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# Cost-benefit Analysis of Small Hydroelectric Generation Project utilizing Resident Volunteers

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**Abstract:** A small hydroelectric generation project utilizing resident volunteers is proposed in this study, and the project is evaluated economically by using cost-benefit analysis. The WTW function which is used to measure social benefit of the project was estimated by using the conjoint analysis in our previous study. The project has a feature of utilizing resident volunteers in order to reduce its costs. Effect of such feature is expected to vary greatly depending on the work ability of resident volunteers. In this study, the work ability of resident volunteers is defined as the rate of substitution for regular workers. By changing the rate of substitution for each unit value of reward, we have analyzed cost-benefit ratio of the project utilizing resident volunteers. As a result, even if a small hydroelectric generation project which aims to both global warming adaptation and regional economic revitalization is deficit, a countermeasure which can be expected economic efficiency for such project by utilizing resident volunteers has been found.

**JEL classification:** Q42, Q51, R13

**Keywords:** *cost-benefit analysis, resident volunteers, small hydroelectric generation, willingness to work*

## 1. Introduction

Renewable energy projects well-known as possible ways to reduce greenhouse gas emissions are projects for mitigation of global warming. Such projects are currently being discussed by many local governments in Japan. If such projects are enacted, people will be asked to contribute a sizeable proportion of the project's implementation and upkeep. In many local cities in Japan, problems such as falling birth rate, aging, and stagnation of regional economy are important subjects, and mitigation projects do not have high priority. In addition, despite abundance of natural resources such as forests, wind, water and sunlight, local cities may face financial problems in funding projects that utilize these resources. Hence, in order to undertake aptly renewable energy projects in such local areas, not only environmental effects,

but also regional economies and social effects should be identified. Some cities in foreign countries provided successful cases regarding the above issues; they conducted low-carbon measures and revived regional economies in stagnation areas by utilizing those resources. Japanese government should consider renewable energy projects, which are fit for Japanese society, with reference to such cases.

If a project has positive effects on regional economies such as reducing leakage of regional capital by cuts in use of fossil fuel even if the short-term effect is lower, it will be a rational decision to support public funds upon careful evaluation of environmental and regional economic effects. Also, it is important to invest limited public funds in the most suitable project. Taking these matters into account, our discussion now turns to "which projects and how much public funds and human resources should be supported". For this reason, the quantitative evaluation model is necessary in order to determine policies regarding our discussion.

Through evaluating impacts of low-carbon measures on regional economies, it is possible to provide materials for rational policy-making. Accumulation of knowledge is also needed for such materials, but accumulation of such materials regarding studies in environmental economics is not enough. Moreover, to build consensus among residents is important, when undertaking a project for introduction of renewable energy using common resources. And, through introducing participation of residents, projects which build consensus easier should be considered.

The purpose of this study is to provide knowledge for policy-making of local government which intends to advance renewable energy project, which aims to both global warming adaptation and regional economic revitalization. As an example, we propose a small hydroelectric generation project utilizing resident volunteers and evaluate it economically by using cost-benefit analysis.

## **2. Current status of renewable energy**

In Japan, domestic energy generation by renewable source is increasing steadily, and its percentage share of total power generation is also increasing steadily from 2.5% (FY2000) to 4.7% (FY2013). In particular, the increase after the Fukushima Daiichi Nuclear Disaster in 2011 is significant. According to Figures 1 and 2, the proportion of nuclear power of overall domestic energy generation in FY2009, before the disaster, was 25.1%, but it was reduced to 0.8% in FY2013, after the disaster. Instead, the conventional thermal (coal, natural gas, oil, etc.) power was increased from 65.4% to 88.4%. Since the amount of carbon dioxide emissions is expected to increase significantly, the Japanese government established the "Feed-in Tariffs" of electricity, and actively promoted introduction of renewable energy into companies and households. As a result, in particular, the solar photovoltaic power generation

systems were introduced one after another, and its proportion of overall domestic energy generation was increased from 0.3% (FY2009) to 1.3% (FY2013).

