Doctoral Thesis (Abridged)

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Evaluation of public acceptance and co-existence strategies of marine renewable energy development in Japan

（日本における海洋再生可能エネルギーの社会受容性と共存戦略の評価）

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A Dissertation

by

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ABSTRACT

Marine Renewable Energy (MRE) which consists of offshore wind energy, wave energy, tidal and ocean current energy has been identified as a key component of global renewable energy production. However, MRE industries are still in their initial phases except for offshore wind energy in Europe. With the increased urgency to avoid conventional energy sources, Japanese government has given prominence to accelerate the development of MRE industry to commercial level in the last decade. Japan's MRE sector is in transition to the commercial scale thus will create significant impacts to the local marine users in the future. However, on the contrary to European cases, Japan still lacks clear policies and regulations which provide guidance and legal assurance for the MRE sector. General public also have a vague perception about the ocean as a source of energy. According to the existing regulations which are complex and scattered, MRE project developers are given the responsibility of getting the consensus of local stakeholders prior to the project initiation. Further, the policy makers are required to obtain the local consensus for the development of long term marine spatial plan and a management strategy which satisfies the requirements of MRE sector. Understanding the public acceptance behavior and creating a sustainable co-existence among stakeholders have been identified as the cornerstones of consensus building for MRE projects. Literature review has shown that there is no universal formula for local acceptance which varies significantly with the local conditions, project management strategies, stakeholder knowledge and perceptions. Further, there is a significant research gap on understanding public acceptance of commercial MRE projects in Japanese context and options to create co-existence between local community and MRE projects. Hence the objective of this study is to 'analyze local stakeholders' MRE acceptance, underlying factors and potential co-existence options for the development of commercial MRE projects in Japan'. Specific research questions focused in this study are; (1). 'What is the current stakeholder acceptance level, trend and underlying factors of MRE acceptance?', (2). 'What are the options available for creating a win-win situation and co-existence between MRE industry and local community?', and 3. 'What is the feasibility of the preferred strategy?'. The thesis is divided into six chapters where the first chapter is dedicated to the introduction to explain the above mentioned background data, research gap and objectives.

Second chapter explains the overall research framework with specific data collection and analysis methodologies used for the three research questions. This study used a 'case study approach' where Nagasaki and Kitakyushu MRE developments were selected as the main case studies. Stakeholders in the selected case studies have experienced the early phases of MRE sector which is now in transition from technology readiness phase to the commercial phase. Data collection was done through key informant interviews and focus group discussions, site observations and three questionnaire surveys between 2016 and 2019. Public acceptance factor analysis was done using descriptive statistics and logistic regression analysis. Evaluation of stakeholder preferences of potential co-existence options was done using multi-criteria analysis and Dempster Shafer Analytic Hierarchy Process (DS-AHP). A new computer software tool was developed to run the DS-AHP analysis. Feasibility of the optimum co-existence option was evaluated by technical and economic feasibility studies.

Third Chapter evaluates the public acceptance and underlying factors behind acceptance, focusing on the first research question. Nagasaki case study had a higher level of stakeholder interaction activities and about 63% have formed a decision to support MRE projects in contrast to the 40% in Kitakyushu. However majority of supporters have a soft decision or just a tendency which might change with counter-factual information. Supporters are more sensitive to the potential negative project impacts such as adverse effects to marine life, local fisheries, and have a high tendency to reduce existing support. Opponents' decision is more rigid and less sensitive to the potential project benefits. Sharing project information with stakeholders, inclusivity of local community interests, and improving stakeholder engagement have significantly improved the local acceptance. However sharing only positive project information also did not improve the level of acceptance in comparison to sharing both positive and negative information. Impacts to marine and bird life as well as local fisheries are sensitive factors of acceptance decision while majority are expecting an adverse impact with respect to those factors. Acceptance trend analysis indicated a reduction of the current acceptance level with the development of commercial level MRE projects. Hence the developers are expected to put more effort in consensus building to maintain the current level of acceptance. Strategies which ensure long term commitment and nationwide MRE development such as being first of many projects, government led projects tend to improve the local acceptability. Logistic regression shows that project characteristics and management practices employed such as sharing project information have a significant influence on local acceptance than demographic parameters such as gender, education and residence area. Perception of visual impacts and preference over the project location tend to differ from the literature from western context.

Fourth chapter evaluates the potential local benefit creation and co-existence strategies focusing on the second research question. A three step process of option identification, multi criteria analysis and preference evaluation was used. Five broader level co-existence options were identified from literature review and expert interviews in the first step; (O1) sharing in-situ, real time ocean information, (O2) using MRE structures as artificial reefs and support structures for commercial fishing, (O3) co-location with other industries such as leisure and tourism, aquaculture, (O4) sharing generated electricity for local users at a subsidized rate, and (O5) use of local resources to construct and operate the power plant, creating business involvement opportunities. Quantitative and qualitative data relevant to identified options were collected in the second step by key informant interviews based on criteria such as costs and benefits, scalability. This multi criteria analysis results were then used for the third step of DS-AHP multi criteria decision making model. DS-AHP preference results show that the main stakeholder, fishery industry generally prefers the option of sharing ocean information which can be generated by MRE projects. Further small and medium scale fishermen who use fishing methods which do not require large sea areas have shown a high preference to the positive environmental impacts created by underwater structures and their capability to act as artificial reefs. However, the general community preferred the fifth option of using local resources to construct and operate the power plant. It was identified that the co-existence option preference is highly dependent on individual impacts. Hence the co-existence preference was more dependent on the respondents' occupation than other factors such as geographical location. The level of preference for each option was different even among local fisheries according to their fishing method, and fishing scale, even though their general preference is for the ocean information sharing option.

Fifth chapter evaluates the feasibility of the optimum co-existence strategy as per the third research question. Fishery being the main stakeholder, their preferred strategy of sharing oceanographic information was further analyzed based on technical and economic feasibility perspectives. This analysis proved that most of the oceanographic information required by fishermen can be generated by the MRE projects' condition monitoring systems

(CMS) and supervisory control and data acquisition (SCADA) systems at a minimum additional cost to the developer. Fishers were willing to pay a significant amount in comparison to their current level of expenditure on ocean information due to the availability of high resolution, real-time, in-situ data such as depth-wise temperature distribution and current velocities. Comparison of fishers' Willingness to Pay (WTP) with the estimated additional costs indicated that it is financially feasible to achieve the proposed solution provided that fishers pay the identified WTP amount. Thus it was identified that oceanographic information sharing option is technically and economically feasible and has the potential to create a win-win situation between fisheries and MRE developers. Further analysis on the potential impacts and economic feasibility is required due to the uncertainty and unavailability of data, which will be the future work of this study.

As suggested in previous literature, provision of local benefits may lead to a higher public acceptance of renewable energy projects, if they were initiated as a policy requirement rather than a voluntary act by the developers. Hence the policy level implementation of these results is discussed in the sixth chapter. Overall summary of study, generalization of the results, limitations and future research opportunities are also discussed in the sixth chapter as the conclusion of the study.

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DEDICATION

Effort, dedication, and commitment were fundamental elements for the completion of my doctoral dissertation, but even more important was the support of my supervisor, family and friends. Today, I dedicate this important professional achievement to my supervisor, family and friends because without their presence, support, love, and understanding, I would have never been able to achieve my goal.

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LIST OF ABBREVIATIONS

ABM	- Agent Based Modeling
ADCP	- Acoustic Doppler Current Profiler
AHP	- Analytic Hierarchy Process
CBA	- Cost Benefit Analysis
CI	- Confidence Interval
CISE	- Common Information Sharing Environment
CMS	- Condition Monitoring System
CO_2	- Carbon Dioxide
CTD	- Conductivity Temperature Depth (sensor)
DS-AHP	- Dempster Shafer Analytic Hierarchy Process
DST	- Dempster Shafer Theory
DVL	- Doppler Velocity Log
EEZ	- Exclusive Economic Zone
EM	- Electromagnetic
EMEC	- European Marine Energy Centre
ERS	- EuroGOOS Requirement Survey
EuroGOOS	- European (component of) Global Ocean Observation System
FINO	- *Forschungsplattformen in Nord- und Ostsee* (Research platforms in the North and Baltic Seas)
GHG	- Greenhouse Gas
GOOS	- Global Ocean Observation System
GPS	- Global Positioning System
GPSS	- Graduate Program in Sustainability Science
ICT	- Information and Communication Technology
ICZM	- Integrated Coastal Zone Management
IEA	- International Energy Agency
IPCC	- Intergovernmental Panel on Climate Change
JAXA	- Japan Aerospace Exploration Agency
LCOE	- Levelized Cost Of Energy
MAFF	- Ministry of Agriculture, Forestry and Fisheries (in Japan)
MCA	- Multi Criteria Analysis
MCDM	- Multi Criteria Decision Making

LIST OF ABBREVIATIONS (continued)

METI	- Ministry of Economy, Trade and Industry (in Japan)
MFSTEP	- Mediterranean Forecasting System Towards Environmental Predictions
MLIT	- Ministry of Land, Infrastructure and Transport
MSP	- Marine Spatial Planning
NaMICPA	- Nagasaki Marine Industry Cluster Promotion Association
NEDO	- New Energy and Industrial Technology Development Organization
NIMBY	- Not In My Back Yard
NOAA	- National Oceanic and Atmospheric Administration
OTEC	- Ocean Thermal Energy Conversion
OWC	- Oscillating Water Column
R.Q.	- Research Question
RIOE	- Research Institute for Ocean Economics (in Japan)
SCADA	- Supervisory Control And Data Acquisition
SDG	- Sustainable Development Goals
WTP	- Willingness to pay

LIST OF UNITS OF MEASUREMENT

¥	- Yen (Currency of Japan)
%	- Percentage
GW	- Gigawatts
km	- Kilometers
kW	- Kilowatts
m	- Meters
MW	- Megawatts
n.mil	- Nautical miles
TWh	- Terawatt hours

1 INTRODUCTION

1.1 Marine Renewable Energy in the global perspective

Access to affordable and clean energy is central to nearly every major challenge and opportunity the world faces today. Thus the seventh sustainable development goal (SDG) of 'ensuring universal access to affordable, reliable, sustainable and modern energy through increased energy efficiency, increased use of renewable energy, and promoting investments on clean energy infrastructure and technology creating new economic and job opportunities' is crucial in creating sustainable and inclusive communities which are more resilient towards environmental issues like climate change. Second target of seventh SDG is increasing the share of renewable energy in the global energy mix substantially by 2030 (UN General Assembly, 2015). According to Edenhofer et al., (2014), electricity and heat production alone contributes to about 25% of the global greenhouse gas (GHG) emissions (Figure 1.1) and the energy sector has the highest emission reduction potentials in the future (Figure 1.2). Electricity is the key component of the energy sector which has the highest impact on GHG emissions. Hence, the desire for sustainable electricity generation is increasing steadily. The ratio of renewable energy to non-renewable energy at the point of generation is a key factor which determines the sustainability of the energy sector. However, in 2016, the Nuclear based electricity production is about 10.4% and the contribution of renewable energy sources (Hydro, Solar, Wind, Tidal Current etc.) is only about 24.3% of the global electricity supply (IEA, 2018).

