 kWh/year. These amounts of electricity correspond to about 85% and 135% of the annual energy consumed in 2008 in Yoshida campus, respectively. Initial cost for the system is around 500,000,000 yen. However, the total weight enabled on the buildings' roof is around 10000 Kg. As a result, the expected reduction percentage of CO_2 by using PV cell system was around 30%.

2-1-2 Biomass

Biomass is a plant-derived energy source. There are various types of biomass fuel such as wood (from trees), straw, poultry litter, food wastes and a special grass. They have charged energy during their growth which is produced by a process called photosynthesis that converts carbon dioxide into organic compounds, especially carbohydrates, using the energy from sunlight.

The most important advantage of biomass is called "carbon neutral cycle"; though carbon dioxide (a greenhouse gas partly responsible for climate change) is released into the atmosphere when the plant is burned, the amount of carbon dioxide released is not more than the amount absorbed by the plant when it is growing up. A simple illustration of how the cycle works is shown in the Fig.1.

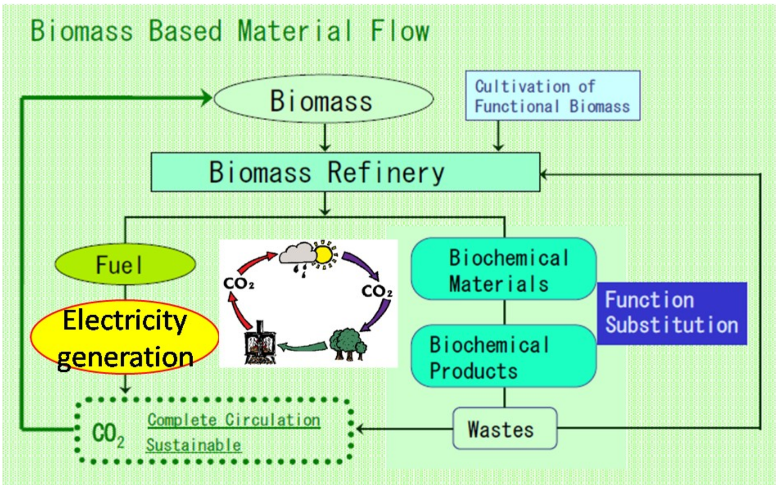


Fig.1 Biomass based Material Flow

The expected energy generated, cost and reduction of CO_2 by using a biomass power plant which was assumed to be constructed in Yoshida campus as below:

- Electricity generated by biomass: around 19,200,000kWh.
- Cost of electricity generated by biomass: 11yen/kWh
- The total cost for the generated electricity: around 211,200,000 yen.
- 15% of electricity consumed in Yoshida campus may be produced by using the biomass system.

Table 2 shows the estimation results of the biomass plant constructed in Yoshida campus.

Table 2 PV cell specifications

Item	Specification
Size	20 MW
Biomass use (green ton/year)	200,000-300,000
Capital cost (million yen)	4.000
Operation cost (million yen)	400-1,000
Efficiency (%)	18-24%

2-1-3 Fuel cell

Fuel cell is electric power generation system by using a chemical reaction between oxygen in air and hydrogen produced form LP (Liquefied Petroleum) gas or urban gas as below that is inverse reaction of electrolysis of water.

$$O_2\,(\text{air}) + 2H_2 \rightarrow H_2O$$

Because thermal plants are ordinary established at the place far from where the energy is used, mostly home, about 60% of generated energy, almost of which is thermal energy, is exhausted and 5% is lost at the electric power transmission. On the other hand, fuel cell is one of on-site electric power generation systems which enable us to use thermal energy. As a result, although the fuel is equally fossil fuel as thermal power plant, the energy utilization efficiency of fuel cell is up to 70～80%, twice as much as the one by conventional system.

Table3 Specs of merchandised fuel cell

Item	Specification
Rated power output	700W
Power generation efficiency	More than 36% (urban gas)
Exhaust heat recovery efficiency	More than 50%
Installation area	2.7 m^2
Life time	10 year
Utility charges	28.7 yen/kWh
Initial cost	2,650,000yen

Osaka gas has started service to supply fuel cells with Toshiba from 2009 / 6. Main specs are listed in Table.3. Using these data, we estimated the amount of CO_2 reduction and energy cost etc. by the introduction of fuel cells. Several fuel cells were assumed to be equipped in each building in Yoshida campus. The results are listed in Table.4. We assumed the situation that several fuel cells are equipped in each building in Yoshida campus.

