Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Trial of Overall System Design for Geothermal Development to Achieve Harmony with both Regional Environment and Local Society

Nobukazu SOMA

Research Institute for Geo-Resources and Environment, AIST, 1-1-1 Higashi, Tsukuba, Ibaraki 305-8567, Japan

n.soma@aist.go.jp

Keywords: Social acceptance, Regional circulation system, Economic impact, Adaptive governance, Environmental management

ABSTRACT

We describe the concept of how to use the overall system design (OSD) of geothermal research and development to increase the social acceptance in Japan. The OSD is a methodology to optimize the entire geothermal project, including not only the technological optimization of survey, development, and utilization, but also the relationship with local communities, and also the coordination and communication of stakeholders themselves. In the OSD concept, both positive and negative impacts can be evaluated by using the "Input coefficient" assumed for activities in geothermal survey and development, and the method of "regional Input-Output analysis". Showing economic effects is one of the important elements in the OSD concept that is easily understood by all the stakeholders. In the geothermal survey and development based on the OSD which advances step-by-step, we proposed to refer the idea of "adaptive governance" which allows much flexibility and acceptance of disagreement so that communication and decision-making can be done with high enough social acceptance. For that, we tried to use GIS visualization of the relationship with nature, public facilities, residential areas, etc. The OSD is useful in future geothermal research and development in Japan, where social acceptance can be much more important.

1. INTRODUCTION

Japan is one of the world's most promising areas with high geothermal potential (Muraoka et al., 2009), and it is recently paid great attention from general public since the Great East Japan Earthquake and the nuclear power plant accident in 2011. However, the installed capacity has still been 532.219 MW in 2016 since it exceeded 500 MW in 1995. Therefore, many efforts have been made to increase the use of geothermal mainly lead by the Japan Oil, Gas and Metals National Corporation (JOGMEC) and the New Energy and Industrial Technology Development Organization (NEDO). They assist private companies in challenging development with extensive financial support, and conduct various research and development to improve certainty of development and expansion of scale in one development, such as airborne exploration techniques (Shimada et al., 2015) and supercritical geothermal resources (Tsuchiya and Yamada, 2017).

The present national goal for geothermal power development in Japan is considered to be about three times the current total capacity, which is 1550 MW by 2030. This goal is described in "Long-term energy supply and demand forecast" from the Agency for Natural Resources and Energy in 2015. It is a big problem that each geothermal development is small scale and insufficient in Japan. Increasing the number of survey points is simply a useful approach to enhance a number of successes in geothermal utilization, although various research and development are conducted. Unfortunately, the success rate of geothermal development is very low at a new site without enough priori information. There is not enough pre-existing deep geological and reservoir information since very non-uniform subsurface conditions exist in general.

Social acceptance is an important factor to increase the number of geothermal explorations. It is a crucial factor not only for the acceptance of a whole geothermal development, but even for a very initial investigation phase. This means that "social acceptance" should change with time and space, and also changes according to the type of development activities and relationships with stakeholders. We are studying an idea of "Overall System Design (OSD)" of geothermal energy utilization (Soma et al, 2015, Yasukawa et al, 2018). It aims for the comprehensive optimization among all aspects in geothermal survey and development, e.g., adaptation to resource characteristics, feasibility of each of the engineering choices such as a type of power plant with various specifications, business formation and profit earning, lower risk and higher positive impact on a regional society, maintaining local tradition and culture, and maximizing the sum of the benefits of each stakeholder. The OSD may also work to average out the opinions of the noisy minority and silent majority if there are such people around a geothermal project.

In this paper, we explain the concept of the OSD for enhancing social acceptance after we define model of social acceptance in our study considering Japanese social conditions. Next, we present an approach to promote communication between stakeholders using "regional Input-Output analysis" in terms of the benefits obtained from each step of geothermal survey and development in the regional economic circulation. We also briefly provide an idea for using GIS to discuss social and cultural issues. Finally, the idea of "adaptive governance" is introduced as a base concept of OSD in relation to good decision-making.

2. CONCEPT OF SOCIAL ACCEPTANCE MODEL FOR JAPANESE GEOTHERMAL SURVEY AND DEVELOPMENT

Various conceptual models of social acceptance have been proposed in several technical fields in order to understand and improve it for introducing science and technology into society. One standard concept is based on the trade-off between risk and benefit which we feel when various new technologies, such as car, large nuclear power plant, etc. are introduced into society. For most new commercial products, social acceptance is not an issue because the risks are believed to be very small compared to their benefits. For existing nuclear power plants, bringing great local benefits seemed to improve regional social acceptance very well. In such cases, a careful explanation was sufficient to gain enough social acceptance for any target product or development. It is often regarded as "passive social acceptance".

When introducing renewable energy, it is difficult to discuss the optimal solution in the whole society and the optimal solution of individual projects on the same dimension. Therefore, three aspects of social acceptance are proposed for the assessment of the degree of acceptance. They are macro social acceptability ("socio-political acceptance" and "market acceptance") to assess economic and institutional policy, and micro social acceptability ("community acceptance") to evaluate the relevance in the specific region where the project is conducted (Wüstenhagen et al., 2007). Such ideas can lead to another attitude called "active social acceptance". For example, we have recently recognized the effectiveness of local community participation and collaboration in addition to companies and renewable energy professionals in order to gain enough social acceptance. Here, it is necessary to establish deep mutual trust in order for successful collaboration between locals and outsiders. Therefore, it is recognized that both "distributive justice" of risk and benefits and "procedural justice" of survey and development are essential in order to gain and maintain mutual trust. Both justices are essentially concepts based on people's psychological reactions. Distributive justice is the justice that is recognized when the ratio between the amount of benefit earned and the effort required to earn, which does not vary very much from person to person. Procedural justice is the justice that is recognized when a process taken to reach a result is evaluated as correct by the people involved in the result or process. Six rules are suggested for achieving procedural fairness (Leventhal, 1980). They are consistency, bias suppression, accuracy of information, correctability, representativeness, and ethicality and morality.