Marine renewable energy (MRE) is often referred as the renewable energy resources that can be extracted from nearshore and offshore areas such as waves, tidal and ocean currents, thermal and salinity gradients and, offshore wind (Borthwick, 2016; Lewis et al., 2011; Soukissian et al., 2017). VanZwieten et al., (2013) has estimated the power densities of the most powerful ocean currents in the world while 'Huckerby et al., (2012) and Arent et al., (2012) have estimated the different other MRE potentials as shown in the Figure 1.3.

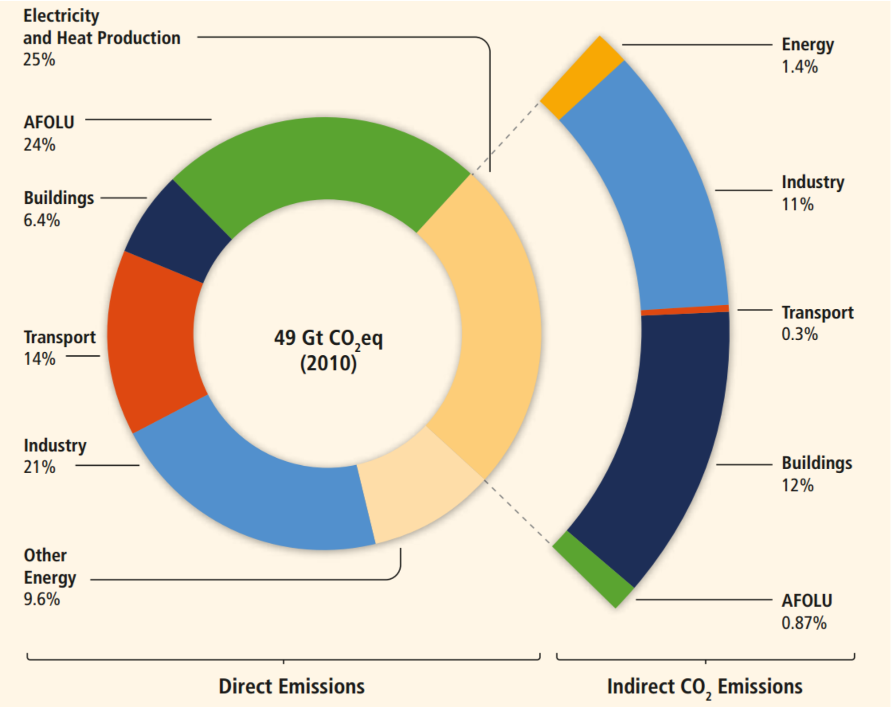


Figure 1.1 Greenhouse Gas Emissions by Economic Sectors in 2010

Source: Mitigation of Climate Change: Climate Change 2014 by Intergovernmental Panel on Climate Change (IPCC), Technical Summary, page.14 (IPCC, 2014)/ Edenhofer et al., (2014),

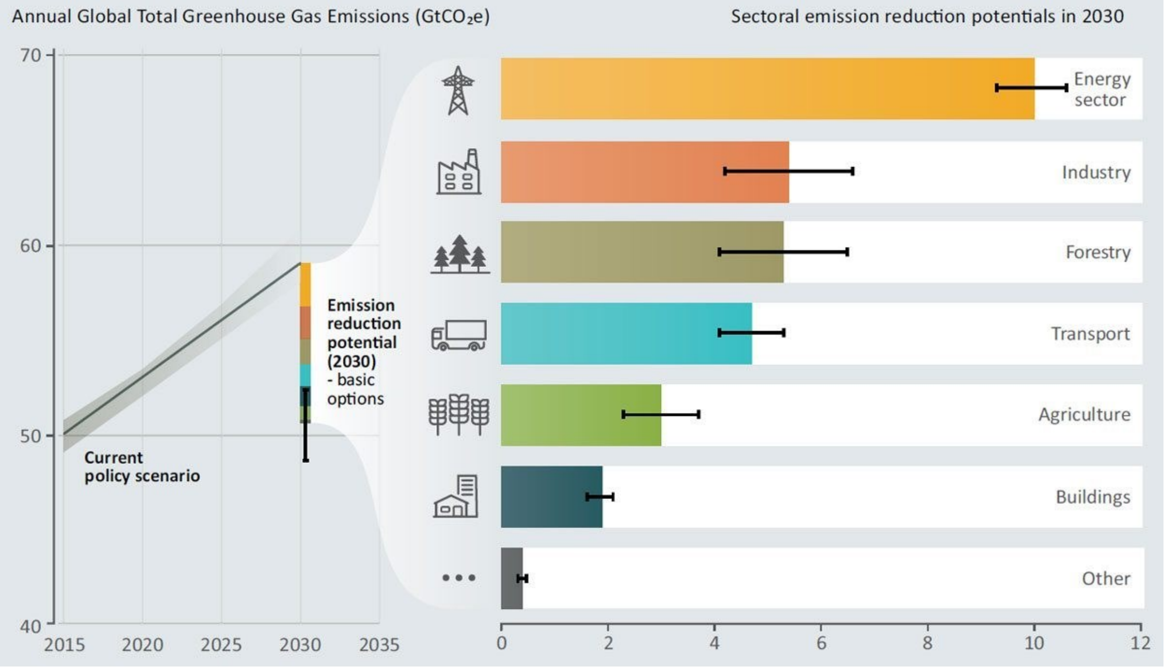


Figure 1.2 Annual Global Total GHG emissions and sectoral emission reduction potentials in 2030

Source: The Emissions Gap Report 2017, United Nations Environment Programme, page 33 (UNEP, 2017)

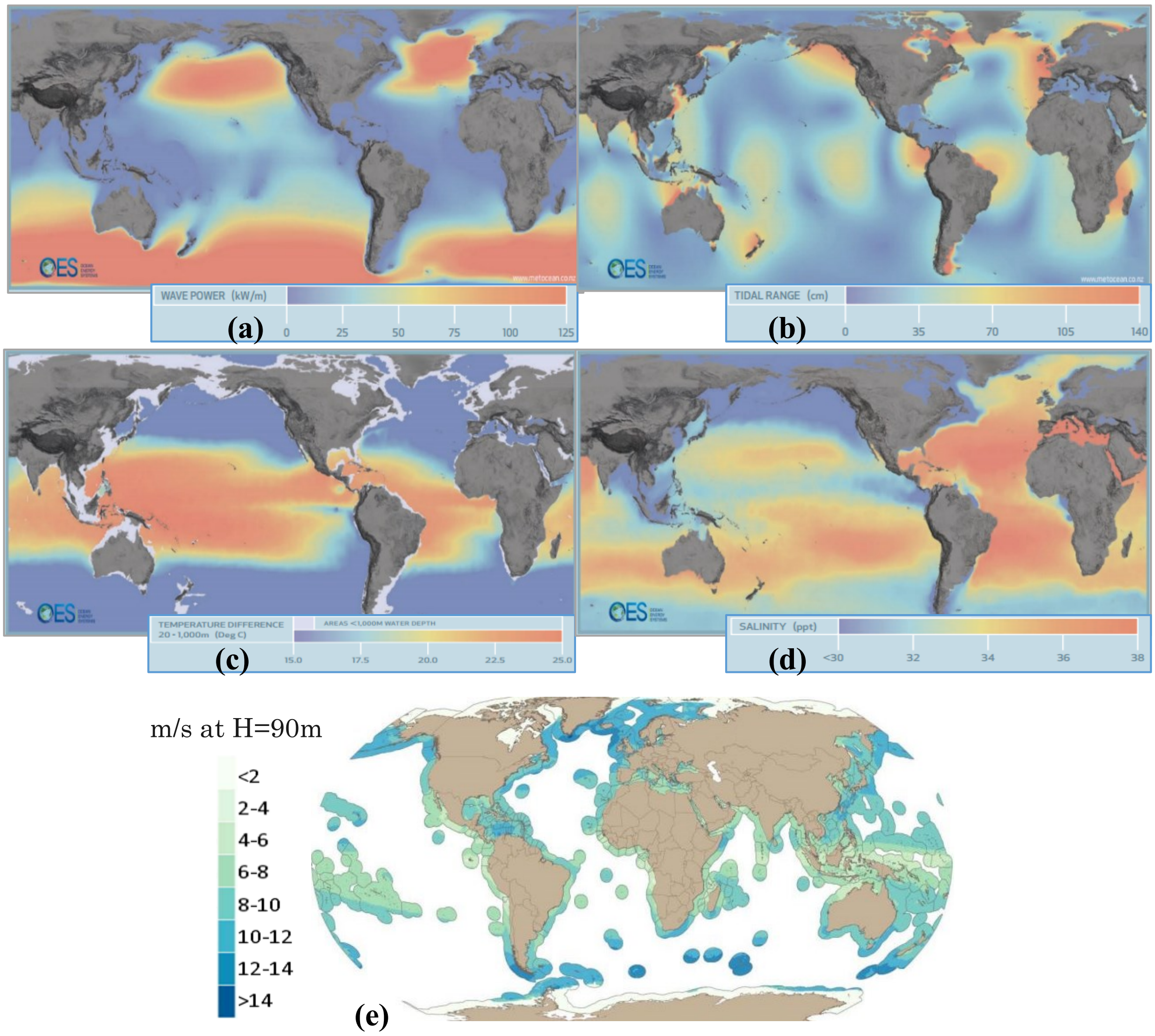


Figure 1.3 (a). Global Wave Power (b). Tidal power (c). Temperature difference (d). Salinity difference distribution (e). Offshore Wind energy distribution

Source: "An International Vision for Ocean Energy" Huckerby et al., (2012) and Arent et al., (2012)

Offshore regions near Western Europe has a significant energy potential from waves, tidal currents and offshore wind while the equatorial countries have lots of energy potential from ocean thermal energy. Having identified this potential, several European countries have started MRE projects and already reached the commercial level in offshore wind industry. By analyzing the similar cases in the past such as the gradual development of onshore wind and solar energy technologies, we can expect that MRE technologies also become popular in the future with the development of related technologies. Hence, there is a very high possibility for MRE to become a major energy source in the future global energy mix which will ultimately contribute to achieving a sustainable global energy supply.

1.2 MRE development in Europe

MRE development in Europe initiated in 1970s and many scientific advancements were made by 1980s but followed by a lapse of activities until 1990s (Mueller et al., 2010). Even though there have been demonstration projects to test different MRE technologies such as wave energy devices (Falcão, 2010, 2014) in 1970s and 1980s, the major MRE projects appeared after 1990 mainly in Europe. Many literature has separated offshore wind energy from other types of MREs due to the different development paths taken and associated technologies where the offshore wind was developed as an extension of onshore wind technologies while other MRE technologies had started as a separate field. Figure 1.4 shows the development of MRE projects since 1990s.