Table4 Estimated results for CO_2 reduction by introduction of fuel cells

	Amount	Ratio vs. 2008
Electricity	14.892MW/year	0.01%
Cost	71.9 yen/kWh	4 times higher
CO_2 emission	3,600kg/year	40% less than conventional system
Reduction	2,700kg/year	0.003%

2-1-4 Discussion

Based on the above results, we may be able to become optimistic in the sense that the closed zero carbon energy system should be established in Yoshida campus because totally, up to 40% amount of CO_2 emission in the campus in 2008 is possibly reduced by introduction of solar PV cells, a biomass plant and fuel cells. However, many technological problems are still lying. One big problem is the cost. Energy costs by using each energy source are compared in Fig.2.

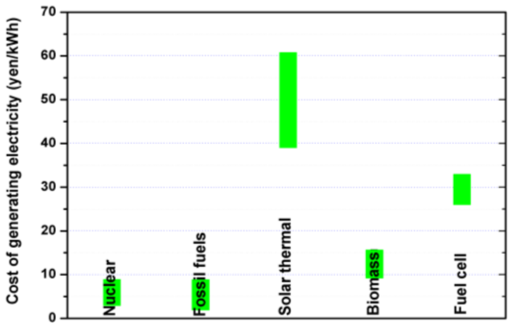


Fig.2 Energy costs of some kinds of energy sources

The energy cost of energy sources proposed above is much higher than that of conventional energy sources (fossil fuels). The high cost is well-known to be a main reason of the hesitation for introduction of new energy sources. Since nuclear energy is cheap and emits little CO_2, Japanese government promotes it, though dangerous impression of citizens hasn't been casted aside.

Therefore, many efforts must be devoted to make technological breakthroughs for implementation. Here, we briefly enumerated problems and solutions on each subject.

- For solar PV cells, silicon is the most favorable material to accomplish the sustainable development of the human beings for the following reasons. It is the second most abundant element in the earth's crust. In addition, silicon is nontoxic and stable as a material. However, the problems especially on silicon PV cells are the high production cost, uneven distribution of high-purity raw materials (silica stone), low energy conversion efficiency, degradation, weathering, and necessity of cleaning, etc. The production cost may be reduced by introducing electrochemical processes. The energy conversion efficiency may be developed by utilizing quantum dots. The cost and the labor to clean the surface of the PV cells may be saved by using TiO_2 photocatalytic glass.

- For biomass plants, one of the most serious problems is increase of food cost caused because the fuel of biomass electric generation is kinds of food plants like wheat and corn. However, countries like Brazil where there are abundant wheat production have succeeded to popularize bio-diesel vehicles. Recently, algae are eagerly studied to be adopted as an alternative fuel.
- For fuel cells, Pt catalyst in oxygen electrode (anode) has still remained expensive. Many efforts to find alternative catalyst alloys or to reduce its amount are now conducted. The fuel, H_2 gas, is proposed to be produced by the electrolysis of water by using solar energy or exhaust heat from nuclear reactor. The problem of transportation of H2 gas seems to be solved by using urban gas pipeline network.

2-2 Energy consumption = Kyoto university report

Concerning to energy consumption side, Kyoto University has published an estimation report[1] on its web site. In the report, some individual activities for energy conservation are proposed. Examples of them are listed below.

- Turning off PC when people go home
- Turning off lights in lunch time
- Setting temperature of air conditioner to soft condition (28℃ in summer and 20℃ in winter)

The report says that by these efforts, 8% amount of CO_2 emission in Yoshida campus is possibly reduced. Please find additional information about this estimation on the web site. We adopted this result for following discussions.

3. Questionnaire survey

3-1 Method

A questionnaire survey was conducted from January 13th to 20th, 2010. Number of respondents of the questionnaire survey was 96. 72 of the respondents were graduate school students and the rest were staffs. All respondents work or study in Yoshida campus. Number of respondents (sample size) was decided considering parent population, 95% confidence interval, and detailed procedure of calculation of sample size is shown in appendix. The questionnaire sheet includes nine question items and each question item was answered on 4-point scale (For example, 1=”No” to 4=”Yes”) without some exceptions. Both Japanese and English versions of question sheets were prepared, and they are shown in appendix.