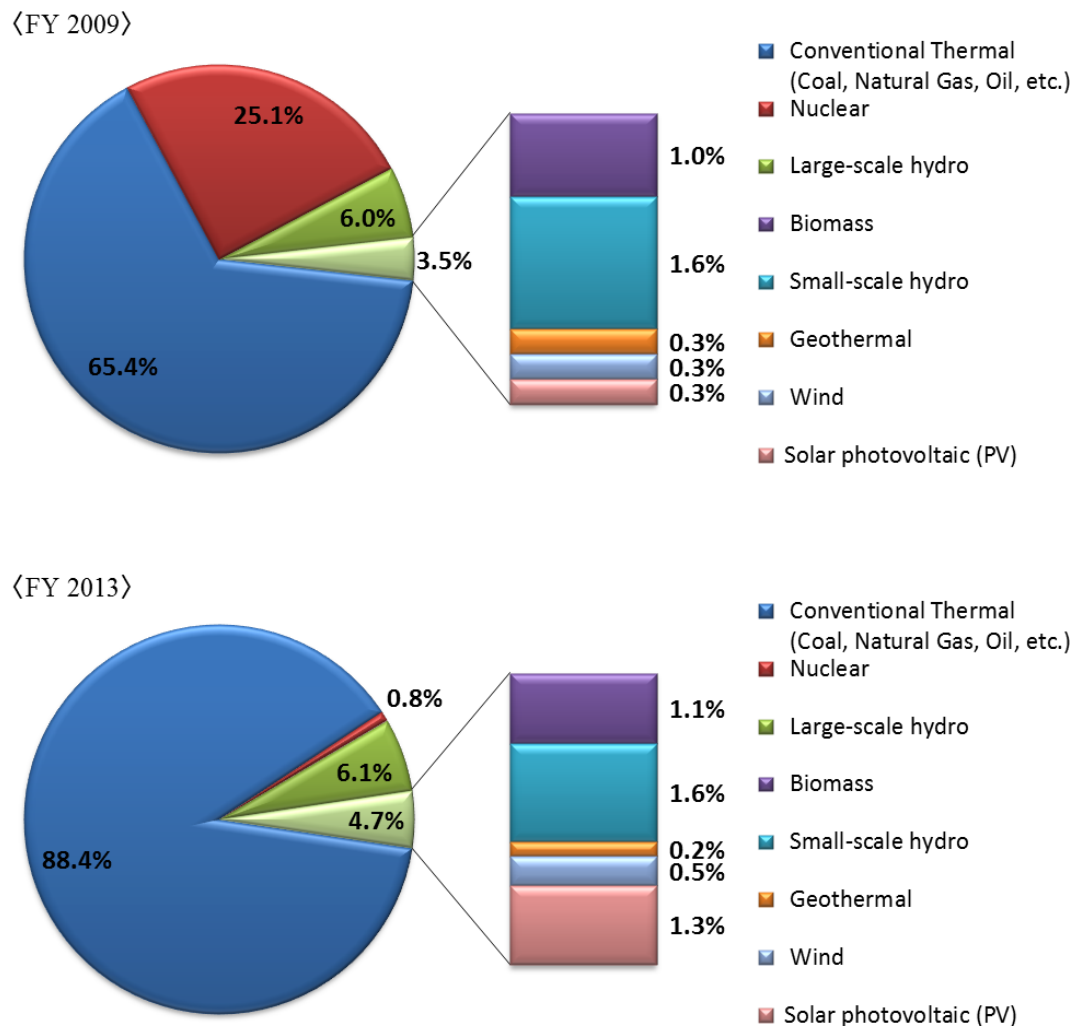


Figure 1 (upper) and 2 (lower): Proportions of overall domestic energy generation by source  
Source: Japan for Sustainability, 2011 and 2015

Renewable energy projects are well-known as projects for mitigation of global warming. After the Great East Japan Disaster, such projects are also noteworthy possibilities for adaptation to global warming, because they can provide various energy sources and locally produce energy for local consumption. So, such projects are currently being discussed by many Japanese local governments. However, in Japan, problems such as a falling birth rate, aging, and stagnation of the regional economy are important subjects, so mitigation and adaptation projects do not have high priority. In addition, despite abundance of natural resources such as forests, wind, water, and sunlight, local cities can face financial problems in funding projects that utilize these resources.

On the other hand, development of renewable energy projects utilizing such natural resources can provide a big boost to revitalizing local economies. Furthermore, through such a type of project with citizen participation, local residents will become both more environmentally aware and active, and we can expect that the quality of the semi-public service will improve and local residents will have higher levels of satisfaction. Accordingly, we propose a small hydroelectric generation project with citizen participation that includes not only citizen donations to the project but also cooperation in some activities such as cleaning and patrols, and evaluate the project economically.