Also, under the condition that geothermal energy is one of the right choices for the general public in the future, no stakeholders should draw conclusions from the beginning, even if the company wants to create hydrothermal geothermal development or hot spring owner wants to oppose any developments. We need sufficient information on all aspects of geothermal survey and development, based on the fair attitude of all stakeholders without arbitrary, inductive, too negative, and too positive manner. The OSD concept we are studying is a good tool for such good communication and optimal judgement.

In this study, we regard that social acceptance of "geothermal" to consist of six elements; "socio-political acceptance", "market acceptance", "technological acceptance", acceptances defined by "resource characteristics", "distributive justice", and and "procedural justice" (Figure 1). These elements of social acceptances are categorized on a global scale which corresponds to a common understanding at the country or global level, and regional scale, too. It is also important to consider that social acceptance changes with time in response to various activities such as the acquisition of new underground information, progress of development, communication with residents, etc. We call this characteristic as "dynamic social acceptance". This means social acceptance is not stable, but by changing the design variables of geothermal development, we may be able to control social acceptance to some extent. Therefore, we will treat the OSD as a "step-by-step" time-varying evaluation tool to increase "dynamic social acceptance".

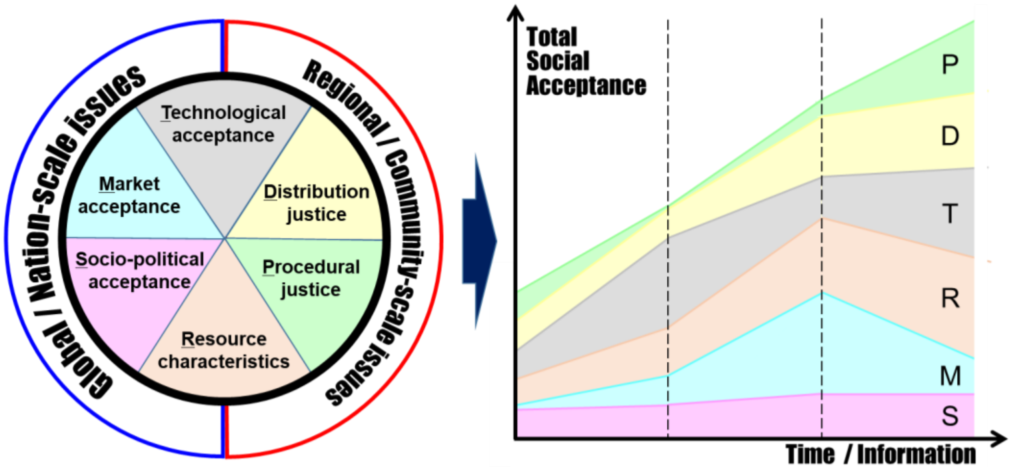

Figure 1: Schematic model of social acceptance for Japanese geothermal survey and development.

3. CONCEPT OF OVERALL SYSTEM DESIGN OF GEOTHERMAL DEVELOPMENT FOR ENHANCING SOCIAL ACCEPTANCE

We have already created the concept of the basic framework of OSD in the past research, which enables comprehensive optimization of the geothermal utilization system and enhances the social acceptability of the area. It was firstly focused on technological aspects because it was originally created for an optimization of HDR (Hot Dry Rock) or EGS (Engineered Geothermal System) type development discussed after the past Japanese HDR/EGS studies (Oikawa, et al., 2004, Soma et al., 2004). We have extensively updated the concept of OSD to cover all aspects of geothermal survey and development, including social issues, because "social acceptance" is often more important than simple technical optimization in case where the practical increase of geothermal energy is strongly desired. The objective of using OSD is to increase the acceptance of geothermal exploration, successfully achieve proper style of geothermal development at the local site, and maximize the value of geothermal utilization among all stakeholders. In this section, we briefly explain the concept of OSD of which details are explained in Soma et al. (2015) and Yasukawa et al. (2018).

One function of OSD is to promote a most suitable type of geothermal energy usage at the region by achieving comprehensive optimization of a utilization system acceptable for all stakeholders. This does not mean simple optimization for single objective target such as only technical and/or business aspects. Simultaneous evaluation of technical, economical, and social acceptance provides possible types of geothermal energy utilization systems from universal usages of geothermal resources, and the simultaneous evaluation can present multiple options which may be good for each stakeholder. OSD is designed to address stakeholder's concerns including the selection of the type and size of utilization system which are the important factor for acceptance of projects by local populations; the extent of social impacts depends on characteristics of the utilization system; lack of provided (or shared) information may raise fears among the local residents, and resulting in resistance to the project even if a new project has only positive impacts on the region. Another important role of the OSD is that the local people can clearly understand what kind of geothermal energy utilization system should be created in the target area. Two major roles of OSD are technological optimization of each candidate utilization system, and overall optimization of the regional society by selection and specification of an appropriate utilization system.

In OSD, meaning of design for "geothermal" is much different from that of standard industrial products because it is strongly affected by uncertain subsurface parameters. We cannot make any deterministic design drawings for overall geothermal utilization system before practical survey and development. The design drawing, which may correspond to strategy of geothermal development, is changed as the project progresses while we gather and update subsurface and regional information which are used as "design variable" and "constrained condition" in designing geothermal utilization system. Although the subsurface information is normally less reliable at the beginning of any project, the quantity and the quality can be improved as a geothermal development progresses. We emphasize reliability of the parameters increases as a number of drilled boreholes and conducted geophysical explorations, too.

Another important point of OSD is to evaluate stakeholders themselves. Identifying appropriate stakeholders is one of the most important points for successful geothermal development and long-term utilization. The range of influence, which is defined by the considered extent of geothermal development, definitely varies due to the size of the planned energy utilization system. The larger geothermal utilization normally activates the larger size of stakeholders, and the size of stakeholders affects how to optimize the geothermal energy utilization system. The configuration of stakeholders themselves should be updated while the survey, development, and communication are progressing and new results come up. Through OSD, appropriate information is extracted at each development stage, aiming at achieving "adaptive governance" by appropriate stakeholders, and the direction of the project is defined based on the communication according to the occasional situation. Therefore, OSD should not be fixed rigidly from the beginning but should vary flexibly to incorporate updated information; OSD evolves in time and space.