Departments where the respondents work or study are shown in Fig.3. However, the respondents include not only students in energy science but also ones in medical, low and humanities to avoid bias answer. Nationalities of respondents are shown in Fig. 4.

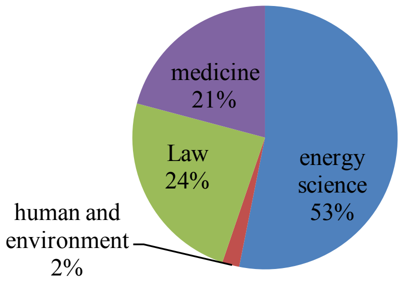


Fig.3 Department of respondents

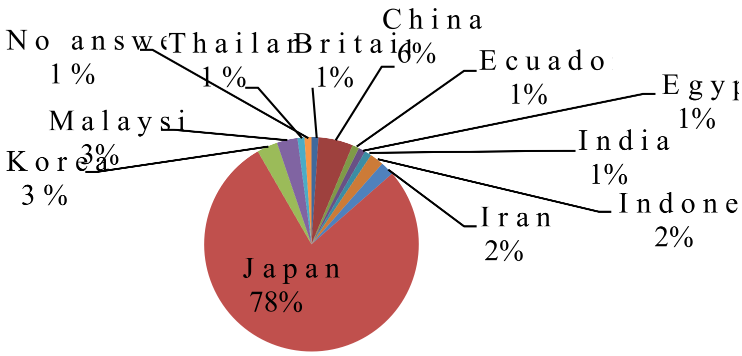


Fig.4 Nationality of respondents

3-2 General Consciousness

Based on the questionnaire survey result, more than half of respondents, i.e. around 60%, considered that the climate change is dangerous. On the other hand, around 13% of respondents thought that climate change is not dangerous at all. The rest of respondents (27%) still considered that climate change has a dangerous effect although the effect is not too dangerous.

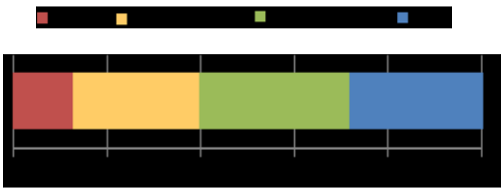


Fig.5 Q&A results about perception of respondents on the danger of global warming

With regard to the opinion of respondents on the Kyoto Protocol as an effort to reduce CO_2 emissions, over 60% of them agreed with the protocol. Moreover, around 30% respondents showed a little agreement with the efforts and the scheme. On the other hand, there were around 5% of respondents who stated their disagreement with any efforts on CO_2 emission reduction and the Kyoto Protocol scheme.

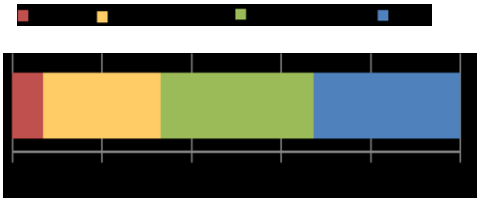


Fig.6 Q&A results about perception of respondents on the effort to reduce CO_2

3-3 Energy supply side

We concluded in the section 2.1 that introduction of new energy sources, such as solar cells, fuel cells and a biomass plant, possibly reduce not a little amount of CO_2 emission in Yoshida campus though energy cost would be required to be increased. Part of this cost is considered to be charged on students and staffs in the campus. In this reason, interests and motivations of them are needed to be studied, to know a feasibility of our assumption to reduce CO_2 emission from energy supply side.

In this section, we will report the results of questionnaire survey. Some questions concerning to energy supply side were conducted with showing our estimated result above.

3-3-1 Applicability of new energy sources into Yoshida campus

There are many new energy sources proposed and some of them seems to be applicable to be introduced into Yoshida campus and others do not. By questionnaire survey, students and staffs were checked their knowledge about new energy sources and thoughts about their applicability.

Solar cells were the most applicable energy source, they think as shown in Fig.7. In addition, someone who knew well about biomass and fuel cell statistically tended to answer that they are applicable. These results almost supported our choice for the estimation in section 2.1.

Geothermal energy was the least one to be known though in Japan (but not in Yoshida campus), geothermal is one of the expectable energy sources because Japanese islands locate in the pacific ring of fire; there are many volcanoes and hot springs in Japan. As the case of biomass and fuel cell, additional information would possibly improve students' thinking about the applicability of geothermal energy.

