A CASE STUDY ON INSTALLATION OF SMALL HYDROPOWER PLANTS: FOCUSING ON THE SMALL HYDROPOWER POTENTIAL SURVEY WITH RESIDENT INITIATION

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Renewable energy becomes a popular topic all over the world. Small hydropower schemes produce a sustainable and predictable supply of electrical energy compared to other renewable technologies. Trust from local residents may be lost if small hydropower plants are installed without their agreement. It is necessary that the main constituent that consists of local residents and governments should be formed in order to build a consensus efficiently through democratic dialogues on the introduction of small hydropower systems. In Japan, actually, regional development with civic participation and endogenous processes for forming main constituents are enthusiastically researched. However, there is a paucity of studies on how to create the main constituent for installing small hydropower plants in rural areas. The purpose of this study is to reveal what kind of action contributes to the creation of local main constituents through a project for implementing small hydropower systems in Asakura City, Fukuoka Prefecture. We analyzed what kind of activity brought about positive influence to the formation of local main constituents based on the results gained through participant observation on each activity and a hearing survey with each resident. We revealed that the new style survey had significant effects on formation of the local proactive body for installing small hydropower systems. The proposed survey takes into account the social aspects at each candidate location as well as the physical potential, namely the feasibility of small hydropower generation is evaluated based on both physical and social potential. We also revealed that the proposed survey gave positive effects on organizing the proactive body that was vital to the smooth and prompt implementation of small hydropower systems for regional vitalization.

1 INTRODUCTION

The use of renewable energy is becoming more popular worldwide over the past decade for the purpose of the environmental preservation against global warming. The number of renewable energy facilities has been on the increase since 2000. In particular, the demand for renewable energy has been rapidly growing since 3.11 known as the Tohoku earthquake in Japan.

Installing renewable energy is one of the methods for regional development and vitalization in rural areas because it helps improve the environmental value in the area by realizing the low-carbon society. The promotion of the use of energy from renewable sources contributes a lot to the economic vitalization in mountainous regions facing the problems such as population aging and depopulation [1]. This is because the exchange population increases through green tourism, local industry and new industry creation. Installing renewable energy is also effective to enhance the consciousness of appropriate preservation and management for natural resources.

Ministry of the Environment in Japan started “Community-Based Renewable Energy Project” from fiscal 2011 [2]. In 2011, 7 out of 68 proposals were adopted and medium/small-scale hydropower generation is considered in 6 projects, which indicates that medium/small hydropower attracts considerable attention in Japan. One of the common definitions of small hydropower is eco-friendly power obtained from water less than 10 MW in size. Small hydropower generation does not need heavy investment in its installation and large-scale development such as water-storage dams. Small hydropower schemes produce a predicable supply of electrical energy compared to other renewable technologies. Japan has many rivers and ample water resources because the greater part of the Japanese landmass is mountainous, which is suitable for hydropower generation. In addition,

people living in rural areas eager to vitalize their region with the help of the river since their lifestyle is closely related to the river.

Basic plans and policies for energy are determined by the Japanese government in general, thus energy managements have been entrusted to private business operators so far. Local governments, therefore, have not been qualified to get opportunities to take part in the discussion about energy plans and policies. It is shown in [3] [4] that local residents and governments are required to participate in the argument for the introduction of plants in order to realize the smooth and prompt spread of renewable energy. Small hydropower system uses the river whose degree of publicness is quite high. In Japan, there exist hard and fast rules on the uses of water of a river, which are decided by the government in charge of the river. Whoever makes use of the river has to obey the rules. The spread of small hydropower does not make much progress since it takes a lot of time to adjust the water rights. Trust from local residents may be lost if small hydropower plants are installed without their agreement. It is necessary that the main constituent that consists of the local residents and governments should be formed in order to build a consensus efficiently through democratic dialogues on the introduction of a small hydropower system. The main constituent for small hydropower plants serves not only as a business operator but also as a planner of the community vision. In this paper, the term main constituent is defined as a local organization that provides the residents with place where they can proactively discuss the usage of regional resources and can make democratic decisions on their community vision. In Japan, actually, regional development with civic participation and endogenous processes for forming main constituents are enthusiastically researched. However, there is a paucity of studies on how to create the main constituent for installing small hydropower plants in rural areas [5] [6] [7].