### **3. A small hydroelectric generation project**

Photos 1 and 2 indicate installation examples of micro hydroelectric generator in Itoshiro, Japan. Itoshiro is a small village in Gifu Prefecture, which is located at a central part of Japan. Its population was about 1,200 in 1964, but it has dropped to less than one fourth, that is about 270 in 2015. Photo 1 is a spiral water turbine for run-of-river power generation which was installed in June 2009. This water turbine generates 0.8 kilowatts of power for a single household, but has a head of only 50 centimeters. Photo 2 is another water wheel was installed in June 2011. This water wheel generated 2.2 kilowatts of power, taking advantage of a head of 3 meters.



Photo 1 (left) and 2 (right): Installation examples of generator in Itoshiro, Japan

Source: photos taken by Ohno, 2014

According to Edahiro (2016), no river had flowed through the village in the past, so villagers of Itoshiro built a 3-kilometer hand-dug canal in order to divert water from a river in the Meiji period (1868-1912). This enabled them to grow rice in paddies, and they cooperated in cleaning out the agricultural canals before flooding rice fields in spring and after harvesting

rice in autumn. In the Taisho period (1912-1926), an electric power utilization union was established in the village, and water wheels powered by water diverted from a valley through these canals were used to run a timber mill in the daytime and used for residential electricity in the evening. When the condition of electricity would become poor, someone in the village would go to the water wheel to clean it out. In this way, villagers had created, operated and maintained the canals and the water wheels by themselves, and provided water and electric power for themselves. In 2007, villagers of Itoshiro decided to launch micro hydroelectric generation; not because they were interested in the energy and environment problems, but because they were afraid that their community would disappear if the situation remained unchanged.

In our previous study (Ohno, Ishikawa, Nakazawa, Nakatani, Morita, Matsumoto, and Shimoura, 2015), we proposed a following small hydroelectric generation project that aims to address both global warming adaptation and regional economic revitalization. 1) A small hydroelectric generation company can be made responsible for the development of small rivers and canals and installation of small-scale power generation facilities; such a company can be launched by resident volunteers in the region as a project to help revitalize the local economy. 2) Daily maintenance, such as dredging trash from rivers and patrolling power generation facilities, can be conducted coordinated by the local residents who installed the small hydroelectric facility. 3) Tasks requiring technical expertise such as maintenance of power generation facilities will be tendered out to a professional contractor. 4) A proportion of the project's revenue from electricity sales is allocated to the region where the small hydroelectric facility is installed.

The following points are significantly different from the solar power generation project described above. 1) A project can be expected not only to offer investment and donation opportunities in financial terms but also to elicit participation and cooperation by the community in activities such as dredging and patrolling. 2) Profits derived from the project that utilizes local resources can be returned to the region. 3) These improve the satisfaction of local residents and contribute to regional activation.

#### **4. Measurement method of benefit**

##### **(1) Specification of utility function**

In constructing an evaluation model for the small hydroelectric generation project, the individual utility function is specified as Equation (1):

$$V = a_1 X_1 + a_2 X_1 X_2 + a_3 \cdot (L - X_3) + a_4 X_3 X_4 + \left( \sum_{i=5}^n a_i X_i \right) \cdot X_3 \quad (1)$$

where  $V$ : utility level of the small hydroelectric generation project;

$X_1$ : revenue from electricity sales of the small hydroelectric generation project;  
 $X_2$ : percentage of amount to be reduced for local residents from electricity sales revenue;  
 $X_3$ : amount time of work required by local residents;  
 $X_4$ : unit value of reward to work;  
 $X_i$ : personal attributes; for example, gender, age, annual income;  
 $L$ : leisure time; and  
 $a_1, a_2, a_3, a_4, a_i$ : unknown parameters.

Each term on the right-hand side of Equation (1) means element relating to the benefit for local revenue, local public services, cooperator's available leisure time, his income, and his burden, respectively. Here, it is assumed that cooperator would participate in the work within his leisure time.

## (2) Derivation of WTW

The utility level for “agree” with implementation of a small hydroelectric generation project is described by applying values ( $X_1, X_3$ ) for the project, and the utility level for “disagree” with the project should be described by ( $X_1, X_3$ ) = (0, 0). These utility levels can be expressed as follows:

$$V_1 = (a_1 + a_2 X_2) \cdot X_1 + \left( -a_3 + a_4 X_4 + \sum_{i=5}^n a_i X_i \right) \cdot X_3 + a_3 \cdot L \quad (2)$$

$$V_0 = a_3 \cdot L \quad (3)$$

where  $V_1, V_0$ : utility levels for “agree” or “disagree” with the project.