The schematic of OSD is shown in Figure 2. There two major parts in OSD: one is "system design" which is the selection and the specification of methods, and the other is "detailed design" which is the optimization of each proposed method. Outputs from the "detailed design" obtained at each stage of development will be used in the decision-making process for the part of "system design". In Figure 2, the "method" describes a choice of technology and its combination, those are important parts of the OSD concept. There are many types of geothermal energy utilization. Flash steam power plant using natural hydrothermal reservoir is the most typical systems in Japan. EGS type development has not been adopted in the past commercial Japanese geothermal development, but it has been studied to be a near future practical option. Combination with direct and/or cascade heat use for various purposes may increase the number of unique types of geothermal energy utilization systems.

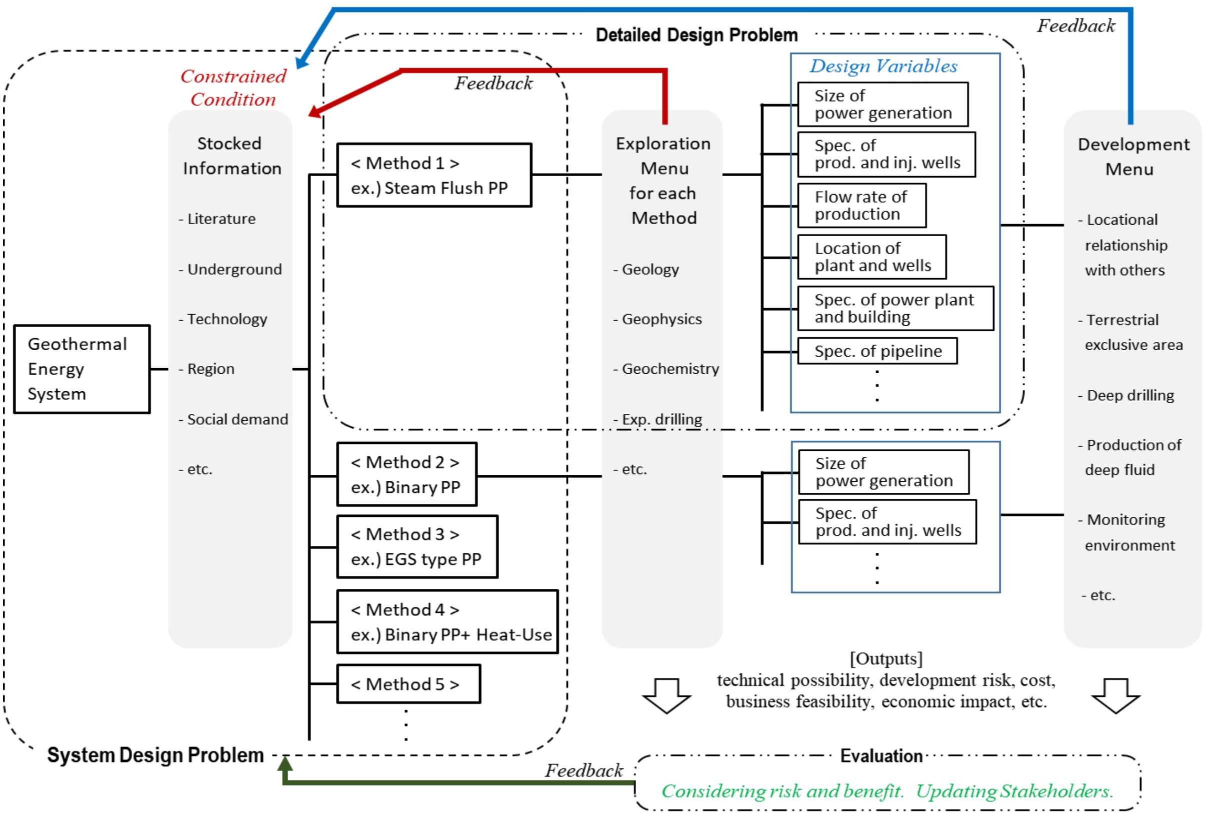

Figure 2: Conceptual structure of OSD for geothermal energy utilization system.

Once the geothermal project decides directions of “system design”, OSD provides some answers such as technical possibility, development risk, cost, business feasibility, impact on regional society and culture, etc., even at the very beginning of the project. Total evaluation results of OSD may relate to “social acceptance” of the planned geothermal energy utilization system at the objective region. In the early part of the OSD, grasps of stakeholders’ outlook on geothermal energy utilization system, which is based on wide characteristics, such as mind, history, industry, and economic circulation, should be valued greatly. The maximum and minimum boundaries of an acceptable geothermal energy system can be known based on the stakeholders’ evaluation on the system, although it may change during progress of survey and development. They are very basic values of a constrained condition to determine various design variables in OSD. When types of geothermal use are proposed through OSD, we evaluate the performance of them. The overall economic effects on the objective region from geothermal exploration and/or development are one of the important key indicators as well as various technical and social factors. To make it easy to understand for general stakeholders, we suggest using regional “Input-Output analysis” in OSD as mention in later section.