The proposed project is moving forward for installing small hydropower plants in Asakura City, the pilot area in this study, keeping in mind the fact that main constituents comprised of local residents and local government officers were absolutely vital to the smooth and prompt implementation of them. The purpose of this paper is to reveal what kind of action contributes to the creation of local main constituents through a project for implementing small hydropower systems in Asakura City, Fukuoka Prefecture.

2 FIELD SITE AND METHOD

2.1 Basic information of Asakura City

In this study, we set Asakura City, Fukuoka Prefecture as the pilot area. Asakura City was born in 2006 as the result of the merger between one city and two towns: Amagi City, Asakura Town and Haki Town. Asakura City is located in the middle basin of Chikugo River, a class A river in Fukuoka Prefecture, and it has an extensive rice-growing area. The population of this city is 56,204, the ratio of juvenile population to total population is 12.9 % and the rate of aging is 27.6 %, as of September 2014. Asakura is famous for a triplicate waterwheel and it was designated as a National Historic Site in 1990. The triplicate waterwheel has supported agriculture all over Asakura City since around 1600. Asakura City is close to Fukuoka City, which is the largest city in the island of Kyushu. Fukuoka City is located inside the range of the commuting area from Asakura. However, the problems such as population aging and depopulation have been gradually advancing in Asakura.

Asakura City stretches 25 kilometers from east to west. There exist some differences in the range of their daily lives between the citizens of Amagi Borough and that of Haki Borough. In other words, they do not have their lifestyle in common. They are aware of the differences in their temperament that result from their lifestyle. The lack of common perceptions shared among the residents is regarded as a problem in the view of the future of Asakura. In 2012, Asakura City suffered great damage form the heavy rain. In particular, Haki Borough suffered great damage from the flood, where two people were killed and a few colonies were isolated since they were cut off from communication. The heavy rain also caused even more flooding in Hita City and Yame City close to Haki Borough, which resulted in the largest damage in the entire area. These two cities received much attention from the media because of the serious damage. A number of volunteers gathered in these cities due to intense media coverage in order to help the sufferers recover from the aftermath of the disaster. Meanwhile, Haki Borough had a lack of volunteers and there was not significant progress in the revival. This was because almost all the residents in the damaged areas were the aged, so they had difficulty in disposing of the rubble. Even in these adverse conditions, though few in number, volunteers from universities and other regions gradually got together in Haki Borough. Thus the residents in Haki Borough were becoming aware of necessity for the network connecting local communities and universities.

2.2 Method of this study

We had continuously participated in the project for installing small hydropower systems in Asakura City for three years, from August 2012 to August 2015. In the project, we had taken part in some activities such as an observation study of the advanced areas in which small hydropower plants are enterprisingly installed, a survey on small hydropower potential, an implementation of handmade power plants and spiral waterwheels, workshops, open seminars and symposia on small hydropower systems, environmental education and a regular meeting. We analyze which activity stated above brings about positive influence to the formation of local main constituents based on the results gained through participant observation on each activity and a hearing survey with local residents. Participant observation is one type of the methods for data collection, where the observer takes part in ongoing activities and observes their progress carefully to make a record of them. Whether a local main constituent is formed or not is determined by focusing on changes in utterance and actions of residents in the activities above. On top of that, we take into account the changes in a role of residents in an organization. We conclude that a local main constituent is created if these changes are caused by spontaneity of residents. Details on these activities are explained as follows.

- Observation study of advanced areas

Some residents inspected the advanced areas where small hydropower plants had already been implemented so that they could have concrete ideas or visions to introduce small hydropower systems into their region. Through the symposia and seminars held in the advanced areas, they acquired and shared lots of knowledge on how to successfully install small hydropower plants and how to develop a region with renewable energy.

- Survey on small hydropower potential

In order to plan to install small hydropower plants for the sake of regional vitalization, we carried out the potential survey that considered both physical and social aspects of the region. Physical potential was assessed by topography and water volume at each location. Social aspect includes the opinions of residents, history of floods and relation between their lifestyle and the usage of river water, to name a few.