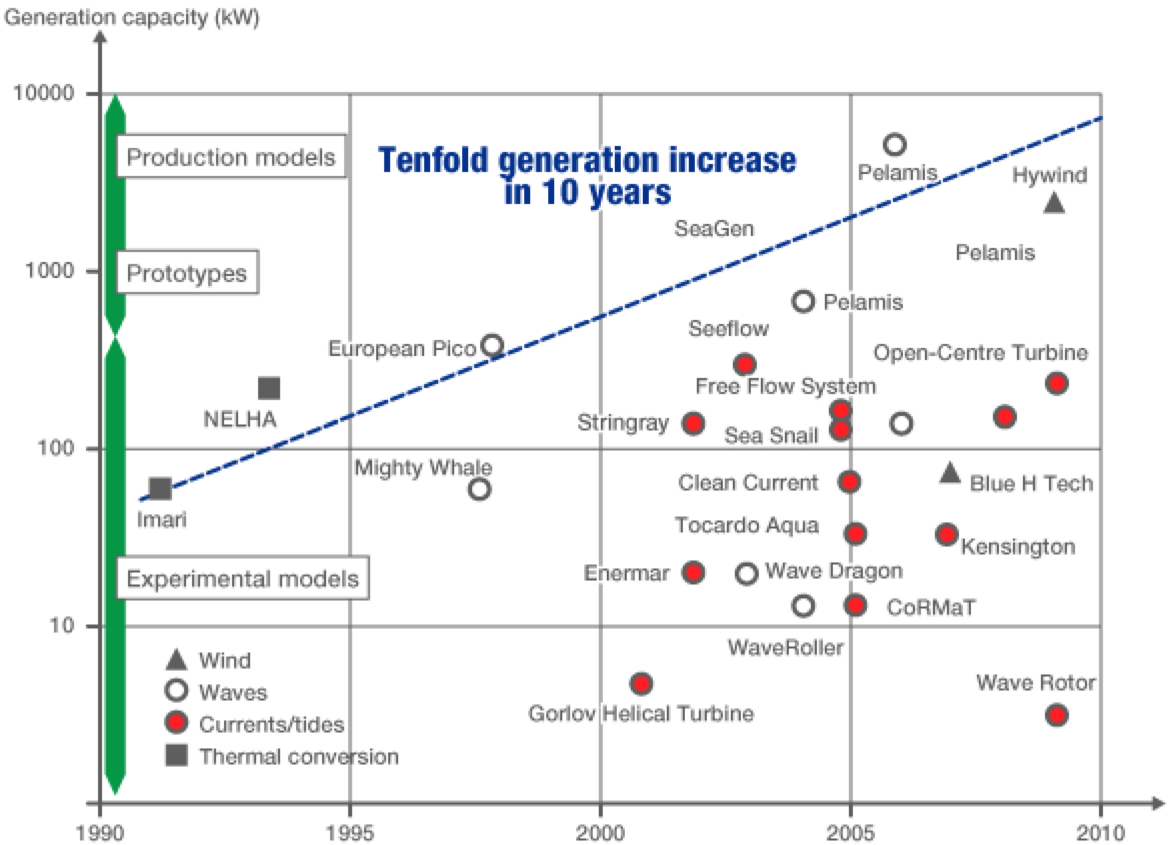


Figure 1.4 History of MRE development (excluding experimental offshore wind projects)

Source: Kitazawa, (2015) and : https://www.nippon.com/en/in-depth/a01203/ [accessed on 01/07/2019]

The first offshore wind turbine appeared in 1990 in Nogersund, Sweden (220 kW) and Vindeby offshore wind project (eleven turbines 450 kW each) developed in Denmark in 1991, was the world first offshore wind farm (Henderson, 2002). Offshore wind projects developed steadily thereafter in 1990s in European countries such as Sweden, Denmark, Netherlands, etc. as summarized in the Table 1.1. Figure 1.5 shows the steady growth of offshore wind development in the last decade which led to the large scale projects further away from shore and in deeper waters. Even though it is not yet developed to commercial level in terms of capacity and cost, Europe's tidal and wave energy is also in steady progress in recent years (Figure 1.6).

The steady development since 1990s has made the European offshore wind energy sector to reach commercially competitive with other energy sources by now and currently providing 2% of entire Europe's electricity requirement with installed capacity of 18.5 GW (WindEurope, 2019). In addition to the technological advancements and the establishment of supply chain industries, the steady development of MRE in Europe has resulted a well-established licensing system, long term national level policies and regulations, marine spatial plans with provisions for future MRE projects as well as a better public knowledge levels in Europe. Existence of the offshore oil and gas industry, and its gradual diversification towards MRE projects also have contributed for the high public awareness on MRE projects in European regions.

Most of European countries leading the MRE sector have a centralized authority over marine areas hence a centralized licensing system is applicable for new project developments. For example, 'Crown estate' is the owner of EEZ of UK waters and from whom the MRE developers have to get the user rights for their projects. Similarly, other European countries have organizations such as the respective national energy agencies in Netherlands and Denmark, Federal Maritime & Hydrographic Agency in Germany etc. with the sole authority over the MRE project developments. Further, 'a one-stop licensing process' as well as clear regulations and policy guidelines have been well-established in these countries. These types of non-technical aspects also have contributed to a rapid but stable development of MRE sector in Europe in comparison to the other regions.

Table 1.1 Details of initial offshore wind projects in Europe

Year	Offshore wind project	Capacity	Water Depth	Distance from shore
1990	Nogersund, Sweden	1 x 220 kW	7 m	250 m
1991	Vindeby, Denmark	**11** x 450 kW	3.5 m	1.5 km
1994	Medemblik, Netherlands	4 x 500 kW	5.1 m	750 m
1995	Tunø Knob, Denmark	**10** x 500 kW	3.5 m	**6 km**
1996	Dronten, Netherlands	**28** x 600 kW	5 m	20 m
1998	Bockstigen Valar, Sweden	5 x 500 kW	6 m	**3 km**
2000	Middelgrunden, Denmark	**20 x 2000 kW**	3.6 m	**3 km**
2000	Utgrunden, Sweden	7 **x 1425 kW**	7.1 m	**8 km**
2000	Blyth, UK	2 **x 2000 kW**	8 m	800 m
2001	Yttre stengrund Sweden	5 x **2000 kW**	6.1 m	**5 km**

Source: Barthelmie (1998) as quoted in (Henderson, 2002)

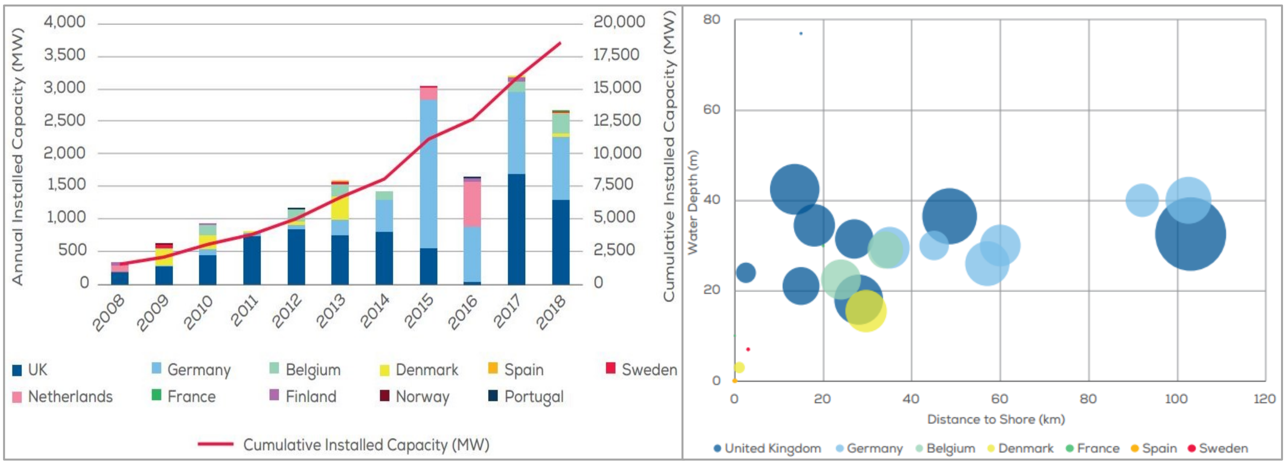


Figure 1.5 Offshore wind development in Europe in the last decade (left); Size and location characteristics of projects in 2018 (right)

Source : WindEurope, (2019)

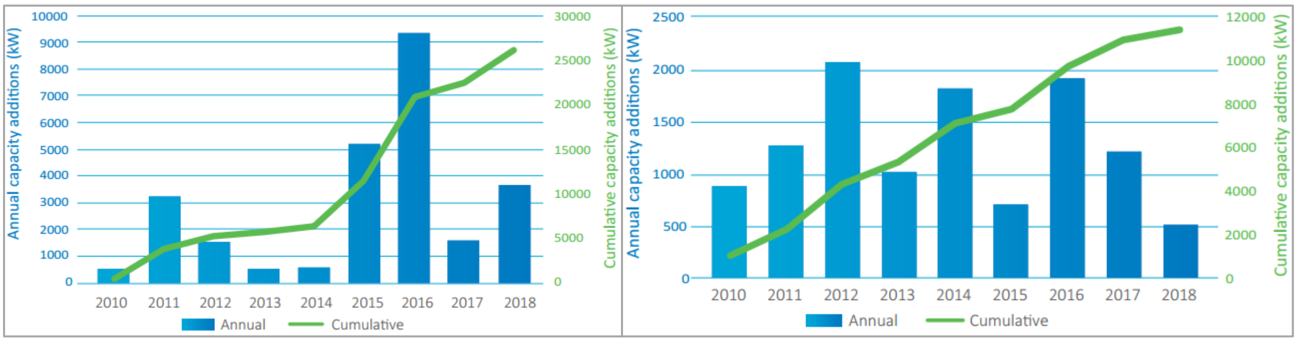


Figure 1.6 Tidal (left) and Wave (right) energy development since 2010

Source: Ocean Energy Europe, (2019)

1.3 MRE development in Japan

Figure 1.7 shows Japan's energy supply percentage by source during recent years and the energy generation target by 2030 according to the latest Japan's energy policy (METI, 2018). Japan has reduced the percentage of electricity generated from nuclear energy after the 2011 Fukushima disaster and shifted towards the Oil and Natural gas since the total demand has not been changed much. However, according to the 2030 target, burden from fossil fuel based energy generation is expected to reduce by increasing the nuclear power and renewable energy. However, MRE is not been considered in this plan since the related technology is still in the very early development stages to give a reliable estimate. Rather the 100% increase in renewable energy is expected from Solar, Wind and Geothermal energy (METI, 2015).