By “detailed design” of OSD, we can judge what type of utilization "method" is enough to continue to survey and develop, or not. One may decide to shrink (or expand) the surface area of the geothermal development based on the result of OSD. Some people may leave (or join) from the group of stakeholders. Thus, “system design” of OSD procedure is modified, and updated new "method" of geothermal utilization will be added into the OSD procedure. We repeat to evaluate with OSD concept as each step of survey and/or development, and the result can be used for decision-making and modification of the project at each development step. The "detailed design problem" of OSD really needs detailed engineering design of the geothermal energy extraction system, such as borehole design and arrangement, pipelines, power generation systems, and their auxiliary equipment. However, this study does not focus on these points. Although they are essential to make a geothermal business for any company, considering some representative values is enough to study the OSD concept since the main target here is enhancing the social acceptance. At least in the Japanese geothermal development, the efforts for business feasibility of geothermal development company are high enough, and their qualities are reliable, too. Therefore, we expect providing some updated representative values to the company is enough to improve the overall geothermal system design when we practically manage geothermal project by using OSD concept in future

Optimization, recommendation and judgment are also done along the OSD procedure. The overall optimization is based on an idea of “Multi objective optimization”, in which conflicting items are dealt with such as opinions of pros and cons. For example, trade-off adjustment between positive technical aspect and negative aspects may be serious subjects. The OSD can indicate scores of mutually conflicting elements, although the evaluation from OSD is not a final conclusion of stakeholders. In our past study, we introduced the idea of “Pareto optimal solutions” (Miettinen, 1999) which is a one approach to show scores of multiple possible types of geothermal utilization system. However, the way of decision making which provide maximum social acceptance may not be such an objective, deterministic, nor rational approach, but emotional, indeterministic, or non-rational approach may be often rather agreed in Japanese local culture. We treat the outputs from OSD as just information for local decision-making support.

4. EVALUATION METHOD OF GEOTHERMAL IMPACT OF ECONOMICAL ASPECT ON OBJECTIVE REGION

4.1 Relation between regional economic circulation and effect of geothermal survey and development

The geothermal areas in Japan are generally located in the countryside such as rural area and mountainous areas, and there are often some serious regional social problems in addition to the problems by confliction of geothermal development with existing businesses or/and nature to be protected. The social problems such as depopulation, high aging rate, and inactivation of the area is particularly important at countryside areas where geothermal potential is usually noticed. If the activity of geothermal survey and development, even if it would be temporal, is useful for improvement of such regional social problems, it is valuable for both Japan and the regional society.

The idea of regional economic circulation analysis has been proposed to understand the regional structure and making the regional strategy to obtain more benefit and improve local social problems (METI, 2004). Originally, it treats not only economy (product, service and money) but also humans and information. The concept of regional economic circulation analysis is good for an evaluation of social structure of objective region and of possible impact of geothermal survey and development. We can imagine the relationship between new coming activities of geothermal survey and development, and pre-existing various local activities, as shown Figure 3. If the local economy exists as mutually stable (although there may depopulation etc.), the local people may be afraid that the new activities from geothermal development would break the stable condition of the objective region. Typical worrying may occur from a conflict between local industry of a hotel with hot spring and activities of geothermal survey and development. It is understandable that they are afraid of the potentially bad effect by geothermal development because they may lose all or some degree of source of their business as well as cultural values of hot springs if a serious trouble occurs, such as interference between geothermal production or injection and the hot springs aquifer. However, it has not been determined that geothermal development will cause serious adverse effects before a deep drilling is completed and/or deep resources are extracted in large quantities. On the other hand, there is certain possibility that geothermal can bring any positive impact on the regional circulation system in views of economy, social issue, etc. It is useful if we can evaluate possible influences from planned geothermal survey and development in a calm manner in terms of both positive and negative effects, before any large-scale activities such as wide-range exploration, deep drilling, fluid production, and large investment are conducted. It can be a good promotion tool of geothermal energy utilization if it doesn’t reduce very much preexisting regional activities and if it does enhance and open new regional possibilities.

As a first trial, we focus on evaluating the economical aspect using the regional economic circulation model. For explanation of the influence of planned geothermal energy utilization to the regional community, we use the "regional Input-Output analysis" in the objective region. Input-Output analysis is usually used as a standard method when an economic effect is evaluated from such as an Olympic game, new railway, etc. If the "regional Input-Output table" of objective region and the "Input factor" of geothermal survey and development at each step are prepared, we can analyze the influences of “geothermal” to the objective region along with the step-by-step progress in the geothermal survey and development. In this paper, we evaluate the only temporal influence of “geothermal” by the Input-Output analysis as a preliminary study because making the effect of introduction of geothermal survey and development clearer can have dominant effect on enhancing the social acceptance at the beginning (or planning) of a geothermal project.

Once the geothermal project is completed, where the power plant was built and local geothermal service company is established, new geothermal industry will be built in to the regional economic circulation. At this stage, the local geothermal company acts as one regular player in the regional economic circulation system. Therefore, when we analyze such a condition at the later part of geothermal development with OSD concept, it is better to use the "expanded Input-Output tables" in which the geothermal relating industries are shown as an independent activity in order to make more accurate evaluation of economic values as long-term regular industry. For example, Moriizumi et al. (2015) and Nakano et al. (2017) have proposed nation scale “expanded Input-Output table” including geothermal power plant industry and its related industries. We can refer the "Input factor" of geothermal relating industries from those expanded tables when we evaluate the effect of regional geothermal industry established after the geothermal project.

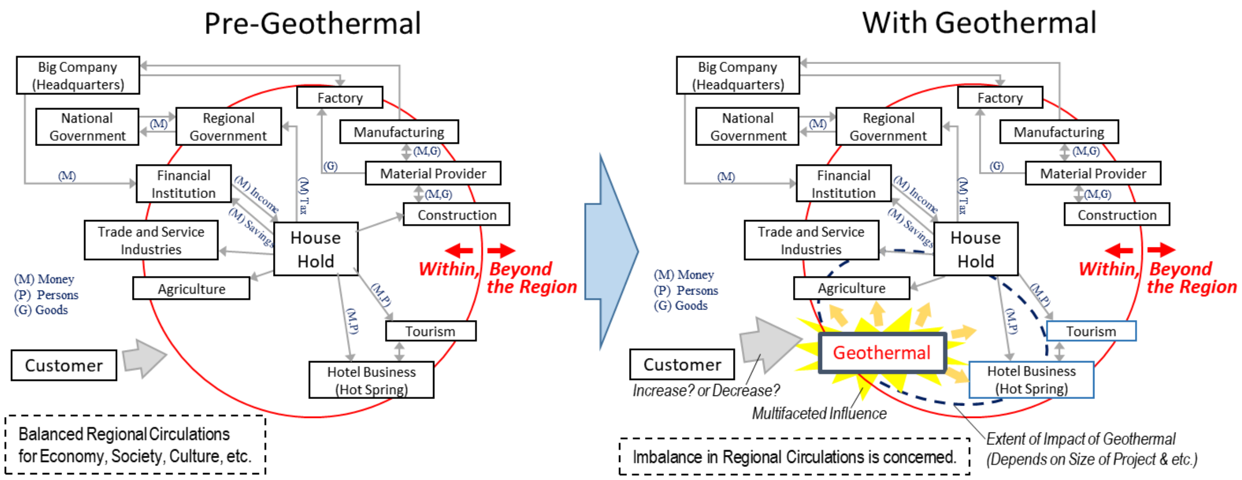

Figure 3: Conceptual relationship between regional economic circulation and “geothermal” coming. (Soma et al., 2015)