Based on the concept of compensating variation (CV) or compensating surplus (CS), willingness to work (WTW) for the project can be defined as the amount time  $X_3$  when  $V_1 = V_0$  in Equations (2) and (3):

$$X_3 = - \frac{(a_1 + a_2 X_2) \cdot X_1}{-a_3 + a_4 X_4 + \sum_{i=5}^n a_i X_i} \equiv WTW \quad (4)$$

where  $WTW$ : willingness to work.

## (3) Definition of benefit

Because WTW is based on CV or CS, it is a kind of benefit measure. When the unit value of reward to work is equal to zero ( $X_4 = 0$ ), the work is a free voluntary activity. In this

case, the social benefit of the small hydroelectric generation project may be evaluated by the value of leisure time, where we have assumed that people would participate in the work within his leisure time in Equation (1). This benefit can be defined as social benefit of free voluntary activity for the project, and be expressed as Equation (5):

$$SB_{FV} = -\frac{(a_1 + a_2 X_2) \cdot X_1}{-a_3 + \sum_{i=5}^n a_i X_i} \times VLT \quad (5)$$

where  $SB_{FV}$ : social benefit of free voluntary activity; and  
 $VLT$ : value of leisure time.

On the other hand, when the unit value of reward to work is greater than zero ( $X_4 > 0$ ), participants of the work might have recognized its activities as a kind of part-time job. In this case, the social benefit of the small hydroelectric generation project may be evaluated by the producer surplus. This benefit can be defined as social benefit of paid voluntary activity for the project, and be expressed as Equation (6):

$$SB_{PV} = \int_0^{X_4} \left( -\frac{(a_1 + a_2 X_2) \cdot X_1}{-a_3 + a_4 X_4 + \sum_{i=5}^n a_i X_i} \right) dX_4 - \left( -\frac{(a_1 + a_2 X_2) \cdot X_1}{-a_3 + \sum_{i=5}^n a_i X_i} \right) \times (X_4 - VLT) \quad (6)$$

where  $SB_{PV}$ : social benefit of paid voluntary activity.

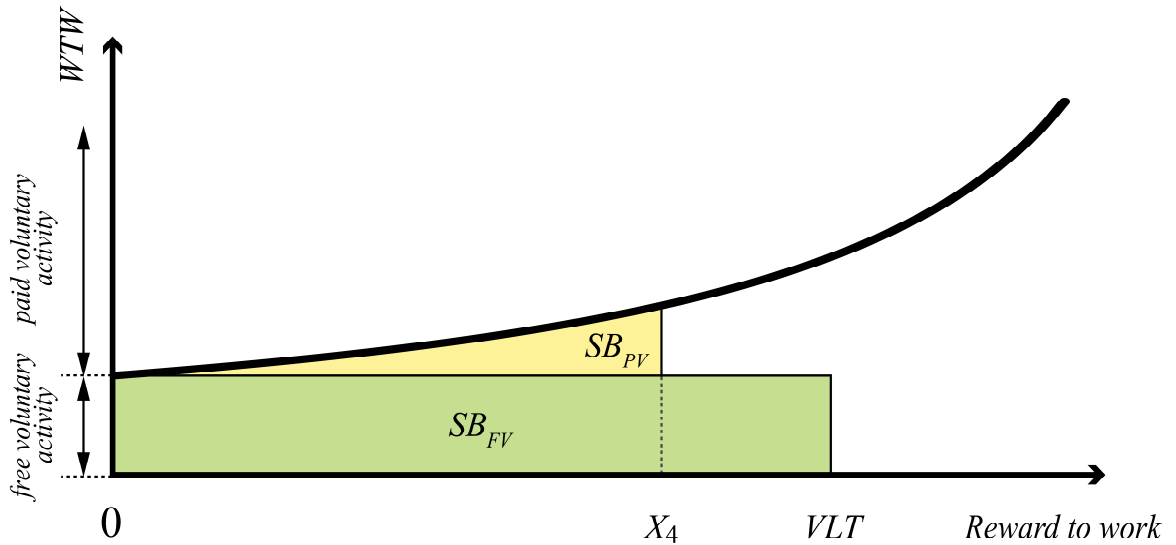


Figure 3: Social benefit of voluntary activity



$SB_{FV}$  of Equation (5) and  $SB_{PV}$  of Equation (6) can be illustrated in Figure 3. When the unit value of reward to work is equal to zero ( $X_4 = 0$ ), the social benefit ( $SB_{FV}$ ) concerning “free voluntary activity” would be generated. When the unit value of reward to work is greater than zero ( $X_4 > 0$ ), the social benefit ( $SB_{PV}$ ) concerning “paid voluntary activity”, which means producer surplus, would be generated in addition to  $SB_{FV}$ .