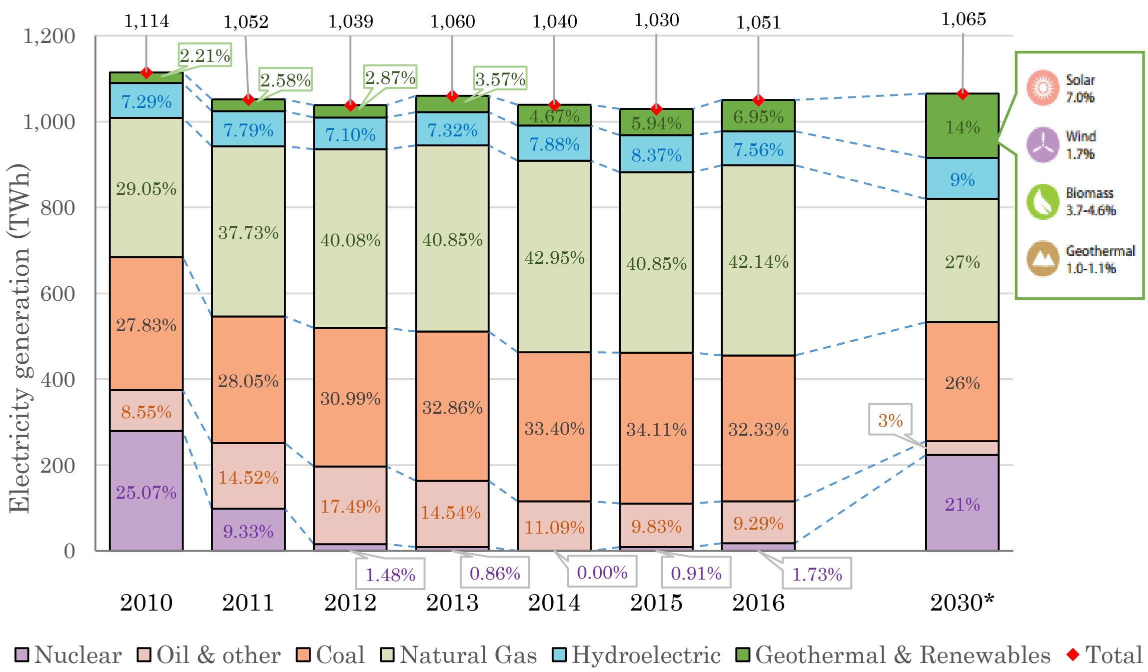


Figure 1.7 Historical trend of power generation & 2030 target by source in Japan.

Source: Agency for Natural Resources and Energy, (2019) and METI, (2015)

Even though the technology has not been proven to be commercially viable by actual deployments, past studies such as VanZwieten et al.,(2013), and MOE (2010) etc. have proved the high potential of offshore wind and other MREs in Japan. Figure 1.8 shows the distribution of different MRE potentials in the Exclusive Economic Zone (EEZ) of Japan. Since this high energy potential areas are within Japan's EEZ, there is no legal barrier to harness that energy from the open oceans.

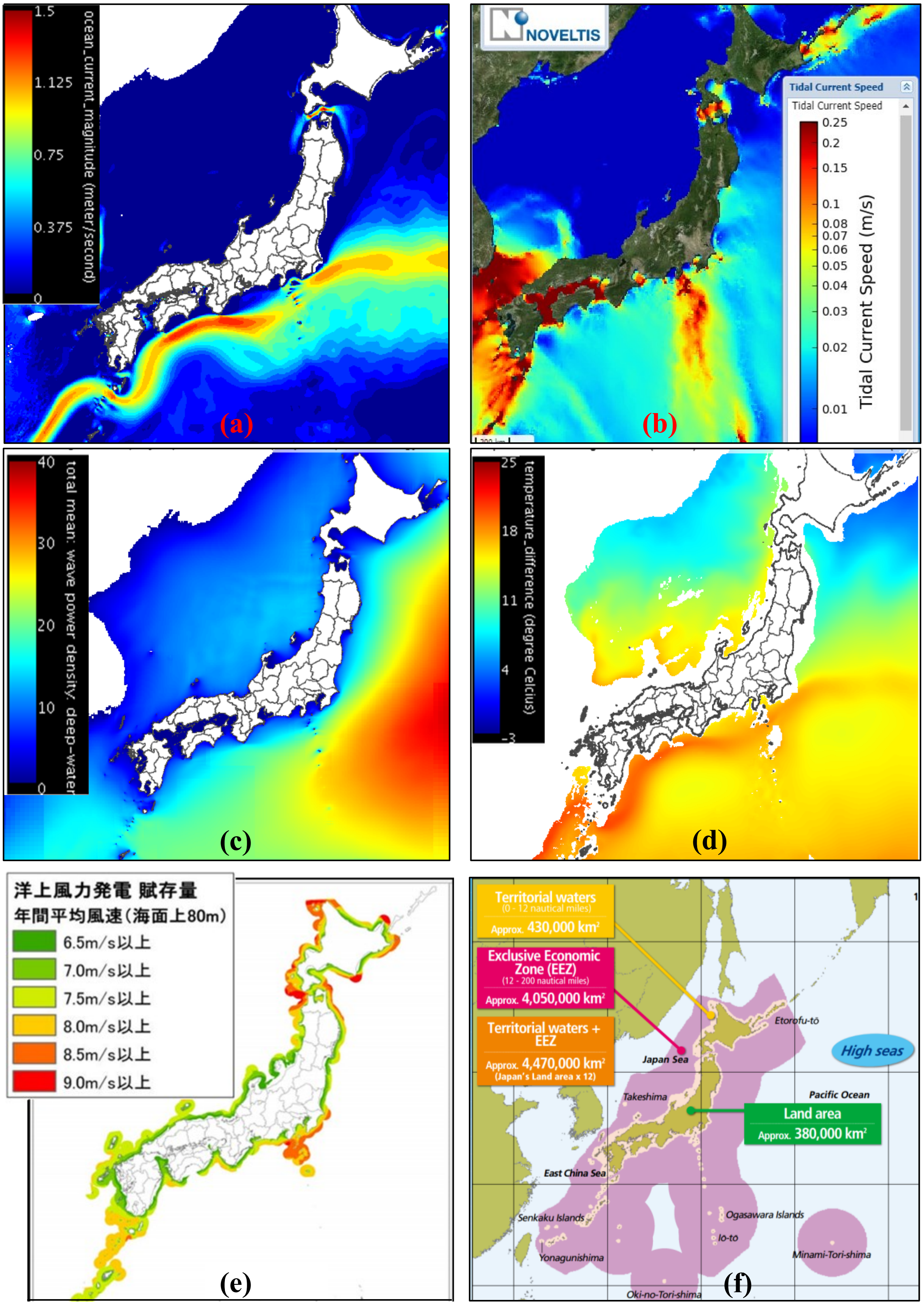


Figure 1.8 (a) Ocean current, (b) Tidal current (c) Wave, (d) Thermal, (e) Offshore wind energy potential and (f) EEZ of Japan

Source: Compiled by author from ME–webGIS , tips.noveltis.com, page 12, ITOCHU, (2010), Japan Coast Guard

Japan’s MRE development initiated in 1970s where the first wave energy convertor is developed in 1976 by Yoshio Masuda (who is considered to be the father of modern wave energy technology) by means of housing several oscillating water columns (OWC) equipped with different types of air turbines on a large barge named ‘Kaimei’(Falcão, 2010, 2014). Ocean thermal energy conversion (OTEC) project has been carried out by the University of Saga from 1982 and developed the IMARI OTEC project in 1992. The next main MRE project before 2000 was the floating OWC wave energy project named; ‘Mighty whale’ by JAMSTEC in the Gokasho bay in 1998. However, these key miles stone projects (Figure 1.9) that happened before 2000 were basic pilot projects aimed on validating related technologies and had minimum exposure to general public. Some level of public interaction with MRE projects started with the initial pilot scale nearshore wind projects developed in early 2000s shown in Table 1.2. Public interaction with offshore wind projects started due to the project siting in nearshore areas due to highly visibility.

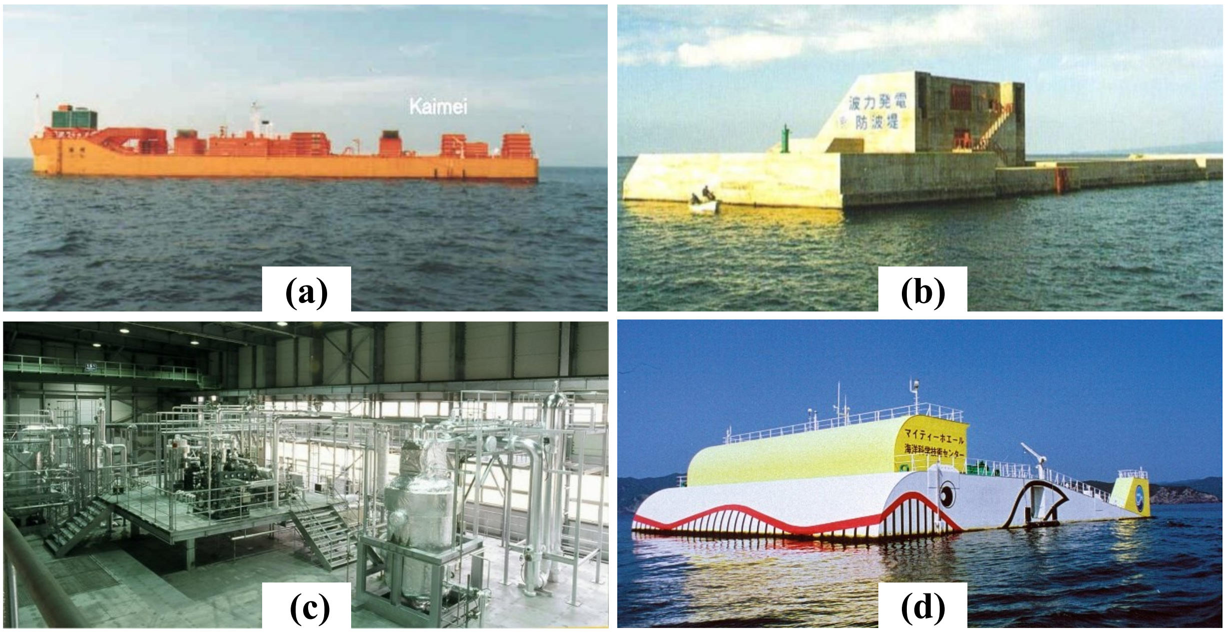
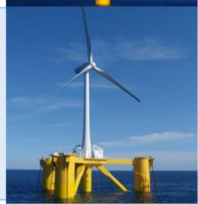


Figure 1.9 (a) OWC wave energy converter, ‘Kaimei’ in 1976, (b) 60 kW OWC plant integrated into a breakwater at Sakata harbor in 1990, (c) 30 kW OTEC facility in Imari in 1992 and (d) 110 kW floating OWC plant 'Mighty Whale' in Gokasho Bay, 1998

Source: (a), (b) - A. F. O. Falcão, (2014) (c) - http://www.ioes.saga-u.ac.jp/en/facilities/ioes_facilities, (d) - A. F. O. Falcão, (2014) and http://www.jamstec.go.jp/gallery/e/research/system/002.html [retrieved on 15th May, 2019]

The main reason for general public to have a vague perception of Japan's initial MRE projects, is that most of those projects were developed on the ocean areas belong to the ports or harbors. Since many of these projects were in port areas, developers had no requirement to do consensus building with stakeholders other than the local port authority. Further, there has not been policy guidance for developers to extend their development efforts until 2014, when the national government first announced the test site selection results for developing demonstrational MRE projects (Prime minister's Headquaters for Ocean Policy in Japan, 2014). With development of technological expertise as well as related national policies, many more MRE projects have been planned with the aim of commissioning in early 2020s.