- Implementation of a handmade power plant

Some proactive residents constructed a handmade power plant in Shirakitani Borough. The plant had a traditional wheel made of wood and a hut to save power plant equipment. Both of them were made by the residents themselves. In addition to the wooden wheel, they eventually installed a propeller wheel made in Indonesia, and they could succeed in power generation with it in cooperation with Watershed Management Laboratory in Kyushu University, which was the first successful implementation in Japan. They gave a demonstration of their handmade plant to whoever visited them to observe it.

- Symposium on small hydropower systems

Some residents held symposia on small hydropower systems for the purpose of conveying the significance of the system to other residents and their becoming interested in it. They carried out an on-site inspection of Shirakitani Borough at once. Many people external to Asakura City had participated in them.

- Workshop and open seminar on small hydropower systems

Some residents planned workshops and open seminars to study about small hydropower systems. They invited some experts in the several fields, so they could figure out how small hydropower plants worked and for what the electric power generated from the system was used in general. Making full use of the knowledge they had acquired, the residents came up with ideas on usage of the power for their local community. These events gave the residents some clues to install small hydropower plants successfully.

- Environmental education

The residents who are familiar with environmental issues gave classes for environmental education to elementary school students so that the students would have more interests in environmental problems. The students learned about environmental issues, renewable energy and the small hydropower scheme. After the class, the students actually assembled a kit to make a spiral waterwheel with a dynamo that had been developed in Japan, and they went to the stream nearby their school to experience small hydropower generation with the handmade spiral waterwheel.

- Implementation of spiral waterwheels

The spiral waterwheels that had been assembled by the students were set into their school zones, which are used for environmental education for elementary school students. The electric power obtained from the spiral waterwheels was used for streetlights.

- Regular meeting

We had regular meetings at least once a month. Participants of the meetings were residents who had been proactive at installing small hydropower plants, government officials and people from the university. We confirmed the progress of the project and discussed what we should prepare for the upcoming events. The regular meeting was also a good opportunity to share our knowledge and experience.

3 RESULTS OF THE CASE STUDY FOR INSTALLING SMALL HYDROPOWER PLANTS IN ASAKURA CITY

3.1 Results of participant observation on the project

3.1.1 The details of the project "The survey on small hydropower potential in Asakura City 2012."

In 2008, "Challenge College of Asakura City for local vitalization" (as referred to Challenge College) was started as a public project in Asakura City. The major aim of Challenge College was to provide the place where citizens could enhance their ability to solve the various social problems through the eyes of them. Challenge College did not receive financial support from the city government of Asakura, so it had been run by college fee support money from companies and grant funding. Challenge College had various seminars, one of which was a seminar on small hydropower systems. Students finding a way for local vitalization decided to introduce small hydropower plants in Asakura. Some students took part in other seminars and they acquainted us with the residents familiar with the local community, then we gave the residents the information that Fukuoka Prefecture had established a grant system for potential surveys on small hydropower. We suggested that the city government of Asakura should apply for the grant. Thus the project started in August 2012 in cooperation with the department of environment in the city government, voluntary residents and our laboratory.

3.1.2 "The survey on small hydropower potential in Asakura City 2012."

We were entrusted with the potential survey on small hydropower, and we conducted it. At the beginning of the project, we were required to set up council of advisers, so we conferred with officials in charge of this project on how we should choose advisers. We decided to nominate residents with enough knowledge on Asakura as the advisor. We invited citizens to join the council through a brochure monthly issued by the city government, and anyone interested in small hydropower systems was allowed to participate in the conference. As a result, the council consisted of voluntary residents such as leading members of the small hydropower seminar in Challenge College and people from community organizations, the land improvement district, and the forestry cooperative and civic associations.

We performed fieldwork with members of the council at each candidate location in all the rivers in Asakura. We had to measure flow rate and the head of water at each candidate location with them. Note: The head of water refers to the quantity of water. We asked the members to show us the river with higher potential and introduce us to regional residents who have much knowledge on the region. The members of the council who came to guide us were just looking at our measuring process at the beginning. However, they tried to learn how to measure the flow rate and head by watching us. Finally they picked up the instruments and started measurement on their own initiative instead of us, and they seemed to be used to the measurements quickly. After finishing the physical potential survey, some residents participating in the measurement gave an interview with other residents who lived near the candidate location. They heard about current state of the river, problems of the local community, local history related to water management and a record of floods.