4.2 Regional Input-Output Table for area of geothermal survey

We need “regional Input-Output table” in the objective region where influence of geothermal survey and development is evaluated. However, no research has been done for a small city, town, or village from government office, although there are released so many statistical information from the Statistics Bureau of Japan. Therefore, we must make it by ourselves by assuming regional economic capacities based on various statistic information. The regional Input-Output table of prefectural size is published by each prefectural office in Japan. We can make the “regional Input-Output table” for the objective region where we want to analyze the influences of planned geothermal survey and development.

Basic structure of Input-Output table is shown in Figure 4. The Input-Output Table was developed by Dr. Leontief, a U.S. Nobel laureate economist (Leontief, 1936, and 1987). The Japanese government has begun to create national-scale tables since 1951, and now it is widely used in the analysis of economic and industrial structures and economic forecasting. For example, it is used as "The economic effect of 32 trillion yen by the Olympics is expected including the preparation period”. The Input-Output Tables systematically present and clarify all the economic activities being performed basically in a single country, showing how goods and services produced by a certain industry in a given year are distributed among the industry itself, other industries, households, etc., and presenting the results in a matrix (row and column) format. It is generally accepted that input-output tables are useful and important for economic and industrial structural analyses, and economic projections (after MIC, website).

Here, we focus on two real cities for an example to show its function in OSD concept. These two cities are located in Ibaraki prefecture, same with AIST (author’s organization). Two cities are selected considering the past Geothermal gradient data, although Ibaraki prefecture is not a proven or known geothermal area. There are the borehole data of thermal gradient of 31 K/km in the city A and of 46 K/km in the city B, but there is no information of such as high temperature hot springs and obvious hydrothermally-altered geology. So, only EGS type development is so far technologically applicable in such a low geothermal activity area.

Even though we assume EGS type geothermal development of 5 km deep, which will be 155 degree Celsius at the city A and 230 degree Celsius at the city B, at the moment, they might be nearly zero possibility to be able to develop practical geothermal power plant, because of unknown deep hydraulic conductivity, difficulty of adequate water resources, and various possible engineering difficulties. Therefore, what we show here is just a demonstration of OSD concept using information of the city A and B.

We estimated the "regional Input-Output table" of 108 industrial sectors for the city A and B by referring to that of Ibaraki prefecture. Basically, regional production amounts of each industry are assumed to be proportional with various ratios with prefecture such as population, number of households, number of offices, shipping value of agricultural products, etc. Estimation of Input-Output table was done by a method called "non-survey approach" including estimation of regional import and export amounts without additional field survey. This may sometimes cause a relatively large gap between true value of import and export. Therefore, when the OSD concept is practically applied to the geothermal survey and development at a certain region, we hope to improve the error of such regional economic estimates with the cooperation of the local government. Even small amounts of real field survey data improve reliability of the "regional Input-Output analysis" although we regard the results presented in this paper are reasonable as an example.

Basic information of city A and B at the base year of estimation are described in Table 1. The parameter used for making the “regional Input-Output tables” and some social feature of each city are also shown. Both cities are only 20~30 km away from the prefectural office location, and the city A is located on the south side and closer to Tokyo. It takes about only 1 hour from the city A to Tokyo. Although the area of the city B is larger than that of A-city, other indexes generally look better in the city A. The Financial strength index, that is an indication of the local government's fiscal capacity, is better in the city A, too. If this index exceeds 1.0, the local government doesn't need any "tax allocation grant" from central government of Japan. In the city B, although the ratio of agriculture, forestry, and mining tended to be relatively larger than that of the city A, the city B apparently has aging, and the public service and medical expenses are large, so in general it seems not as lively.

Under the OSD concept, we should make the strategy of geothermal survey and development include its multi-lateral utilization considering such characteristic and industrial trends of the objective region. If the "geothermal" can be useful to solve regional social problems and/or can extend regional strength and cover its weakness, the social acceptance may be improved very much.