## 5. Estimation of utility function

### (1) Interview survey

To estimate the utility function of individuals to use for the benefit evaluation, a web-based interview survey was conducted in early October 2013, which was reported in detail in our previous study (Ohno, Mori and Matsumoto, 2015). The survey was targeted at people living in Nagano Prefecture, including Iida City, who were over 20 years old. A total of 1,096 responses were obtained, but only 1,077 were valid. The survey was titled “Attitude survey on global warming adaptation and regional economic revitalization”. The major questions of this survey were based on the binomial choice format. In each question, two hypothetical small hydroelectric generation projects, which had different profiles, were presented to the subjects, who were asked to select the more desirable one.

### (2) Estimation of parameters

When we describe people’s choice of behavior in response to the binomial choice format questions within the framework of the random utility theory, we can express an individual’s choice behavior as the following logit model:

$$P_A = \frac{\exp[\omega \cdot V_A]}{\exp[\omega \cdot V_A] + \exp[\omega \cdot V_B]} \quad (7)$$

$$P_B = 1 - P_A \quad (8)$$

where  $P_A$ ,  $P_B$ : theoretical probabilities of an individual choosing project “A” or “B”;

$V_A$ ,  $V_B$ : utility levels of an individual’s decision to choose project “A” or “B”; and

$\omega$ : parameter of variance (generally  $\omega = 1$  for convenience).

The simultaneous probability density function, that is likelihood function, is constructed by using Equations (7) and (8). And unknown parameters of Equation (1) are estimated by the maximum likelihood procedure, by applying one’s choice behavior for agreement with the policy. Table 1 indicates the result of parameter estimation of utility function using conjoint analysis (Ohno, Mori and Matsumoto, 2015). It was found that most estimated parameters were statistically significant because their t-values exceed 1.960 at the 2.5% significance level.

Table 1: Estimated parameters of utility function

Parameters	Estimated value	t-value	Variables
$a_1$	$6.621 \times 10^{-3}$	9.061	$X_1$ : Revenue from electricity sales
$a_2$	$1.599 \times 10^{-2}$	1.898	$X_2$ : Percentage of amount to be reduced
$a_3$	$7.544 \times 10^{-2}$	9.128	$X_3$ : Amount time of work
$a_4$	$5.386 \times 10^{-3}$	6.487	$X_4$ : Unit value of reward to work
$a_5$	—	—	$X_5$ : Gender
$a_6$	$-3.670 \times 10^{-4}$	-2.903	$X_6$ : Age
$a_7$	$-7.106 \times 10^{-5}$	-1.473	$X_7$ : Annual income
$a_8$	—	—	$X_8$ : Environmental conservation activities
$a_9$	$1.347 \times 10^{-2}$	3.652	$X_9$ : Neighborhood association activities
$a_{10}$	$2.036 \times 10^{-4}$	2.404	$X_{10}$ : Interest in global warming
$a_{11}$	—	—	$X_{11}$ : Interest in renewable energy
$a_{12}$	$4.964 \times 10^{-6}$	5.757	$X_{12}$ : Interest in small hydroelectric generation
Hit ratio	0.722		
Likelihood ratio	0.133		
Number of samples	4,308		

## 6. Cost-benefit analysis of project

### (1) Scenarios of project

Profile of a small hydroelectric generation project which is the subject of cost-benefit analysis in this study is shown in Table 2. Scales of item are set in reference to the "Hydro Valley Planning Guide Book" (New Energy Foundation, 2005). The scale of project is relatively small in Japan.

Costs of the project are shown in Table 3, which are also set in the same reference above. These are composed of construction cost, repair cost, personnel cost, other cost, overhead cost, and payment of reward to volunteers for the project. Total cost during project life is 110,814 [thousand JPY]. Here, the project life is set to 20 years, because the useful life of equipment is 20 years and the duration of Feed-in Tariff (FY2016) of small-scale hydraulic power in Japan is also 20 years (Ministry of Economy, Trade and Industry, 2016).

On the other hand, total revenue from electricity sales during project life is 104,440 [thousand JPY], and this business is slightly unprofitable. Since the unit price of electricity sales was about 10 [JPY / kWh] before introduction of Feed-in Tariff, un-profitability of this business will be more serious if Feed-in Tariff is finished.