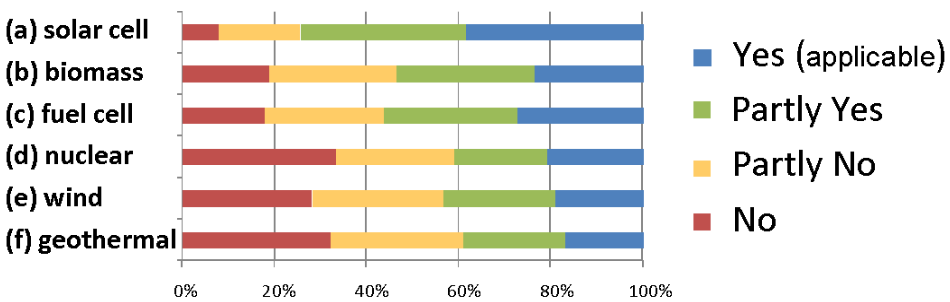


Fig.7 Q&A results about applicability of new energy sources in the campus

3-3-2 Acceptability of tuition increase

At first, please look at Fig. 8.

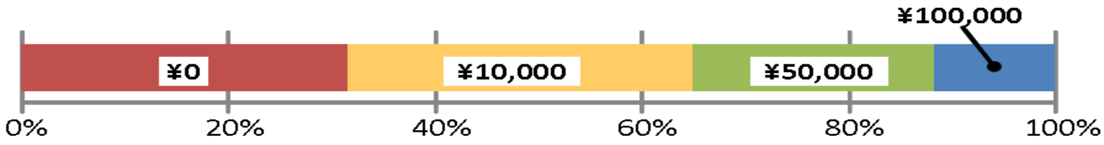


Fig.8 Acceptable tuition increase by introduction of new energy sources

Sadly, over 30% respondents disagree with tuition increase by introduction of new energy sources and 40% was little willing to pay (10,000yen) even though most of energy in Yoshida campus is consumed by them.

However, some hopes are still remained because people who are interested in the issue of climate change and agree with efforts along Kyoto Protocol (see section 3.2) tended to accept tuition increase. Kyoto University is an educational organization, which means it has advantage to get chances to improve students' minds toward global issues.

Though our questionnaire survey revealed that tuition fee increase is not the best-applied motivation policy for CO_2 reduction from energy supply side, the cost (=responsibility) should be shared. We considered that another simple way is to charge the cost on laboratories/working units depending on their amount of power use.

3-4 Energy consumption

As already mentioned in section2-2, pro-environmental efforts can save 8 % of energy consumption which is related to the reduction of CO_2 emission. The importance of energy conservation is no less than the importance of the energy supply side. In this regard, part of the questionnaire survey was conducted to check individual behavior pattern of energy consumption in Yoshida campus.

At first, it was started to investigate how many people have got the knowledge about the Kyoto university report. The result shows that about half of respondents answered "Yes".

Next, in order to investigate individual behavior pattern, survey items were categorized into three as shown in Fig. 9. About 50 % have done efforts to save energy consumption. Respondents who already knew the Kyoto university report usually do act environmental-friendly acts. This result indicates that Kyoto university report had a impact on people's mind.

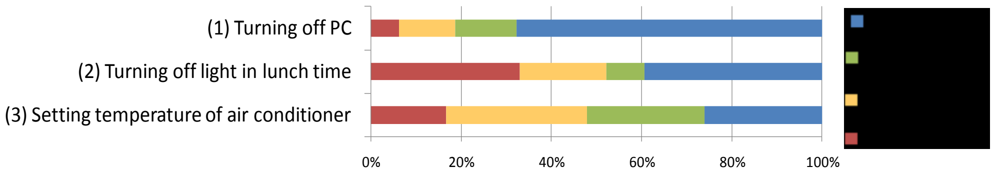
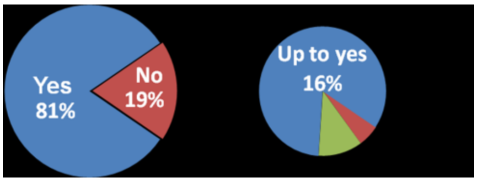


Fig. 9 Individual life pattern to save energy

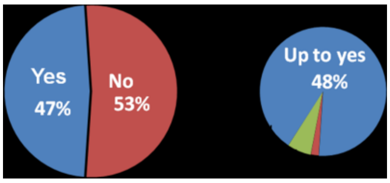
Fig. 10 shows the result of willingness of respondents to start or continue the efforts to save energy. Over 65 % of respondents will try to save energy consumption from now.