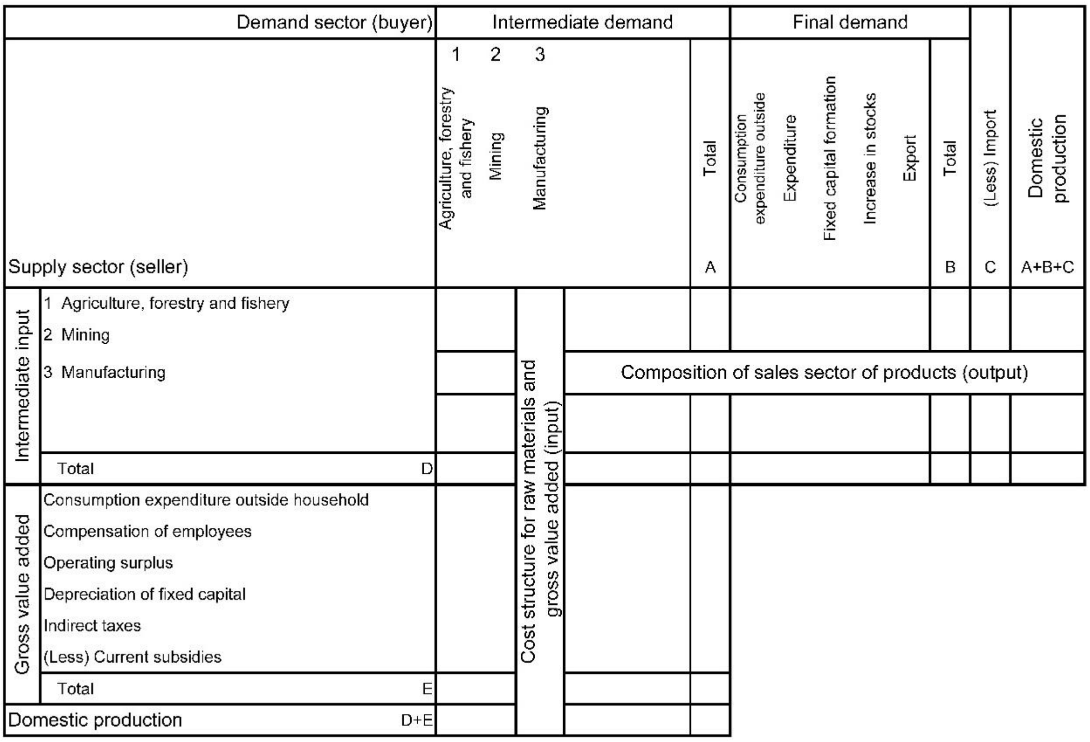

Figure 4: Structure of basic Input-Output tables. (after MIC, website)

Table 1: Basic information of A- and B-cities comparing to Ibaraki prefecture, and top five industries listed in each "regional Input-Output table".

	Ibaraki prefecture	A-city	B-city
Area	6097.06 km^2	215.53 km^2	371.99 km^2
Population	2,916,976	76,020	52,294
Households	1,124,349	27,288	19,436
Rate of 65 years old or older	26.76 %	29.58 %	33.96 %
Rate of under 15 years	12.63 %	11.42 %	9.52 %
Number of schools	884	30	23
Financial strength index	0.63	0.61	0.41
Top 5 industries from each "regional Input-Output table" (Numbers means rate in each region.)	Commerce (6.08 %)	Commerce (6.66 %)	Public service (14.63 %)
	Food (4.61 %)	Medical (5.69 %)	Commerce (5.54 %)
	Production machine (4.14 %)	Steel material (5.03 %)	Medical (5.29 %)
	Steel material (3.81 %)	Public service (4.83 %)	Architecture (4.87 %)
	Public service (3.61 %)	Other metal products (4.51 %)	Steel material (4.64 %)

4.3 Input coefficient of geothermal survey and development

In order to evaluate temporal economical influence of geothermal survey and development on the objective region, we need to know the structure of economic impact of activities along with survey and development, such as geophysical exploration, drilling and construction. For evaluation with the "regional Input-Output table", "Input coefficient" of some activities in geothermal survey and development is assumed from published data and company interview surveys on the cost structure of those activities. For the step-by-step evaluation, here, we classify flow of geothermal development into four segments: 1) exploration phase by using geophysical exploration, 2) exploration drilling phase, 3) phase for drilling production wells, and 4) construction phase for power plant, pipelines, and transmission line (if needed). For this flow, we assume the "Input coefficient" of geophysical exploration, drilling borehole, land preparation, and power plant construction.

For the case of drilling, we refer to published cost structures such as from Lukawski et al., (2016), and re-mapped the values into the 108 segments classification used in the "regional Input-Output tables". Then we corrected these numbers to match the Japanese condition based on company interview survey. The example of some major elements of the "Input coefficient" of drilling geothermal wells is shown in Table 2. These numbers mean ratio of input from total cost of drilling wells. If the total cost of drilling is 1 billion yen, 760 million yen (multiplied by 0.076) will be costed as inputs into cement and cement products industry. In the same way, 510 million yen and 300 million yen may reach the accommodation and road transportation, respectively. Because one activity spread widely like this, geothermal development will be able to link with other industries in the objective region. For the "Input coefficient" of geophysical exploration, land creation, and power plant construction, we can refer the Input-output table for the construction sector analysis released from the Ministry of Land, Infrastructure, Transport and Tourism of Japan. This dataset is not specialized to geothermal or deep resources industry, but it is thought to be the average structure of relating where industries might be reflected.

One of the important factors to achieve reasonable economic analysis caused by geothermal development activities at the objective region is to grasp appropriate regional self-sufficiency rate. Results of economic analysis of geothermal impact strongly depend on not only estimating the more accurate "Input coefficient" but also obtaining a reasonable regional self-sufficiency rate. In the geothermal survey and development, some special things and materials are necessarily needed, therefore, regional supply rate is usually lower than that of general construction. In future work, cooperation with local government and company interview survey on regional industry is needed to obtain such datasets which may be difficult to estimate.

Table 2: Estimated "Input coefficient" of geothermal drilling. (Only top five Industries are shown.)

Industry	Assumed Input-coefficient
Steel material	0.171
Other business services	0.121
Other metal products	0.089
Cement, cement products	0.076
Goods rental service	0.061

4.4 Regional Input-Output analysis and calculation of economic benefit from geothermal survey

Here, economic impact of each step of simulated geothermal survey and development using model data of the city A and B are estimated by the "regional Input-Output analysis". It shows the economic ripple effect that is produced at each stage in flow of geothermal development.

Firstly, we simulate 165 million yen of geological survey and surface geophysical exploration at both cities. In this case, production induction amounts are expected as 24.8 million yen at the city A and 16.3 million at the city B-, and numbers of increased working people are 2.5 for the city A and 2.3 for the city B. It is clear that same amount of input from geothermal survey activity will raise different levels of effects for each regional economy at the city A and B. Depending on the presence or absence of an industry that corresponds to the work required by the geothermal survey, there will be clear differences in the indirect impact from the input values.