After the fieldwork, we checked whether the results of actual measurement were correct or not by comparing them with the results from another survey which estimates flow rate at each point from inflow data of dams nearby. We assessed how much output the plant would produce and how much profit could be gained selling the electric power generated from it. Some participants attempted to vitalize their region with money that was made by selling power back to an electric company using the feed-in tariff program, only to find it inappropriate to make money with small hydropower systems. The results of the survey implied that the power was not applicable to commercial use because the plant would be able to produce very little power even if it works fine. While some participants were disappointed with the result, the others expected that small hydropower plants could be used for regional vitalization on an even smaller scale than commercial use such as a streetlight or an electrified fence against animal damage. The residents understood that electric power from small hydropower systems theoretically depended on the flow rate and the head of water, but they could not concretely

imagine how much water a streetlamp required to be turned on. Hence we suggested that they make some simple experiments so that they could create a concrete vision for installing small hydropower systems in their region since we had co-developed a small-scale dynamo with a local company near our university before. One of the participants, who was an architect engineer in Shirakitani Borough, set his mind on making a traditional wooden wheel by hand, and he could complete the wheel with the help of other positive residents in accordance with our proposal. After finishing the handmade wheel, an electrical engineer belonging to Kyushu University prepared a dynamo that had a handmade coil for them. Thanks to these components, they finally completed the small hydropower plant that was able to produce approximately 100 watts in power, which was sufficient to power a single street lamp.

We succeeded in making an entire potential map and submitted a report on the small hydropower potential of Asakura, but the residents had no idea how they could contribute to regional vitalization with small hydropower systems. As a final result of the project, we recommended that they should install small hydropower plants for the sake of solving the problem caused by a lack of common perceptions shared among the residents in Asakura as well as regional vitalization. Finally our laboratory concluded an agreement with Asakura City, and the proactive main body named as an association for promoting small hydropower plants in Asakura City was organized.

3.1.3 After the "The survey on small hydropower potential in Asakura City 2012."

On the following year after the survey, the proactive body had strengthened partnership among citizen-government-academia going straight for the common goal of installing small hydropower systems. The new local organization called an association for the small hydropower project in Shirakitani Borough was born as a portion of the association for promoting small hydropower generation in Asakura City. They had the same final goal that they would vitalize their region with the small hydropower plants, but each of these associations played a different role to achieve the goal efficiently. They raised money for their activities by themselves even after the project with us. We tried not to give them much advice on regional vitalization at all times. Meanwhile, we provided technical knowledge on small hydropower systems with them, if necessary. Therefore they were likely to become independent of us. Even after the potential survey, they had delightfully taken activities for installing small hydropower systems in cooperation with citizen-government-academia.

3.2 Analytical results

In accordance with the method of this study in Section 2.2, the results were analyzed through participant observation on each activity and a hearing survey with local residents so that we could discover which activity brought about positive influence to the formation of local main constituent.

- After the survey, the members who came with us as a guide were just looking at our measuring process at the beginning. We saw some residents participating in the measurement give an interview with other residents.
- The proactive residents were likely to become independent of us.
- They raised money for their activities by themselves even after the project with us.
- They had taken activities for installing small hydropower plants with delight in cooperation with citizen-government-academia.
- The council of advisers changed to the two associations, and the role of the council was taken over by them.
- These associations had made aggressive and successive actions.
- The proactive residents shared the results obtained by their actions in cooperation with other residents.
- Some proactive residents constructed the handmade power plant in Shirakitani Borough. Mr. Inoue, who had responsibility for management of the plant, said, "This plant can give brave to people in other depopulated areas." on 13th September 2013.

We had played a leading role in the project for installing small hydropower systems. According to Table 1., we can find that the number of activities taken by the residents began increasing just after finishing the survey. As a result, the leader of each activity changed from us to the local proactive body. Furthermore, a vast range of activities with resident initiation had continued. This indicates that the proactive body for installing small hydropower with resident initiation was formed.

As a result of participant observation, in viewpoint of residents' spontaneity, the behaviors and statements of the residents changed significantly before and after the proposed survey. In consequence, the proposed survey made the residents more spontaneous, and the proactive behaviors spread over other residents. The factors that made positive effects on formation of the proactive body were as follows.

- Promotion of the voluntary participation in the survey

- Cooperation with citizen-government-academia
- Discovery of new local resources obtained from the proposed survey
- Graded independence of the proactive body

The details on the proposed survey are given in the next section. It takes into account the factors above.