Fig. 10 The willingness of saving energy

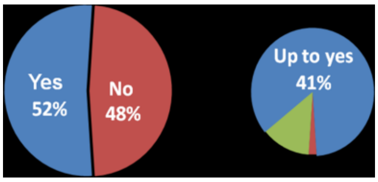
The interesting thing is that people who gave answer "No" for the question of Fig. 9 (people who hasn't begun individual efforts) tended to show willingness to change their mind to save energy as shown in Fig. 11.



(a) Turning off the pc



(b) Turning off light in lunch time



(c) Setting temperature of air condition

Fig. 11 The change of people's consciousness before and after questionnaire survey

These results are a good indication that people could start the activity for CO_2 reduction even through this kind of simple questionnaire activity. Therefore, it can be suggested that triggers such as environment policies or educations are more needed to be known by people in Yoshida campus.

4. Conclusion and Recommendation

Based on the group work, some conclusions can be drawn. Firstly, our calculation showed that there is a likelihood of CO_2 emission reduction in Yoshida campus up to 40% of the amount in 2008 from energy supply side. This reduction can be obtained by introduction of solar photovoltaic cells, fuel cells and a biomass power plant. Considering reported value of CO_2 reduction from energy consumption side, the amount of CO_2 emission in Yoshida campus would possibly decreases half. Secondly, based on the questionnaire survey, most respondents thought the inapplicability of nuclear, geothermal and wind power plants in Yoshida Campus. Furthermore, the questionnaire survey result showed that increment in tuition fee is not the most acceptable option in compensating the cost for introducing the alternative energy sources. Lastly, more participation in energy conservation by turning off unused electronic appliances in Yoshida Campus was likely to be increased if some more efforts are put on the dissemination of the Kyoto University Report.

As for the recommendations, in order to introduce alternative energy sources into Yoshida campus successfully, some important measures should be taken into account in order to increase the sense of crisis upon global warming and to share the responsibility upon the issue. First recommendation is to stimulate energy conservation amongst laboratories in the campus by asking for cost compensation for any laboratories that use electricity above the average use. The second recommendation is to promote more the energy conservation efforts that can be carried out by all staff and students in Yoshida Campus. The more people know about the Kyoto University's acts about energy use and conservation, we would gain the more support from the people. Prior introduction of new energy sources would take the role as a trigger to wake their interests.

5. Reference

[1] Kyoto university pro-environmental behavior manual,
http://eprc.kyoto-u.ac.jp/old/report/manual.pdf

Appendix

Deciding procedure of sample size

In case of finite population, required sample size is calculated as below[1].

$$n \geq \frac{N}{\frac{e^2}{Z^2}\frac{N-1}{P(1-P)}+1}$$

Required sample size: n

Size of parent population: N

Maximum error: e

Normal distribution 95% point: Z

Predicted rate of parent population: P

Parent population was 11,553 people who were graduate school students and staff in Yoshida campus, which was estimated from data in Kyoto university's website[2]. Maximum error was set to 10%. Normal distribution 95% point is 1.96[1]. Predicted rate of parent population was set to 0.5, because there was no information about it.

Calculation realized that required sample size was equal to or more than 96.3.

Kendall's rank correlation matrix of each question in the questionnaire

Table 1 and table 2 show Kendall's rank correlation matrix.