In the case of drilling two exploration wells (200 million yen each), it creates 81.0 million yen of production induction and 7.4 persons of new jobs at the city A. At the city B they are 38.0 million yen of production induction and 5.1 persons of new job creation. Furthermore, in case we assume drilling three production wells at 460 million yen per each, expected effects are 279.3 million yen and 25.3 person at the city A, and 131.0 million yen and 17.6 person at the city B. As a last part of the simulated project we assume the cost of a power plant construction at 8280 million yen. In this case, the geothermal project can bring 2814.0 million yen of production induction and 145.6 persons of new job creation at the city A. At the city B they are 2646.1 million yen of production induction and 195.6 persons of new job creation. Probably from the estimated value of self-sufficiency rate, this estimated result is likely to be over-estimated, but we can calculate the geothermal ripple effect for each development step, and there is definitely an effect, depending on the scale of input. Relationship between new "geothermal" and pre-existing regional industry can be closer together if they think multi-lateral utilization of geothermal energy including cascade heat use. The stakeholders can think and discuss optimal combination with "geothermal" based on social and economic aspect of regional community as well as engineering point of view.

Also, by using the "regional Input-Output analysis", we may be able to estimate a negative impact of geothermal project if we assume a negative demand on an industry of concern. A representative industry of concern that is afraid of "geothermal" is the hotel with the hot spring. In the simulated examples at the city A and B, the city A has no hotel with hot spring, therefore, negative impact can be expected to be relatively smaller. On the other hand, at the city B, at least 50 % of hotels advertise their baths with hot springs. Therefore, we can assume a negative condition that regional demand on accommodation of the city B is reduced by 50 % less from original values due to "geothermal". At such negative condition, economic impact is happened as total 195.4 million yen of production reduction, 29.9 persons of job lost, mainly on industries of commerce, gas and heat supply, and waste disposal. Although number of both positive and negative impact is not very accurate in these simulated economic evaluations, both degree of effect is not quite far from each other.

It is important to note that while the positive effects of geothermal in the survey and development phase are temporary, if adverse effects occur from those such as disappearance of a hot spring, they may remain permanent. However, if the stakeholders can judge that such a permanent risk is low enough considering various information from OSD procedure, and they can recognize positive possibilities, positive decision on geothermal may come up at the region.

5. EVALUATION OF INFLUENCE FOR SOCIAL AND CULTURAL ISSUE

It is difficult to understand and present the value and influence between "geothermal" and social and cultural aspects, because recognition of value is much different for individuals and depends on each background. Therefore, we think about helping the stakeholder debate by making the geothermal survey and/or development and local conditions clearly visible.

For visualization of spatial relationship between geothermal survey and/or development and pre-existing importance, we believe using GIS software is effective. Once the spatial relation is made clear, we may make a communication in terms of importance, type of influences, additional utilization possibilities, alternative option, etc. For example, one can imagine the positive utilization of waste heat from geothermal energy system if there are buildings and facilities above a certain size within a distance that can transport heat practically. If there are different types of facilities, we can refer to not only demand of regional community but also economic characteristics analyzed by the "regional Input-Output analysis" to decide best way of whole energy utilization.

Figure 5 shows the positional relationship of the simulated project at the city A between geothermal energy utilization location and public facilities around the city. In the figure, three stars indicate three separate positions of well-pads in the simulated EGS type of geothermal development. Around the well-pad position, there are a small forest, rice fields, fields, and golf courses. One hospital and one welfare facility for the elderly are located within 1 km of the well-pad. Within 2 km distance from the simulated geothermal site, there are six public facilities such as hospital, post office, fire station, police station, seven welfare facilities, and three schools. One can plan various waste heat utilization applications such as bathing in welfare facility and public buildings or club houses of golf courses. If there are positive applicants, it would also be possible to start greenhouse agriculture using waste heat from the planned geothermal plant.

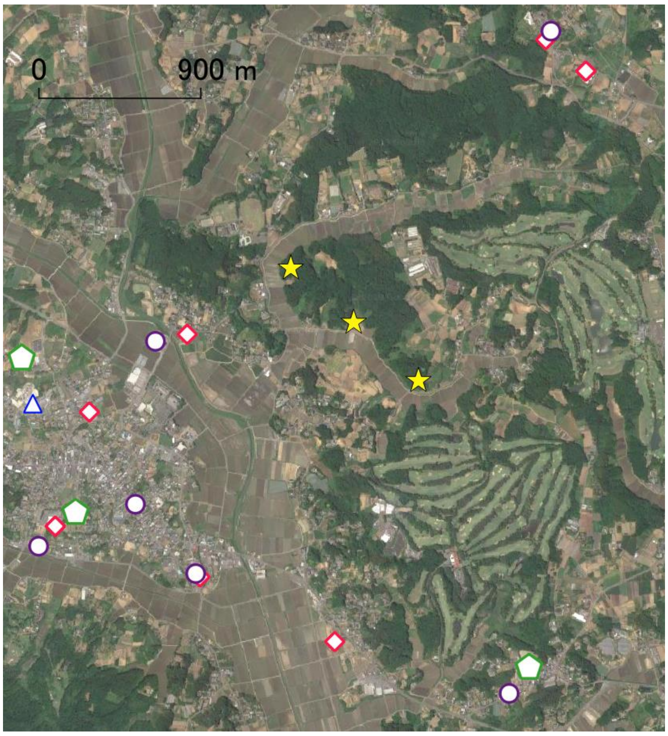

Figure 5: Relationship between simulated geothermal project location in the city A and neighboring public facilities and building by using GIS. (Stars are well-pads of simulated geothermal project, Diamonds are welfare facilities, Circles are public facilities, Pentagons are schools, and Triangle is a farm products direct sale place.)

Although the place simulated is not a district where the natural landscape is particularly valued or emphasized, in some cases, the deterioration of the landscape due to the construction of a power plant may become a problem. The deterioration of the landscape during well drilling, construction of the plant, and drilling additional wells after the power plant operation has started. It can be a very serious issue for the regional community because it is an irreversible process. Recently, application of "Ecological landscape design method" is suggested in order to build consensus in terms of landscape changes in Japan. The "Ecological landscape design method" preserves and creates the environment that should be maintained in the area owing to the potential natural power of the area itself. In this method, by utilizing the power of nature itself, healthy ecosystems including landscapes, can be sustainably maintained. NEDO has already published its manual. We can adopt this method when the project is progressed, and power plant construction get to be concrete along with the OSD procedure.