This project has a feature to utilize resident volunteers in order to reduce costs of the project. This effect is expected to vary greatly depending on the work ability of resident volunteers; for example, volunteers who can patrol along rivers and waterways, who can

dredge trash from rivers and waterways, and who can perform a light work on power plant operation. In other words, we have to consider the work ability of resident volunteers who are substituted for regular workers. In this study, the work ability of resident volunteers is defined as the rate of substitution for regular workers. By changing the rate of substitution for each unit value of reward, we analyze cost-benefit ratio of the project utilizing resident volunteers.

Table 2: Profile of the project

Item	Scale
Power generation scale [kW]	26
Amount of annual electricity sales [kWh / year]	208,862
Revenue from annual electricity sales [thousand JPY / year]	5,222

Note) Feed-in Tariff (FY2016) of small-scale hydraulic power in Japan: 25 [JPY / kWh]

Table 3: Costs of the project

Year	Construction cost [thousand JPY]	Repair cost [thousand JPY]	Personnel cost [thousand JPY]	Other cost [thousand JPY]	Overhead cost [thousand JPY]
0	91,025				
1		282	155	282	86
2		299	155	282	88
3		317	155	282	90
4		334	155	282	93
5		351	155	282	95
6		369	155	282	97
7		386	155	282	99
8		403	155	282	101
9		421	155	282	103
10		438	155	282	105
11		455	155	282	107
12		472	155	282	109
13		490	155	282	111
14		507	155	282	113
15		524	155	282	115
16		542	155	282	117
17		559	155	282	119
18		576	155	282	122
19		593	155	282	124
20		611	155	282	126
Total	91,025	8,930	3,095	5,644	2,120

When we carry out cost-benefit analysis, benefits of the project include revenue from electricity sales and social benefit of voluntary activity for the project. Social discount rate is set to 4% per year. And, costs of the project and project life are set as mentioned above.

## **(2) Measurement of WTW**

By multiplying WTW per person and number of volunteers, we can derive amount of WTW. WTW per person is calculated by applying parameters in Table 3 to Equation (1). Number of volunteers is measured by assuming that 1) the subject of volunteers is 20-74 years old residents, 2) participation rate of volunteers is one person per household near the power generation facility, 3) participation rate of volunteers varies linearly in the region of less than 1 kilometer from the power generation facility, and 4) participation rate of volunteers is zero in the region of more than 1 kilometer from the power generation facility. And the population density is assumed to be evenly distributed in the urban space. Then, the scope of application of the WTW function in this study is defined as 1/9 of 20-74 years old residents. Basic statistics of Nagano Prefecture in 2010 are as follows; population is 2,152,449 persons, area is 13,562 square-kilometers, population density is 161.9 persons per square-kilometers, and household member is 2.71 persons (Nagano Prefecture, 2013).

When we calculate amount of WTW, the values of variables in Table 4 are set as constant as follows;  $X_1 = 5,222$  [thousand JPY / year]: revenue from electricity sales of small hydroelectric generation project;  $X_2 = 5$  [%]: percentage of amount to be reduced to local residents from revenue from electricity sales;  $X_4 = 0, 100, 200, 300, 400, 500, 600, 700$  and  $800$  [JPY / hour]: reward to work;  $X_5 = \text{N/A}$ : gender;  $X_6 = 40$  [years old]: near the average value of age in Nagano Prefecture, 2012 (Ministry of Health, Labour and Welfare, 2016);  $X_7 = 4,000$  [thousand JPY / year]: near the average value of annual income in Nagano Prefecture, 2012 (Ministry of Health, Labour and Welfare, 2016);  $X_8 = \text{N/A}$ : environmental conservation activities;  $X_9 = 0.0$ : neighborhood association activities;  $X_{10} = 0.5$ : interest in global warming;  $X_{11} = \text{N/A}$ : interest in renewable energy;  $X_{12} = 0.5$ : interest in small hydroelectric generation; and  $VLT = 796$  [JPY / hour]: 50% of average wage rate in Nagano Prefecture, 2012 (Ministry of Health, Labour and Welfare, 2016). Then, we have derived amount of WTW and reward as shown in Table 4.

Now, benefits measured by this amounts of WTW are benefits of people who would participate in the work. But there may be other amounts of WTW which exceed consignment workload. All people who live in the region of less than 1 kilometer from the power generation facility may have received same benefits of free voluntary activity, even if they do not participate in the work. So we have measured such benefits; where amount of WTW is 2,151 [hours / year].