Table 1.2 Pilot and commercial MRE projects in Japan after 2000

Time line	MRE project & location	Details	
2003	Nearshore wind project in Setana	2 turbines in Setana port area (~700 m offshore at 13 m depth) Total output 1.3 MW	
2004	Nearshore wind project in Sakata	5 turbines in Sakata port area (~50 m offshore at 4 m depth)) Total output 10 MW	
2010	Nearshore wind project in Kamisu	15 turbines in Nearshore (~50 m offshore at 5 m depth) Total output 30 MW	
2013	Floating offshore wind project in Nagasaki	1 floating turbine in offshore Fukue Island in Nagasaki (~5 km offshore), Total output 2 MW	
2013	Floating offshore wind project in Fukushima	3 floating turbines in offshore (~20 km offshore at ~120 m depth)), Total output 14 MW	
2013	Bottom mounted (Jacket) offshore wind project in Kitakyushu	1 turbine in Kitakyushu port area, (~1.4 km offshore at 14 m depth) Total output 2.4 MW	
2013	OTEC in Kumejima	Coastal region in Kume Island. 100 kW peak output with collaboration with local other industries	
2015	Nearshore wind project in Akita	6 turbines in Akita port area (on shoreline) Total output 18 MW	

Source: Made by the author based on JWPA (2017), http://otecokinawa.com/jp/index.html, http://www.eurus-energy.com/ https://www.4coffshore.com & https://www.thewindpower.net/ [retrieved on 15th May, 2019]

1.4 Legal situation, marine spatial planning, and coastal management practices

According to the "United Nations Convention on the Law of the Sea", sea areas up to 200 nautical miles can be used for the resource extraction (Figure 1.10).

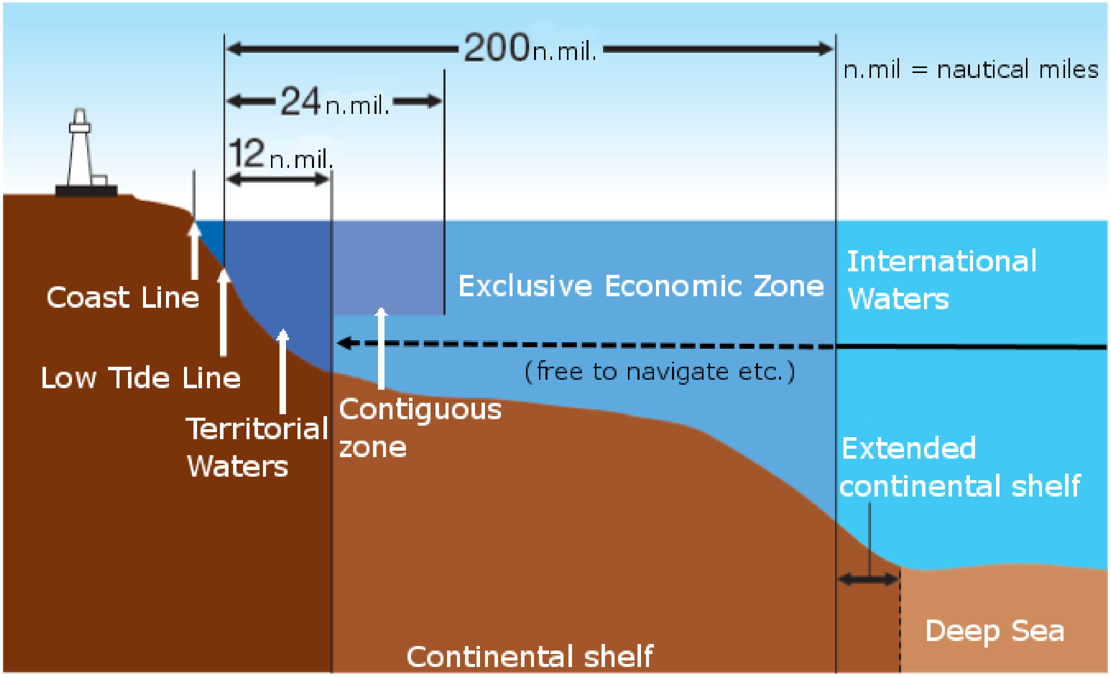


Figure 1.10 Explanation of Sea Areas defined by the United Nations Convention on the Law of the Sea

Source: http://www1.kaiho.mlit.go.jp/JODC/ryokai/zyoho/msk_idx.html [retrieved on 15th May, 2019]

According to the Prime minister's Headquaters for Ocean Policy in Japan, (2013, 2015), the deployment site selection of MRE projects has to comply with several procedures and regulations. However, the existing legal system is scattered among different acts, laws and governmental bureaus (Sakaguchi, 2015). National laws cover only ports and harbors, fishery ports, and coastline. These laws do not define who own the areas but who is the administrator, how to define the zone, what action is permissible in the area etc. Each prefecture set prefectural ordinance for administration for other specific marine zones. According to the general guidelines, MRE developers are required to get permission from local autonomy which administer the specific zone, to occupy the marine zone for a long period of time in order to construct MRE projects. However, MRE developers can obtain the legal acceptance (once they obtain the permission of the port authority) for MRE projects to use ocean areas which are governed under the port authorities according to the port and harbor law. (2016 amendment of the port and harbor law has increased the time span of the permission period from 5 years to 20 years). In other areas, each prefecture gives permission based on its ordinance, once the project developers get the consensus from local stakeholders.

The first national level policy guidance for the development of MRE projects issued in 2014 by accepting 6 marine areas as test sites for demonstration MRE projects (Prime minister's Headquaters for Ocean Policy in Japan, 2014). This list was updated thereafter by adding more potential ocean areas to the list (Prime minister's Headquaters for Ocean Policy in Japan, 2017). However, there was no policy assurance for commercial level MRE projects until the 3rd basic plan of ocean policy introduced in 2018 that proposed to establish rules on using maritime zones for MRE development (Prime minister's Headquaters for Ocean Policy in Japan, 2018a, 2018b). In late 2018, this proposal of using maritime zones for commercial MRE projects was legalized by the parliament of Japan (Diet) by approving the new "act on promotion of the use of the sea area pertaining to the development of marine renewable energy power generation facilities" (Parliment of Japan, 2018b, 2018a). However, with this act, some supplementary resolutions were also added in order to take care of fishing industry and for assuring that the bidding winner secure enough funds for decommissioning at the termination of the commercial operation of the MRE project (JWPA, 2019). According to the new law, the developers and local government are required to obtain the consensus among local stakeholders before application for declaring a maritime zone for MRE project. The bidding process can initiate only after the maritime zone is accepted for future MRE projects.

Even though the new parliament act provide legal assurance to use maritime zones for MRE projects, still there are no such zoning has been done in Japan because Japan has not followed the European approach of marine spatial planning (MSP) for introducing MRE sector. Ocean policy makers are still in the process of building a MSP for Japanese marine areas. However, this process takes a lot of time and resources since it has to go through several steps which need consensus building among stakeholders as shown in the Figure 1.11. It is difficult to expedite the MSP creation process by copying from European examples due to the lack of information and differences of socio-economic perceptions of local marine activities in Japan.

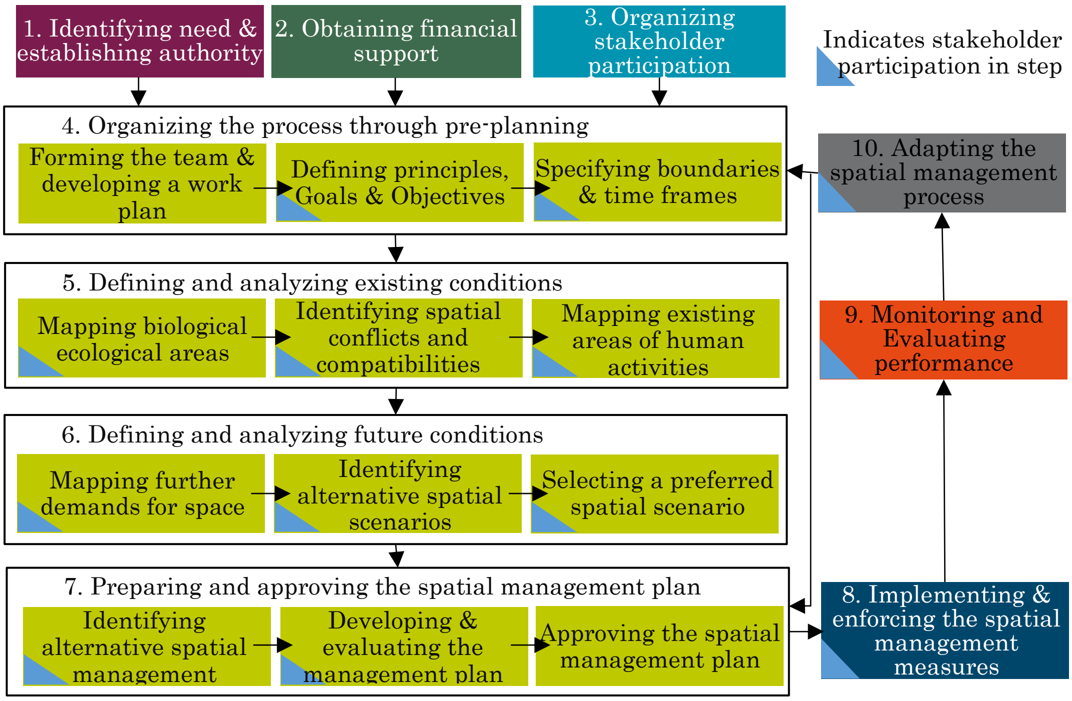


Figure 1.11 A Step by step approach to Marine Spatial Planning

Source: Ehler & Douvere (2009)

Despite the lack of integrated MSP, Japan's oceans are being governed under different laws and acts such as seashore law, port and harbor law, park law, fisheries act, coast guard act, acts on treatment of marine debris, conservation of good coastal landscapes and environments, marine accident inquiry, disaster countermeasures etc.

Basic plan of ocean policy is the main national level policy which combines all these acts and laws which have been established for managing various aspects of marine and coastal activities. In combination, Japanese oceans are being governed under 8 ministries and more than 50 agencies. In terms of rights to use are considered, most of the coastal areas have been allocated for local fishery unions with rights to fish and for ports and harbors. Most of the offshore areas are considered as common sea, and being used by many marine users with a shared permission basis. If the marine areas are being used by other than already allocated purposes, those marine users must get the permission from local authorities as well as the rights holders. For example, if MRE projects are going be located in fishing rights areas, project developers are obliged to get the prefectural governor's, ministers' (of ministry of agriculture, forestry and fishery (MAFF) and ministry of land, infrastructure and transport (MLIT)) and even the local fishery association's approval depending on the changes or impacts occur to the considered marine areas. Generally it is not necessary to compensate or get the permission from existing marine industries provided that MRE project are deployed in common sea areas and it is not proven that MRE project have any negative impact on the other dedicated sea areas such the 'Right to fish' areas, conservation areas etc.