Table 1

			knowledge						applicability					
	Q1	Q2	Q3 (a)	Q3 (b)	Q3 (c)	Q3 (d)	Q3 (e)	Q3 (f)	Q3 (a)	Q3 (b)	Q3 (c)	Q3 (d)	Q3 (e)	Q3 (f)
Q1 Climate change is dangerous	1.0	0.1	-0.1	0.1	0.0	0.3	-0.1	-0.1	-0.1	0.0	-0.1	0.0	-0.2	0.0
Q2 Agreement with CO_2 reducion		1.0	0.1	0.2	-0.1	0.1	0.1	0.1	0.1	-0.1	0.1	0.0	0.3	0.1
Q3(a) knowledge about solar cell			1.0	0.3	0.1	0.0	0.4	0.1	0.6	-0.2	0.5	-0.1	0.4	-0.1
Q3(b) knowledge about biomass			**	1.0	0.1	0.2	0.2	0.4	0.1	-0.1	0.3	0.1	0.3	0.0
Q3(c) knowledge about fuel cell					1.0	0.3	0.4	0.0	0.1	0.1	0.1	0.0	0.3	-0.1
Q3(d) knowledge about nuclear	**			*	**	1.0	0.1	0.3	0.0	0.2	0.0	0.1	0.1	0.0
Q3(e) knowledge about wind			**		**		1.0	0.3	0.3	0.0	0.4	0.0	0.4	0.0
Q3(f) knowledge about geothermal				**		**	**	1.0	0.1	0.1	0.2	0.3	0.3	0.1
Q3(a) applicability of solar cell			**				**		1.0	-0.1	0.5	0.1	0.3	-0.2
Q3(b) applicability of biomass			*							1.0	-0.1	0.4	0.0	0.3
Q3(c) applicability of fuel cell			**	**			**	*	**		1.0	0.0	0.6	-0.1
Q3(d) applicability of nuclear								**		**		1.0	0.1	0.3
Q3(e) applicability of wind		**	**	**	**		**	**	**		**		1.0	0.0
Q3(f) applicability of geothermal										**		**		1.0

Upper half show correlation coefficients, lower half show their significance(* : p<0.05, ** : p<0.01)

Table 2

	Q1	Q2	Q4	Q5	Q6	Q7 (1)	Q7 (2)	Q7 (3)	Q8	Q9
Q1 Climate change is dangerous	1.0	0.1	0.2	0.0	0.0	0.0	0.1	0.0	0.3	-0.1
Q2 Agreement with CO_2 reducion		1.0	0.1	0.2	0.1	0.1	0.3	0.1	0.4	-0.2
Q4 trust for our estimation			1.0	0.2	-0.1	0.1	0.1	0.1	0.1	-0.1
Q5 acceptable tuition increase		*	*	1.0	0.1	0.0	0.0	0.0	0.1	-0.1
Q6 knowledge about Kyoto university's report					1.0	0.2	0.0	-0.1	0.0	0.0
Q7(1) Turning off PC					*	1.0	0.1	0.3	0.4	-0.2
Q7(2) Turning off light in lunch time		**					1.0	0.3	0.3	0.0
Q7(3) Setting temperature of air conditioner						**	**	1.0	0.4	-0.1
Q8 Willingness to effort	**	**				**	**	**	1.0	-0.2
Q9 Acceptable policy(1=pay,2=get)						*			*	1.0

Upper half show correlation coefficients, lower half show their significance(* : p<0.05, ** : p<0.01)

Calculation of confidence interval

From the answer to the questionnaire survey, confidence interval was calculated. The procedure is as below[1].

$$\left(\bar{x} - Z\sqrt{\frac{\sigma_0^2}{n}}, \bar{x} + Z\sqrt{\frac{\sigma_0^2}{n}}\right)$$

Normal distribution 95% point: Z

Standard deviation of parent population: σ_0

Sample average: $\bar{x}$

Sample size: n

Standard deviation of parent population was simply assumed to be equal to sample standard deviation regarding sample size was sufficiently large. Calculated confidence interval is shown in table 3. Table 3 shows that confidence interval of answer ratios of each option in each question item was not higher than 0.1. If confidence interval is considered, there will be some reverse at rank between answer ratios of each option, however, there will be not so big change in answer trend, such as Answer=1 and answer=4 was reversed. Therefore, in this paper, the answer of the questionnaire survey was used and analyzed.