In order to treat social and cultural issues in the OSD concept, Quantitative expression is convenient, although it is very difficult because value recognition and judgment criteria for such issues strongly depends on each individual. Here, we refer to "how to express business risk of renewable energy" which has been published from Japanese Ministry of the Environment. Basic idea is an evaluation combined between severity (or usefulness) and frequency of occurrence of each expected "event". At first, we extract what is a concerned "event" supposed to be from geothermal survey and development. Here, we mainly focus on the extraction "event" from the communication among stakeholders, but, if the scope of influence of "geothermal" is larger, for example, wide questionnaire survey may also be required. In the OSD concept, the configuration of stakeholders should be updated according to the contents of the extracted matter. The stakeholders give an evaluation of the impact on the area and the frequency of occurrence, and map the matters based on these two axes. The result of "regional input-output analysis" and the display results by GIS also serve as a reference for evaluating the degree of influence of matters. In particular, it is important to emphasize that positive effects are regarded as important judgment indicators in this research, on the other hand only negative effects are usually paid attention. This may be a different attitude from regular risk assessment.

6. ADAPTIVE GOVERNANCE OF GEOTHERMAL SURVEY AND DEVELOPMENT USING OSD

Final decision-making is the most important key to gain reliability and high enough social acceptance. Therefore, we don't recommend simply to obey results like mechanical, systematic, objective, deterministic, and rational approach, although the OSD approach can provide a kind of numerical indicator from such as Input-Output table and GIS based Questionnaire survey.

Miyauchi (2017) advocates the concept of "Adaptive governance" for a field of environmental protection, which is named after adaptive management in the field of ecosystem management. The "Adaptive governance" has shown successful results in some environmental protection problems in mainly rural regions in Japan, such as animal harm measure, symbiosis with bear, coral reef conservation, etc. The feature is not to approach the uncertainty in each task to zero, but to treat it on the premise and aim for flexible environmental protection. In the field of ecosystem management, adaptive approaches are known to be useful where they manage flexibly with determining the direction of progress while watching the behavior of creatures and responses. Miyauchi (2017) introduced a similar approach to issues in which interaction between regional society (and human and culture) and science is essential and non-negligible factor. "Adaptive governance" means the way of environmental governance with adaptivity, and they define it as "a mechanism of collaboration that attempts to find solutions with heuristic manner by flexibly changing values and systems in the presence of uncertainty". There are three key points of the "Adaptive governance": 1) Guarantee of trial and error and dynamism, 2) Taking care of multiple values of stakeholders and thinking of multiple goals, 3) Re-contextualization of various regional issues including targeted "environmental protection" while focusing on research and learning by diverse residents (stakeholders).

It is easy to understand that OSD concept is a good fit with the idea of "Adaptive governance". In fact, the way of governance often makes problems between the new "geothermal" community and residents who passively encounter the geothermal project. Improvement in the way of governance, which naturally includes the way of decision-making, is necessary for enhancing social acceptance of geothermal in Japan. At the same time, it may open the possibility that "geothermal" can be useful for regional activation, etc.

In the "Adaptive governance", to have "multiple goals" is an especially interesting idea, and we regard it as one reason why this concept worked well in the fields of environmental protection. Even if the scientist insists to protect the regional or global environment, regional community often does not have interest in it. For example, once regional subject such as regional activation, which regional people easily can understand and agree, is introduced and added in targets of stakeholders, communication and activities using "geothermal" may be more active. Miyauchi (2017) also recommended to have a "loose goal" that all stakeholders can agree with, apart from each original target. In our case, each stakeholder may have each target, such as construction of power plant, protection of hot spring, creation of new job, etc. Here, this "loose goal" is, for example, a kind of slogan that "make the region healthier"; everyone can agree with something like this more or less.

In the geothermal case, the direct benefit to the region after the power generation business has started is relatively small due to the effects of full automation nowadays. Therefore, the basic stance of persuading acceptance of power generation business will not be able to improve the "social acceptance" of geothermal very much. Rather, it may be possible to improve social acceptance and to increase value of geothermal energy utilization in the objective region while taking a stance to solve the problems of the region together with local stakeholders, if "geothermal" gently and impartially acts as a new outsider bringing new possibilities. Ultimately, achieving smooth communication is essential in enhancing social acceptance of geothermal survey and development, and "Adaptive governance" is considered to be very useful by using OSD concept together.

7. CONCLUSION

We have studied and progressed the concept of OSD so that the OSD will a method for enhancing "social acceptance" of Japanese geothermal survey and development, which can be useful to substantially increase the number of basic survey and exploration points of geothermal research and development.

In this study, to elaborate the philosophy of OSD which is close to the idea of regional circulation model, we applied the "regional Input-Output analysis" to simulate the candidate cities and to evaluate the influence of geothermal survey and development by assuming the Input coefficient of various activities in "geothermal". As a result, we could present both positive and negative influences in a simple form that is easy to understand. Also, the same size of input of geothermal activity raised different effects in two simulated cities because of the differences in characteristic and industrial structure. This phenomenon should be paid attention if we want to obtain maximum positive impact from future geothermal development. We displayed how to treat the regional social and cultural issues in the OSD concept using GIS. We also described the importance of the final decision-making, and proposed to follow the idea of "adaptive governance" developed originally for the field of environmental protection. The key point of this idea seems to fit well with problems that occurred in Japanese geothermal survey and development, and therefore, the OSD concept will be useful.

After years of research, the conceptual design of the OSD is recently close to completion. However, the biggest problem is that there is a concern that this concept may not be realistic for a practical geothermal development in realistic Japanese conditions. Next step of this study is definitely to apply it to the real fields of actual investigation, development, and communication as a field research project. In the future, we hope the OSD will be a real useful tool for promoting actual geothermal survey and development, and will be improving life of people in the area where geothermal is expected.

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