Instead of a proper MSP approach, Japanese communities traditionally used the concept of 'SatoUmi' to manage the rivers and coastal regions. "SatoUmi" is a Japanese term meaning "a seascape where human-ecosystem interaction has resulted in increased biodiversity and productivity, thus improving the health of the environment and its ecosystem services" (Mizuta & Vlachopoulou, 2017) or "Coastal sea with high biodiversity and productivity under human interaction" (Yanagi, 2013). SatoUmi concept is based on the management of the eco-systems, specifically based on the nutrient flaw from upstream, to achieve sustainable coastal seas and communities. Even though this concept is being used even in basic ocean policies related to the management of coastal regions, the scope of SatoUmi does not cover the concepts of offshore management or even it does not highlight the concepts of using ocean dynamics and physical conditions to harness energy. Instead, SatoUmi concept is more focused on nearshore and coastal management based on the eco-system based co-management as conceptually shown in the Figure 1.12.

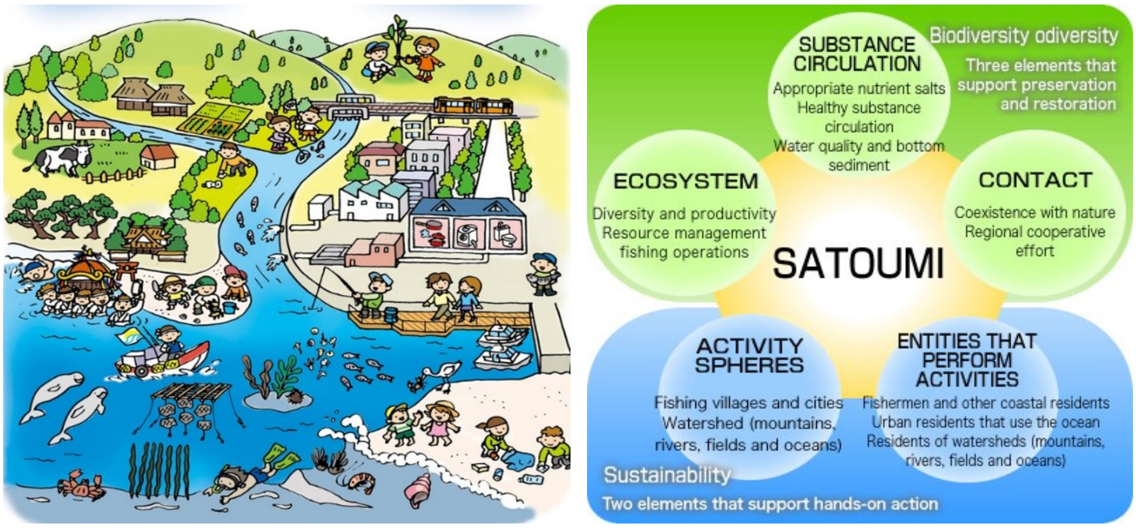


Figure 1.12 Concept of SatoUmi

Source: https://www.env.go.jp/water/heisa/satoumi/en/01_e.html

Second approach considered in coastal management is the 'Integrated Coastal Zone Management (ICZM) which is the civil and coastal engineering approach to manage the resources and community requirements of coastal regions. ICZM is widely used in international level and generally focus on (1) integration between land and sea, (2) integration between sector interests comprising utilization and protection of coastal resources, commercial and recreational interests etc. (horizontal integration), and (3) integration between authorities at state, county and municipal levels and public participation (vertical integration) (Anker et al., 2004). In Japanese context, ICZM is more focused on (1) disaster prevention, (2) human utilization, and (3) provision of ecological services (Isobe, 1998). However, according to Isobe (1998), ICZM in Japan is more focused on the management of coastal and nearshore regions even though energy extraction has been identified under the second theme of 'human utilization'.

Commercial level MRE projects can be sited in nearshore areas, territorial waters or even further offshore areas within EEZ according to the availability of energy resources and associated costs. For example, offshore wind projects have been developed in further offshore areas in Europe with the development of the MRE sector to the commercial level. However current management practices such as ICZM and SatoUmi approach, still focus only on the coastal and nearshore regions. The ownership, scale and the governance responsibilities in the nearshore areas are much clearer than that of offshore areas. Hence it is much easier to match the investments with individual financial benefits (area-wise allocation of tax returns) in the nearshore areas. However, the ownership and the governance responsibilities are not clear in the offshore areas. Further, there are unique objectives behind investments in offshore areas and remote islands such as defense, ocean accident risk management etc., which are significantly different to the objectives of coastal and nearshore investments. Due to these differences (Figure 1.13), it is not expected to fulfil the requirements of a commercial MRE sector by the existing management practices which focus only on the coastal and nearshore areas.

Scale	→ 1~2 km	10~100 km
Management	→ ICZM / SatoUmi	Marine Spatial Planning (MSP) (under development)
Other	→ Clear ownership / Tax returns	Unique utilities (defense, accident management etc.)

Figure 1.13 Coastal/Nearshore and Offshore management characteristics

Source: made by author

1.5 Public perception, previous examples, and expected stakeholder opposition

Ocean is a common resource where many stakeholder groups use for their economic and recreational activities. In addition, some sea areas are rich in bio-diversity which is very sensitive to the anthropogenic eco system changes. Because of the lack of MSP, it is very controversial to introduce new elements to the existing dynamics. There are major economic activities done in the considered ocean areas such as commercial fishing, tourism and transport industry etc. Once the MRE project is deployed, the prevailing economic activities might get impacted. These impacts are adverse to the prevailing industries according to the traditional view. For example, certain fishing methods get banned in the area, restrictions to shipping and recreational activities etc. (Sakaguchi, 2015).

One of the most frequently quoted examples is the conflict and the resulting compensation scheme between the Japan Aerospace Exploration Agency (JAXA) and the local fishery union regarding the establishment of their space center in Tanegashima Island (Figure 1.14.a). The local fisheries were against the project due to the potential adverse impacts to the surrounding fishing grounds. The project was deployed in the end after getting the consensus of the interested parties, which resulted a huge compensation scheme as well as restrictions on rocket launching days for more than 3 decades. (JAXA, 2010; SpaceDaily, 1997)

Similar to the perceived negative impacts to the prevailing industries, Not In My Back Yard (NIMBY) effect is also causing a significant stakeholder opposition for power projects. The term NIMBY is commonly used in previous literature with an implication of 'selfish' nature of local stakeholders while accepting the renewable energy in general. However, Burningham (2000) and Wolsink (2006) suggest that it is more complex and reasonable for stakeholders to oppose the project deployments in their locality.

Another major reason for high stakeholder opposition for MRE is the lack of experience and uncertainties due to the novelty of the technology. These uncertainties have caused a higher perceived risks than the perceived benefits for most of the local stakeholders (Figure 1.14.b). General public still do not have a perception about the idea of 'Energy from Sea'. Lack of offshore oil and gas industry (like in the case of European examples) is also a key factor for the low public awareness regarding the energy extraction from ocean areas. According to Ocean Alliance (2017), most of the Japanese general public has the perception of ocean only as a 'source of food', 'natural phenomena like tsunamis etc.', and 'source of leisure'. Further, perception of general public is difficult to evaluate since only the professionals from limited industries (like fishery, shipping etc.) have a direct contact with the ocean. Due to these reasons and past experiences, it is expected to have stakeholder opposition for future commercial MRE projects.

(a) (b)

Figure 1.14 Previous examples of public opposition for coastal developments in Japan (a) JAXA space center in Tanegashima, (b) Offshore wind farm in Shimonoseki

Source: http://www.spacedaily.com/spacenet/text/fish.html

1.6 Problem identification and previous research findings

Due to the changes caused by post 2011 energy generation shift, MRE development in Japan has been accelerated and has led to may field testing projects and pilot projects since then. Local communities, specifically the fishers, have shown some concerns over these pilot projects due to the uncertainties and perceived negative impacts. For example, local fishers have raised concerns over the marine impacts at the beginning of field testing done on Japan's first floating offshore wind turbine in Goto Islands in Nagasaki from 2013 to 2015. In the case of Nagasaki pilot project, local fisheries' opposition has been reduced significantly with the results of the demonstration project because they have experienced some positive environmental impacts from the project.

Similarly, Japan's first ocean current turbine (Figure 1.15) was tested in Kuchinoshima (in Southern Japan) in 2018.

Figure 1.15 Field testing of Japan's first ocean current turbine in 2018

Source: NEDO and IHI

From the success of previous pilot projects, the MRE developers in Japan are now in the process of developing the MRE sector into the commercial scale. There have been several commercial scale MRE projects proposed since 2018, e.g., in Kitakyushu offshore wind project (Hibiki Wind Energy, 2018), and those commercial MRE projects are expected to initiate in early 2020s. The main difference between the pilot MRE projects done so far, and the proposed commercial level MRE projects are the scale and expected interactions with prevailing marine users. Expected interaction between the prevailing marine users and new commercial MRE projects will be significant to that of pilot MRE projects. Current industrial practices have to be adjusted with the introduction of "commercial MRE projects". For example, the level of impact to the local fisheries by fishing effort displacement and restrictions of using certain fishing gears even in nearby fishing grounds, restrictions on navigation etc. can be significant in commercial MRE projects in comparison to that of pilot projects. However, pilot MRE projects done so far do not show these impacts significantly. Hence the local stakeholders still have significant level of uncertainty over the impacts of proposed commercial MRE projects. According to current regulations and policy guidelines, MRE project developers are required to obtain the local stakeholder consensus before the project licensing application.

Policy makers are also in the process of developing required management strategies and MSP to incorporate these new requirements. Thus, similar to the MRE developers, ocean policy makers are also looking for consensus building strategies among local marine users to define and analyze the existing as well as future marine conditions, spatial conflicts and compatibilities when developing a MSP. Figure 1.11 shows the importance of stakeholder participation and consensus to build an optimum MSP that satisfy the current and future requirements of future MRE projects and other coastal and offshore constructions.

Understanding of local stakeholders' perceptions, beliefs, preferences as well underlying factors of acceptance decisions etc. is necessary for achieving stakeholder consensus. From the previous renewable energy projects, especially from wind energy project deployments in Europe, the expert group on wind energy in International Energy Agency (IEA Wind, 2013) has identified several recommendations for building consensus under 5 main themes, 1), Policy and strategy (including planning and support regimes), 2) Well-being and quality of life (including property value prices and landscape / ecosystems), 3) Distributional design (including costs and benefits for the host communities), 4) Procedural design (including processes, consultation and involvement), 5) Implementation strategies (e.g., local empowerment). Report explains the local community generally feel a sense of injustice or being exploited by national or multinational level corporates especially if the power projects are owned and managed by entities that are not permanent members of the local community because there is no direct economic or financial benefit for the local community. Rather, most probably the local community has to bare the associated industrial and environmental costs. Hence it is recommended to look for strategies to create an equitable distribution of costs and benefits at the early stage of project development. Further it is emphasized that these strategies should not act as a bribe, but a means to achieve a balance of interests and fair distribution of positive and negative project impacts.

Accordingly, it can be shown that understanding stakeholder decision behavior is not sufficient to build consensus since the conflicting stakeholders require sustainable solutions to minimize the competing interests and negative interactions among them. Thus, MRE project developers, ocean policy makers and MSP developers require locally relevant co-existence strategies in order to make the consensus building process a success.