This study aims to analyze cost-benefit ratio of a small hydroelectric generation

project utilizing resident volunteers, that is introduction of free volunteers or paid volunteers who receive a small reward or drink. The unit value of reward which uses in this analysis is set in increment of 100 within the scope from 0 to 800 [JPY / hour], because the minimum wage rate in Nagano Prefecture was defined as 746 [JPY / hour] from 1 October 2015 (Nagano Labour Bureau of the MHLW, 2016). If the unit value of reward exceeds the minimum wage rate significantly, the subject may recognize the work as wage labor rather than volunteer.

Table 4: Amount of WTW and reward

Unit value of reward [JPY / hour]	0	100	200	300	400	500	600	700	800
Amount of WTW [hours / year]	239	263	291	327	374	436	524	659	902
Amount of reward [thousand JPY / year]	0	2	10	27	54	98	171	294	530

### (3) Results of analysis

By introducing resident volunteers, costs associated with routine maintenance of the small hydro-electricity supply sector may be reduced. As shown in Table 4, amount of WTW provided by resident volunteers will increase with increasing unit value of reward. Then social benefit of voluntary activity for the project will increase, but amount of reward paid to volunteers will also increase. Therefore, we analyze economic efficiency of introducing resident volunteers by using cost-benefit analysis.

The results are shown in Figure 4. In this figure, the vertical axis represents the cost-benefit ratio of the project, and the horizontal axis represents the substitution rate of resident volunteers. Some different lines are drawn in this figure, and these indicate some different cases of the unit value of reward. The most important point in observing this figure, the cost-benefit ratio represented by the vertical axis is whether less or greater than 1.0. If the cost-benefit ratio is greater than 1.0, the project has economic efficiency by introducing resident volunteers. If not, on the other hand, there is no economic efficiency in the project.

In Figure 4, firstly, we focus on the case of no reward. When the substitution rate of resident volunteers is 0 [%], the cost-benefit ratio is 0.90. This means that this project does not have economic efficiency originally. This economic efficiency increases with increasing the substitution rate of resident volunteers. When the substitution rate is greater than 183 [%], the cost-benefit is over 1.0. In this case, this project requires high level of ability to resident volunteers, who have 1.83 times ability compared with regular worker. However, when the substitution rate exceeds 252 [%], amount of WTW exceeds consignment workload, and the line has been finished at this point.

Secondly, we focus on the case that the unit value of reward is 700 [JPY / hour]. When the substitution rate of resident volunteers is 0 [%], the cost-benefit ratio is 0.88. This economic efficiency also increases with increasing the substitution rate of resident volunteers. When the substitution rate is greater than 85 [%], the cost-benefit is over 1.0. In this case, this project does not require high level of ability to resident volunteers, but requires volunteers who have 0.83 times ability compared with regular worker. However, when the substitution rate exceeds 90 [%], amount of WTW exceeds consignment workload, and the line has been finished at this point.

Thirdly, in the case that the unit value of reward is 800 [JPY / hour], when the substitution rate exceeds 66 [%], amount of WTW exceeds consignment workload. The cost-benefit ratio is 0.98 at the point where the line has been finished. This means that this case does not have a good point.

Figure 4 indicates the ranges of the unit value of reward and the substitution rate of resident volunteers, which can be expected economic efficiency when we introduce some resident volunteers into the project. Even if a small hydroelectric generation project which aims to both global warming adaptation and regional economic revitalization is deficit, if we can find a countermeasure which can be expected economic efficiency for such project, it is possible to implement the project with public fund. This is a solution which we would like to propose in this study. However, it is not realistic usually that the substitution rate is more than 100 [%], because it means that the ability of resident volunteers is better than that of regular workers. Such cases might be discussed in the strategic policies of the local government; for example, a policy to exploit the talented engineers who have already retired.

Although introduction of volunteers is finished when amount of WTW exceeds consignment workload in Figure 4, this study has evaluated more volunteer activities because external economic benefits of volunteer activity are expected. For example, if the bond of community are strengthened by that residents participate in volunteer activities, the bond strengthened can compensate for the lack of government services such as disaster prevention and welfare, and improvement of resident satisfaction may be expected. On evaluating benefits of volunteer activity, we have assumed that the subject of volunteers is resident who lives in the region of less than 1 kilometer from the power generation facility by considering participation conditions. But, on measuring such external economic benefits, the subject should not be limited to resident who lives in the region of less than 1 kilometer from the facility. In addition, such external economic benefits can be measured by using time value of WTW, but it is not verified that the value is equal to the value of leisure time. These matters will be discussed at the next stage.