Table 3 average, standard deviation(s.d.) and confidence interval

Question items	Average	s.d.	Average ±95% confidence interval	Ratio±95% confidence interval			
				Answer =1	Answer =2	Answer =3	Answer =4
Q1 Climate change is dangerous	2.96	0.82	2.96±0.16	0.04±0.04	0.23±0.08	0.45±0.1	0.27±0.09
Q2 Agreement with CO_2 reduction	3.15	0.75	3.15±0.15	0.01±0.02	0.18±0.08	0.44±0.1	0.34±0.1
Q3(a) knowledge about solar cell	3.38	0.73	3.38±0.15	0.03±0.03	0.05±0.04	0.43±0.1	0.49±0.1
Q3(a) applicability of solar cell	3.56	0.65	3.56±0.13	0.01±0.02	0.05±0.04	0.29±0.09	0.63±0.1
Q3(b) knowledge about biomass	2.66	1.00	2.66±0.2	0.15±0.07	0.29±0.09	0.32±0.09	0.24±0.09
Q3(b) applicability of biomass	2.67	0.91	2.67±0.18	0.1±0.06	0.27±0.09	0.36±0.1	0.18±0.08
Q3(c) knowledge about fuel cell	2.84	0.98	2.84±0.2	0.11±0.06	0.22±0.08	0.36±0.1	0.29±0.09
Q3(c) applicability of fuel cell	2.84	0.96	2.84±0.19	0.09±0.06	0.23±0.08	0.32±0.09	0.27±0.09
Q3(d) knowledge about nuclear	3.25	0.85	3.25±0.17	0.05±0.04	0.11±0.06	0.36±0.1	0.47±0.1
Q3(d) applicability of nuclear	1.69	1.03	1.69±0.21	0.6±0.1	0.17±0.07	0.09±0.06	0.1±0.06
Q3(e) knowledge about wind	3.04	0.84	3.04±0.17	0.04±0.04	0.21±0.08	0.42±0.1	0.33±0.09
Q3(e) applicability of wind	2.11	1.00	2.11±0.2	0.32±0.09	0.33±0.09	0.2±0.08	0.11±0.06
Q3(f) knowledge about geothermal	2.48	0.90	2.48±0.18	0.14±0.07	0.39±0.1	0.32±0.09	0.15±0.07
Q3(f) applicability of geothermal	1.80	0.96	1.8±0.19	0.47±0.1	0.26±0.09	0.14±0.07	0.07±0.05
Q4 trust for our estimation	2.57	0.85	2.57±0.17	0.13±0.07	0.26±0.09	0.46±0.1	0.1±0.06
Q5 acceptable tuition increase	1.86	0.77	1.86±0.15	0.34±0.1	0.48±0.1	0.15±0.07	0.03±0.03
Q6 knowledge about Kyoto university's report	1.31	0.46	1.31±0.09	0.69±0.09	0.3±0.09		
Q7(1) Turning off PC	3.43	0.93	3.43±0.19	0.06±0.05	0.13±0.07	0.14±0.07	0.68±0.09
Q7(2) Turning off light in lunch time	2.54	1.30	2.54±0.26	0.32±0.09	0.19±0.08	0.08±0.06	0.39±0.1
Q7(3) Setting temperature of air conditioner	2.61	1.04	2.61±0.21	0.17±0.07	0.31±0.09	0.26±0.09	0.26±0.09
Q8 Willingness to effort	3.21	0.73	3.21±0.15	0.02±0.03	0.13±0.07	0.48±0.1	0.38±0.1
Q9 Acceptable policy(1=pay,2=get)	1.68	0.53	1.68±0.11	0.34±0.1	0.65±0.1		

Reference

[1] Nagata Y. (2003) How to decide sample size, Asakura shoten,

[2] Kyoto university website <-http://www.kyoto-u.ac.jp/ja/profile/intro/data/index.htm/-> (Reference in December 2009)

[English version of questionnaire sheet]

Questionnaire survey about reduction of CO_2 emission in Yoshida campus

Graduate school of energy science
GCOE research group B

Department ( )
Grade/Affiliation ( )
Nationality ( )

Please mark your answer in four point scale with some exceptions.

Q1. In your opinion, is recent climate change dangerous?

Not at all. — Yes, very dangerous.

Q2. Do you agree with efforts to reduce CO_2 emission followed by Kyoto protocol?

Disagree — Agree

Q3. Do you know about new energy sources below?
And do you think that they are applicable in Yoshida campus?

	Not know at all — Know very well	Not applicable at all — Applicable
(a)Solar cell		
(b)Biomass		
(c)Fuel cell		
(d)Nuclear		
(e)Wind		
(f)Geothermal		

*Please tell us your idea for other energy source to reduce CO_2 emission in Yoshida campus.

Our calculation shows that introduction of solar cells, a biomass plant and fuel cells possibly decrease 40% of CO_2 emission in 2008 in Yoshida campus. Nevertheless, the introduction would increase energy cost.

Q4. Do you trust this estimation of the effect of introduction of new energy sources?

Not trust — Trust

Q5. If introduction of new energy sources increases tuition fee, how much increase of tuition fee will be acceptable for you? Please choose from four options.