Previous studies related to offshore wind development in east coast of USA, have found that local stakeholders have a mixed acceptance decision where clean alternative energy generation, national energy security, economic reasons lead to the supporting decision while believed negative impacts to the aesthetics, marine life, local fishing industry, cost of electricity etc. lead to the opposing decision (Firestone & Kempton, 2007; Firestone et al., 2009; Firestone et al., 2012; Kempton et al., 2005). Further, Firestone & Kempton, (2007), has identified that there are many other underlying factors in addition to the demographics, which become very sensitive over the acceptance decision. Previous studies from Europe, USA and other small MRE markets have shown that local stakeholder acceptance can be based on variety of factors and perception of the communities which cannot be estimated without direct consultation. However, there are very little studies done regarding the public decision making on MRE in Japanese context. Due to this lack of comprehensive studies done in the case of Japan's MRE development (and due to the significant differences of acceptance behavior even within previous study areas in Europe and USA), it is highly doubtful which pattern of public acceptance decision behavior is there in the Japanese context.

The lack of studies on potential options and strategies which can be used to create during consensus building process is the second facet of this problem. This topic is still under investigation even in matured MRE markets such as Western Europe. Centralized licensing system used in European MRE development can be the main reason for the lack of consensus building option generation because it is difficult to come up with a generalized solution applicable for various socio-economic conditions prevailing on those MRE markets. There are very limited studies done in European cases where MRE developers can use their infrastructure to create benefits for local communities such as co-location with fisheries (Bartelings et al., 2014; de Groot et al., 2014; Gray et al., 2005; Stelzenmüller et al., 2016), aquaculture (Buck & Langan, 2017; Buck et al., 2004). However there are no such studies done with related to Japanese marine and coastal conditions as well as with respective the local communities in Japan. Research Institute for Ocean Economics, (RIOE, 2013) has proposed several options to create additional values to local communities, specifically to the fishers, that can be used for consensus building negotiations. However, those options have not been evaluated with empirical data with the consideration of local stakeholder perceptions.

Hence, there is a significant research gap on the main consensus building requirements, i.e. understanding the local stakeholders' MRE acceptance behavior and identifying the potential options to achieve a win-win situation and co-existence among stakeholders in Japanese context.

1.7 Research objectives and research questions

This research is an in-depth analysis of the identified two research gaps discussed in the previous section. The general objective of this research is to 'analyze local stakeholders' MRE acceptance, underlying factors & potential co-existence options for the development of commercial MRE projects in Japan'. To achieve this general objective, three specific research questions (R.Q) were selected;

R.Q.1 What is the current stakeholder acceptance level, trend and underlying factors of MRE acceptance?

R.Q.2 What are the options available to create a win-win situation & co-existence between MRE industry and local community?

R.Q.3 What is the feasibility of the preferred co-existence strategy?

1.8 Structure of the study

The structure of the study is represented in the Figure 1.16. The first chapter up to this point of this thesis describes the background data, an overview of previous work and objectives set up according to the identified research gaps. The second chapter is dedicated to explain the methodology of the study. The results for the first two research questions are discussed in third and fourth chapters respectively. From the results of fourth chapter, it was identified that the sharing ocean information is the best co-existence strategy thus the feasibility of that strategy is further analyzed in the fifth chapter. Final chapter summarizes the entire study outcomes, recommendations and guidance for future studies on the topic as the conclusion of this thesis.

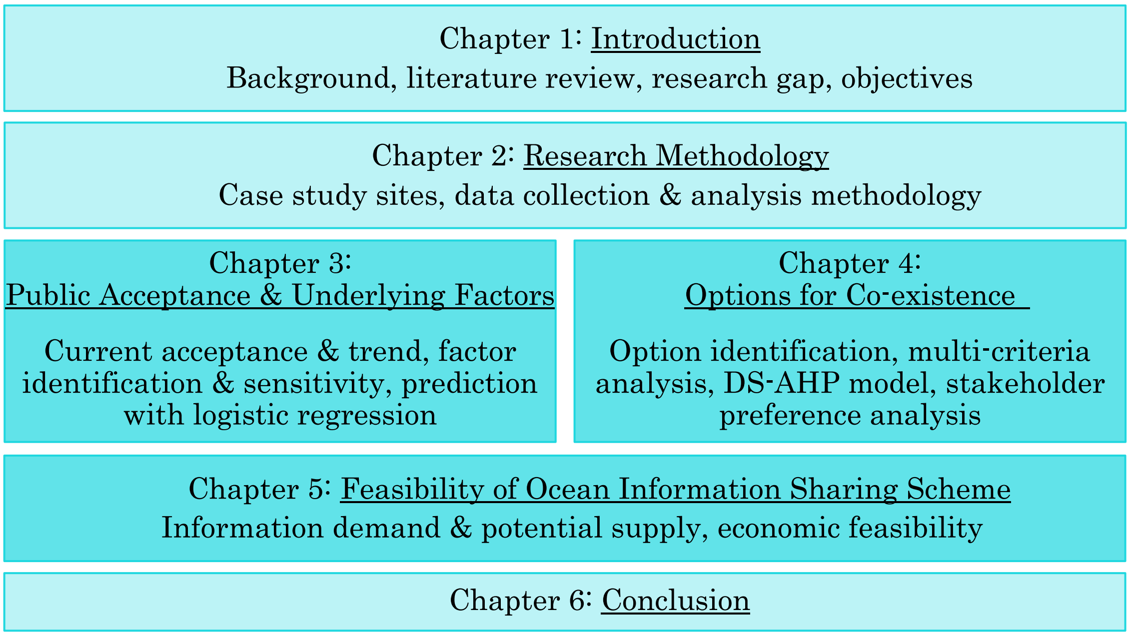


Figure 1.16 Structure of the thesis

Source: made by author

2 RESEARCH METHODOLOGY

The overarching methodology of this research is the case study approach to find solutions to three research questions and then generalizing the findings according to the identified compatibilities and limitations with respect to other MRE projects in Japan. In this chapter, over all methodology is explained under four topics: selection of the case study, identification of the stakeholders and collection and analysis of the data. Data collection and analysis methods are described under each research question.

2.1 Case study selection

Three research questions selected has to be evaluated in different aspects such as social, environmental, economic and technical feasibility aspects. To answer the three research questions in these aspects, the stakeholder should possess a considerable amount knowledge or know-how about the ongoing and proposed MRE projects. Hence the basic criteria for the case study selection is the high knowledge level of the stakeholders. The next criteria is the existence of MRE project in the area or probability of having an MRE project in the future. Several sea areas have been selected as demonstrational test fields for future MRE projects by the Prime ministers Headquater for Ocean Policy in Japan, (2014) (Figure 2.1). However there are very few projects being developed in these selected areas for the time being (Table 1.2).

This study is mainly based on the data set collected from two case study sites from Nagasaki and Kitakyushu in Southern Japan (Figure 2.2). Nagasaki and Kitakyushu project areas represents the best examples of private companies trying to initiate commercial-level MRE projects after experiencing success with government funded demonstration pilot projects. The Ministry of Environment in Japan has been conducting pilot offshore wind projects in Nagasaki since 2010 (and developed into Japan's first full-scale floating offshore wind turbine) near the Goto Islands, about 100 km off the main Nagasaki city (Goto City office, n.d.).

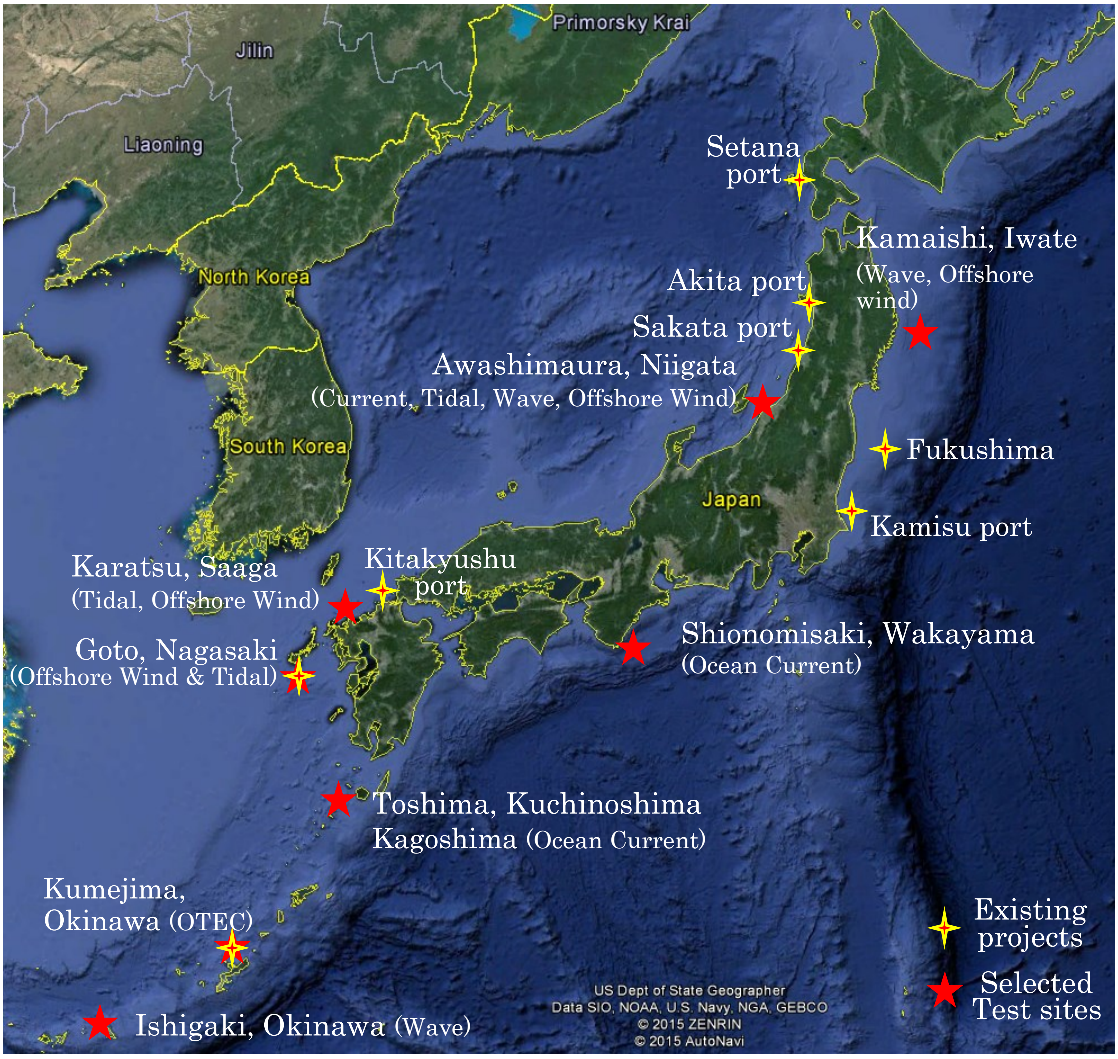


Figure 2.1 Selected sites for demonstration projects and existing MRE projects

Source: Made by author based on Table 1.2 data & Prime minister's headquaters for ocean policy. (2017)