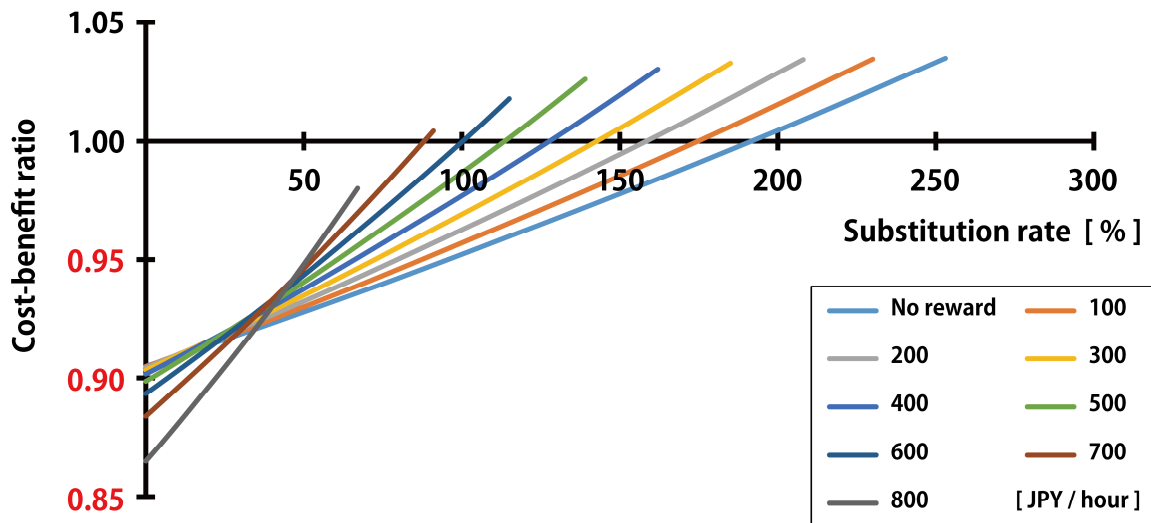


Figure 4: Relation between cost-benefit ratio and substitution rate of volunteers

## 7. Concluding remarks

The renewable energy projects have the potential to address not just the need to reduce greenhouse gas emissions to combat climate change, but also to provide local, sustainable economic and community revitalization. In this paper, we have proposed a small hydroelectric generation project utilizing resident volunteers, and have evaluated the project economically by using cost-benefit analysis. The WTW function, which is used to measure social benefit of the project, has been estimated by using the conjoint analysis in our previous study (Ohno, Mori and Matsumoto, 2015).

The project proposed in this paper has a feature of utilizing resident volunteers in order to reduce costs of the project. This effect is expected to vary greatly depending on the work ability of resident volunteers. In other words, we have to consider the work ability of resident volunteers who are substituted for regular workers. In this study, the work ability of resident volunteers is defined as the rate of substitution for regular workers. By changing the rate of substitution for each unit value of reward, we have analyzed cost-benefit ratio of the project utilizing resident volunteers.

As a result, even if a small hydroelectric generation project which aims to both global warming adaptation and regional economic revitalization is deficit, we have found a countermeasure which can be expected economic efficiency for such project by utilizing resident volunteers. The countermeasure is introducing resident volunteers in order to reduce costs associated with routine maintenance of the small hydro-electricity supply sector. However, because there are some cases which require high level of ability to resident volunteers who have more ability compared with regular worker, such countermeasure seems

not to be realistic usually. Such cases might be discussed in the strategic policies of the local government; for example, a policy to exploit the talented engineers who have already retired.

On the other hand, we have also evaluated external economic benefits of volunteer activity by using the WTW function. On evaluating benefits of volunteer activity, we have assumed that the subject of volunteers is resident who lives in the region of less than 1 kilometer from the power generation facility by considering participation conditions. But, on measuring such external economic benefits, the subject should not be limited to resident who lives in the region of less than 1 kilometer from the facility. In addition, such external economic benefits can be measured by using time value of WTW, but it is not verified that the value is equal to the value of leisure time. These matters will be discussed at the next stage.

When this type of small hydroelectric generation project utilizing resident volunteers is introduced, household utility levels increase. Understanding the dynamism between these factors can allow regional governments to adapt the scheme to best fit the needs of each region.

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