Table 1. Activities in chronological order.

Before 2012	Observation study of advanced areas: Fujioiro small hydropower plant in Oita Prefecture
Jun 2012	Observation study of advanced areas: the symposium on small hydroelectric energy in Itoshima, Fukuoka Prefecture
August	The inauguration of the council of advisers for installing small hydropower plants
September	Map works
October	Potential survey (twice), The council of advisers changed to “an association for promoting small hydropower plants in Asakura City.”
November	Potential survey (twice)
December	Potential survey (3 times)
January 2013	Reflection of the results in the map
March	Observation study of advanced areas: Haki small hydropower plant in Gokase Town, Miyazaki Prefecture
May	Completion of a handmade small hydropower plant in Shirakitani Borough and Haki Borough
Jun	Observation study of advanced areas: the symposium on small hydropower systems in Gokase town, Miyazaki Prefecture
August	Open seminar with high school students
November	Implementation of a spiral wheel in Haki Borough
March 2014	Symposium on small hydropower systems
September	Demonstration on the plant with a propeller wheel made in Indonesia, (only to fail,) Environmental education in Kugumiya elementary school, Haki Borough
November	Observation study of advanced areas: Shiraito small hydropower plant in Itoshima City, Fukuoka Prefecture, Demonstration on the plant with a propeller wheel made in Indonesia (success)
January 2015	Completion of a new handmade wooden wheel in Shirakitani Borough and Haki Borough, Symposium on small hydropower systems
February	Open seminar, where the man who made the wooden wheel was invited, Environmental education in Kamiakiduki elementary school, Amagi Borough
March	We accepted an observation study in Shirakitani Borough: a minister of the Republic of Afghanistan and Dr. Tetsu Nakamura, a head of NGO
July	We entrusted an experiment of power generation with the propeller wheel made in Indonesia
August	We accepted an observation study in Shirakitani Borough: officials of Ministry of the Environment in Japan

4 DISCUSSION

4.1 The new style survey

The new style survey proposed in this paper is conducted by investigators accompanied with local residents, and it is comprised of map work and field work. In the map work, they choose some locations as a candidate for installing small hydropower plants on a map. The field work, which is made up of the physical and social potential survey, is conducted after the map work.

The physical potential at each location for the candidate selected in the map work is assessed by the theoretical formula in (1). Let Q be the flow rate and H_e be the head of water, where the head of water means the quantity of water and is just referred to as Head in this paper. The gross power generated from small hydropower systems is calculated by the following equation.

$$P(kW) = Q(m^3/s) \times H_e(m) \times g(m/s^2) \times \rho(kg/m^3) \times \eta \quad (1)$$

where g denotes the gravitational acceleration and η is the energy efficiency of the system. Small hydropower potential depends on the flow rate Q and the Head H_e. The flow rate at each location is actually measured in accordance with the following procedure illustrated in Figure 1. First, a width of the river is divided into N equal segments whose length is w. At the midpoint of the nth segment ($n = 1, 2, \ldots\ldots, N$), we measure the depth h_n and the flow velocity v_n by means of the velocity meter. Second, the cross section at the nth segment, denoted by A_n, is given by multiplying w by h_n. The flow rate at the nth segment is estimated as the product of A_n and v_n. Finally the entire flow rate Q is obtained as