(a)0 yen (b)10,000 yen (c)50,000 yen (d)100,000 yen

Kyoto University's report says that pro-environmental efforts listed in Q7 can save 8% of energy consumption[1] which will also contribute to the reduction of CO2 emission. And Kyoto University promotes the efforts on its website.

[1] Kyoto university pro-environmental behavior manual <-http://eprc.kyoto-u.ac.jp/old/report/manual.pdf->

Q6. Do you know the Kyoto university's report or the promotion of efforts?

(a)I don't know (b)I know

Q7. Do you usually do following efforts?

Not at all — Always

(1) Turn off PC when you come home.

(2)Turn off light at lunch time.

(3)Set temperature of air conditioner to 28℃in summer and to 20℃in winter.

Q8. After you know how worthwhile these individual efforts are, will you do them from now?

Will not do — I will do

Q9. When Kyoto University introduces a policy to promote efforts for CO_2 reduction, which is the most acceptable policy? Please choose answer (a) or (b).

(a) A laboratory/working unit whose energy consumption is above the standard has to pay some money

(b) A laboratory/working unit whose energy consumption is below the standard gets some money

This is the end of the questionnaire.

Thank you very much for your time and your participation.

[Japanese version of Questionnaire sheet]

吉田キャンパスにおける CO_2 排出削減についてのアンケート

エネルギー科学研究科 GCOE グループ B

所属学部等（　　　　　　　）

学年/役職（　　　　　　　）

国籍　　（　　　　　　　）

このアンケートには 4 段階でお答え下さい（一部のぞく）。

Q1. 近年の気候変動は危険なものだと思いますか？

全く危険だと思わない　　　　　　　　　　とても危険だと思う

Q2. 京都議定書に従った CO_2 削減のための取り組みに賛成しますか？

反対　　　　　　　　　　賛成

Q3. 下記の新エネルギーを知っていますか?

また、これらの新エネルギーは吉田キャンパスに適用可能だと思いますか？

	全く知らない → よく知っている	適用不可能 → 適用可能
(a)太陽電池		
(b)バイオマス		
(c)燃料電池		
(d)原子力		
(e)風力		
(f)地熱		

*他に吉田キャンパスの CO_2 排出削減に役立つ他のエネルギー源のアイディアがありましたら、お書き下さい（自由回答）。

私たちの試算の結果、太陽電池、バイオマス、燃料電池の導入によって、吉田キャンパスの CO_2 排出を 2008 年比で 40%削減可能なことが分かりました。但し、この導入によってエネルギーの使用コストが上昇します。

Q4. 上記の新エネルギー導入による CO_2 排出の削減効果に関する試算結果を信頼しますか？

信頼しない ├──┼──┼──┤ 信頼する

Q5. もし、新エネルギーの導入によって学費が増額になるとしたら、いくらまでの増額なら受け入れ可能ですか？4 つの中から選択してください。

(a)0円　(b)1万円　(c)5万円　(d)10万円

> 京都大学の報告書[1]によると、Q7 に挙げるような環境にやさしい行動によって 8%のエネルギー消費を節約でき、CO_2 排出も削減できます。京都大学は、ホームページでそうした行動を促進する取り組みを行っています。

[1] 京都大学環境配慮行動マニュアル <-http://eprc.kyoto-u.ac.jp/old/report/manual.pdf->

Q6. 上記の京都大学の報告書や、京都大学の取り組みを知っていますか？

(a)知らない　(b)知っている

Q7. 日常的に以下の環境にやさしい行動をとっていますか？

	全く行っていない ├──┼──┼──┤ 常に行っている
(1) 家に帰るときパソコンの電源を切る	├──┼──┼──┤
(2)昼休みに照明を切る	├──┼──┼──┤
(3)エアコンの設定温度を、夏は 28℃、冬は 20℃にする。	├──┼──┼──┤

Q8. 環境にやさしい行動の効果を知ったことで、今後そのような行動をとると思いますか？

行わないと思う ├──┼──┼──┤ 行うと思う

Q9. もし京都大学が CO_2 排出削減のためにある制度を導入するとしたら、どのような制度がもっとも受け入れ可能ですか？(a)か(b)から選んでください。

> (a)エネルギー消費がそれぞれの基準以上の研究室/部局は罰金を払わなくてはならない。
> (b) エネルギー消費がそれぞれの基準以下の研究室/部局は報奨金を得ることができる。

以上でアンケートは終了です。
ご協力ありがとうございました。