$$Q(m^3/s) = \sum_{n=1}^{N} A_n v_n, \qquad \text{where} \quad A_n = w h_n.$$

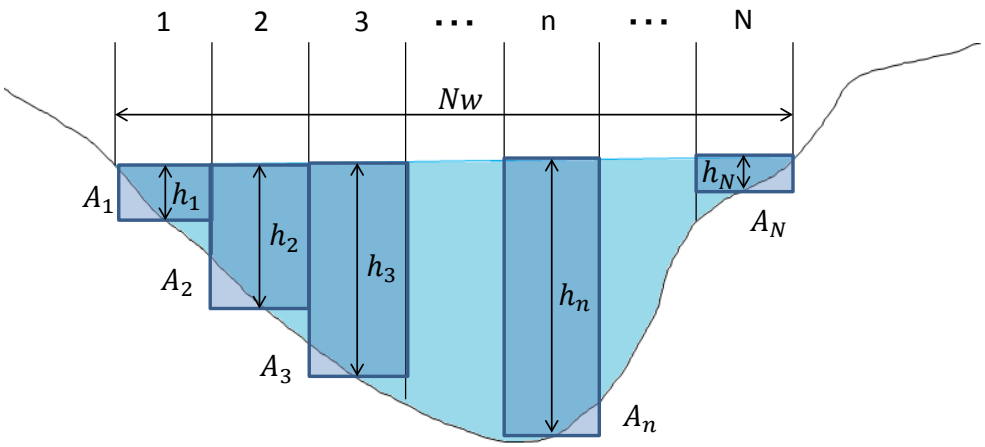

Figure 1. Horizontal section of the river.

The social potential is evaluated based on a hearing survey, and it is also carried out by us accompanied with local residents in parallel with the physical potential survey. The social potential survey is made up of the following three surveys.

First, we give an individual interview to some residents living around each location selected in the map work in order to hear their opinions about the installation of small hydropower plants. We also hear what kind of thing has made their community suffer so far and what they are thinking of their community vision for the future. Second, we arrange positional information about mountains, rivers, intake facilities, shrines and temples nearby the intake facilities so that we can ascertain each location for the candidate to be pertinent to the implementation of small hydropower plants. Shrines and temples are often built nearby the place where there had been a flood before. The location that suffers from frequent floods is not suitable for installing small hydropower systems. It is an effective way to give an interview with the aged who are familiar with the region. Third, we investigate the history of the region and the relationship between their lives and water. We also check whether the festivals held in the region are related to water or not. The book on the regional history issued by the local governments gives us much information about them.

We share the results obtained from these surveys above with the residents. We discuss the results and let the residents present their ideas for regional vitalization. We also invite other residents who do not live in the region to the discussion so that we can hear the opinions with a different perspective. In this way, we can collect many ideas for regional vitalization with small hydropower plants. After the discussion, we summarize the results of discussion, for example ideas and opinions of the residents, feelings about the survey, and what they noticed during the survey. In addition, we reflect the results by writing them on the map we used in the map work or putting up the pictures we took during the survey. In the end, we discuss again to prioritize the candidate locations by means of the map with the residents.

4.2 Discussion

In this study, we revealed that the new style survey had significant effects on formation of the local proactive body for installing small hydropower systems. The proposed survey effectively took into account the social aspects at each location as well as the physical potential, namely the feasibility of small hydropower generation

based on both physical and social potential. Preliminary to the proposed survey, we created the council of advisors. Anyone interested in small hydropower systems was allowed to participate in the conference, which led to positive attitudes of the residents. We moved forward with the project in collaboration with citizens, governments and academia. In the proposed survey, some residents accompanied us as guides and they then experienced the physical and social potential survey learning about the history of the region or the record of floods through an interview with many other residents. This helped them to recognize the problems of their community through repeated learning and meeting, which increased ownership. Once problems were identified, thinking of what they could do to solve them for the community in the future occurred. Moreover, they shared the results obtained by their actions in cooperation with other residents. This appeared to lead to more progressive actions.

The conventional survey is carried out exclusive of the city government and residents in general, and the results on the physical potential are only reported to them. However, the proposed survey used in this study took into account the social potential as well as the physical potential. The analytical results signified that the proposed survey contributed significantly to formation of the proactive body for the implementation of small hydropower plants. Participation of the residents in the potential survey produced a lot of positive effects such as trust and ownership. One of them is that they recognized the problems that their community suffered from and were then able to start to solve them, which brings the accumulation of knowledge on the region through the survey. In addition, the activities for installing small hydropower plants are gradually regarded as those for regional vitalization involving many other residents. As stated above, the proposed survey with resident initiation produces positive effects on organizing the proactive body and it is vital to the smooth and prompt implementation of small hydropower systems for regional vitalization.

5 CONCLUSION

In this paper, we took advantage of participant observations on the project for installing small hydropower systems in Asakura City in order to elucidate what kind of action contributes to the creation of local main constituents. The proposed survey evaluates social potential as well as physical potential at each location for a candidate. Analytical results of participant observation specify that the proposed survey had positive effects on positioning the main constituent in the installation of small hydropower generation.

6 ACKNOWLEDGE

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