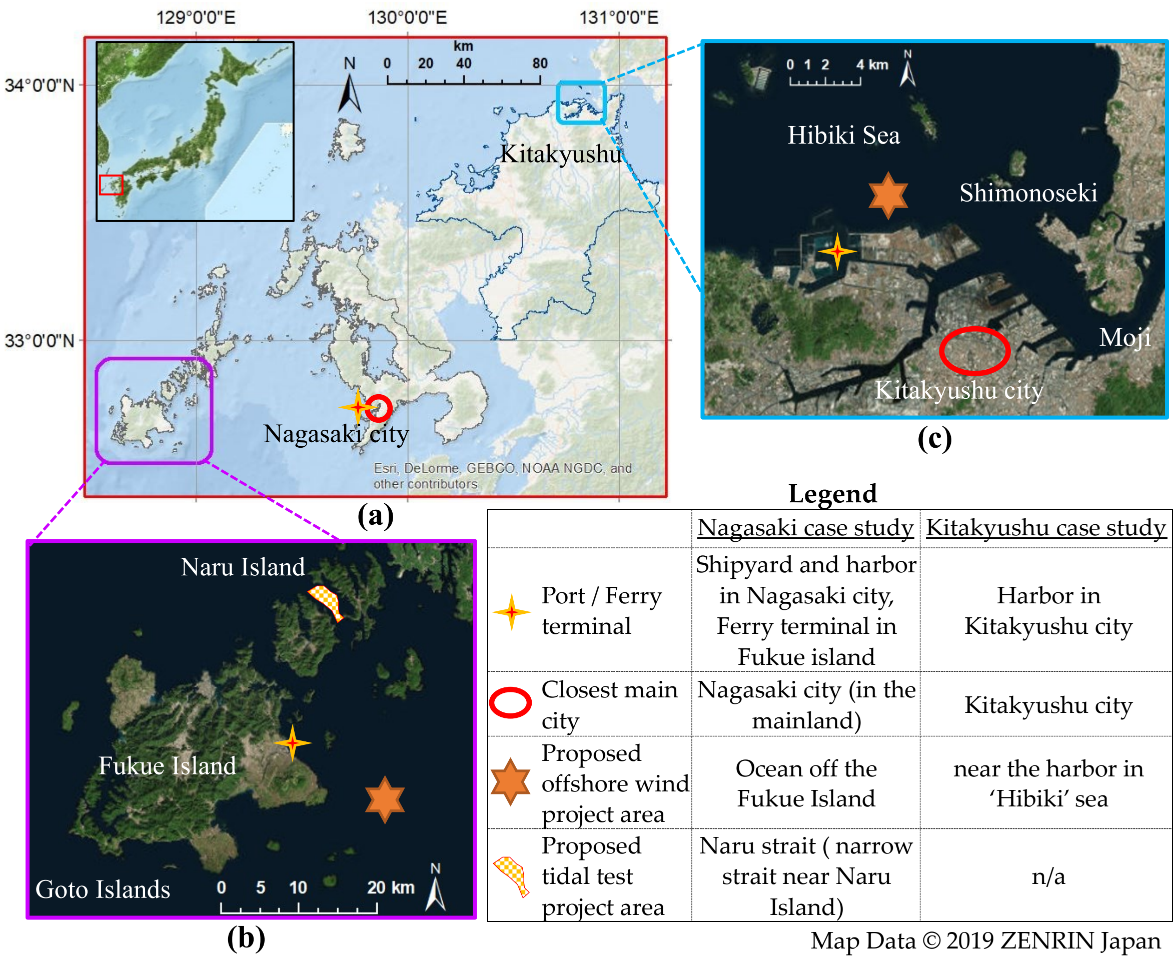


Figure 2.2 Case Study area (a) Nagasaki and Kitakyushu MRE development sites in Southern Japan; (b) Fukue and Naru Islands (in Goto Islands) in Nagasaki case study; (c) Kitakyushu city, Moji, and Shimonoseki area in Kitakyushu case study.

Source : made by author

Initially, the project owners received some local concerns about the development of MRE devices and testing in real sea conditions due to the perceived negative environmental impacts. Given the results of the pilot projects, local stakeholder acceptance of Nagasaki MRE development has increased significantly. A non-profit organization (NPO), Nagasaki Marine Industry Cluster Promotion Association (NaMICPA), comprised of more than 50 public and private entities related to marine industries, was established in 2014 with the aim of supporting the development of marine industries including the MRE sector ("Nagasaki Marine Industry Cluster Promotion Association (NaMICPA)," n.d.). A proposal to build the first commercial MRE project, a 22 MW offshore wind farm has been submitted by a private company with expected commencement in 2019 (JWPA, 2017). The Naru strait, which lies between two smaller islands, has been identified as a potential site for tidal energy projects and authorities are in the process of establishing a marine energy test center similar to the European Marine Energy Centre (EMEC) in Scotland (Waldman et al., 2017). .

Similar to the inception of Nagasaki MRE projects, government agencies have started testing the feasibility of offshore wind energy development in the Hibiki Sea area in Kitakyushu, Japan in 2012 (NEDO, 2013). A consortium comprised of local industries, the Hibiki Wind Energy Group (Hibiki Wind Energy, 2018), won the bid to build the first large-scale offshore wind farm in Kitakyushu in 2017, which is planned to start in 2022 (Figure 2.3).

Figure 2.3 MRE development in Nagasaki and Kitakyushu case study areas

Source: made by author with data from Goto City office; Hibiki Wind Energy Co. Ltd., (2018); and NEDO, (2013)

In the case of tidal energy project in the Goto Islands in Nagasaki case study area, the approval of the local fishery association is necessary since the considered tidal straits have been declared as a marine areas with fishing rights. However, the offshore wind project in the Nagasaki case study is planned in the general offshore area where any marine user can utilize on a shared permission basis with the approval of local authorities. In contrast, the Kitakyushu offshore project is planned in marine areas governed by port law; hence, the local port authority has the exclusive control over the development site. Despite these differences of legal requirements, both Nagasaki and Kitakyushu MRE developers are compelled to search for means to improve public acceptance for their proposed commercial MRE projects.

2.2 Stakeholder identification

Developers have to manage a variety of stakeholder groups and are generally not equipped to balance all their requirements. Local fishery industry is the stakeholder group that is most likely to be directly impacted by MRE project deployments (Yates & Schoeman, 2013). Developers can benefit from the mediation of a local authority because they tend to have a higher trust among local communities and higher expertise in assessing the local priorities, which is vital when identifying the requirements and disbursing resources for the needs of the community. In addition to Fishery industry and policy makers, there can be other stakeholders who can be vital in the local consensus building process. Mitchell et al., (1997) has described who should be counted as stakeholders based on the characteristics of power, legitimacy and urgency as shown in the Figure 2.4.

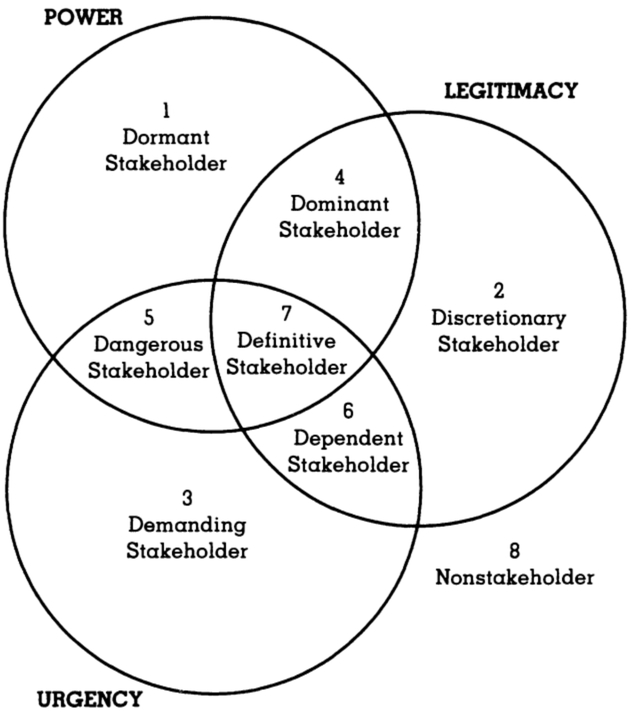


Figure 2.4 Stakeholder identification model

Source: Mitchell et al. (1997)

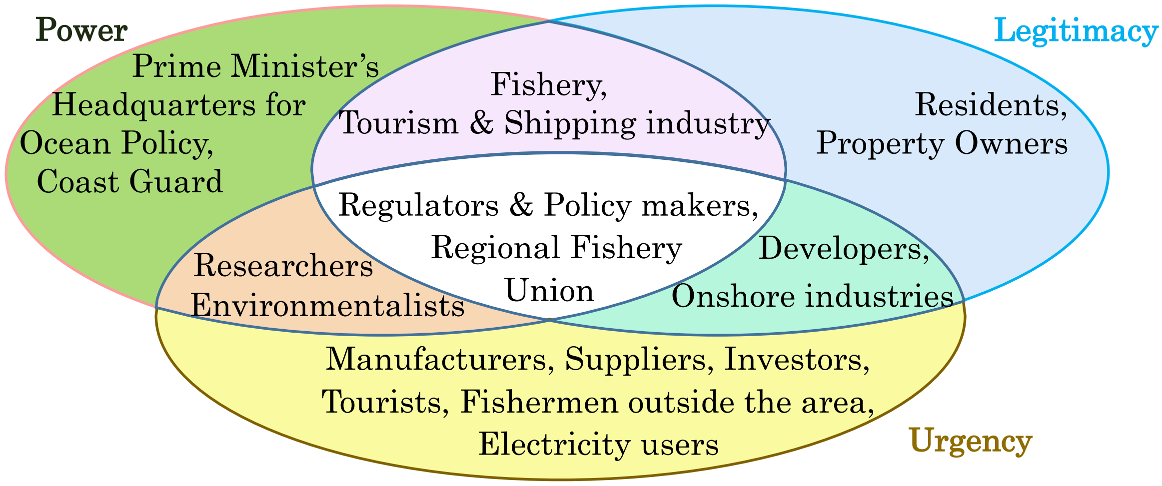


Figure 2.5 Stakeholder map based on Mitchell et al. (1997)'s model

Source: made by author

Figure 2.5 shows the stakeholder map created commonly for both Nagasaki and Kitakyushu case studies based on the stakeholder identification model proposed by Mitchell et al., (1997). In the case of Nagasaki case study, onshore industries include the ship building industry, tourism industry, and harbor thus making them key local stakeholders other than the local fishery unions. The NPO NaMICPA that has more than 50 supply chain industry representatives could represent generally all the other stakeholders. Similar to Nagasaki, main local stakeholders other than the fishery unions in Kitakyushu case study are steel industry and local harbor. The main utility company: Kyushu electric power Co. is common for both these case studies. Apart from the utility company being the same, all other local project stakeholders are different and independent in decision making in these two case studies. Generally both these regions have a prominent fishing and tourism industry in the local context. Further, both regions have been developed as commercial hubs with their sea ports.

Majority of urban population is a mix of workers in these manufacturing industries and their supply chain industries. The communities living in the islands and rural areas are mainly in the primary industries such as fishery and agriculture and experiencing community level issues like ageing society, young generation moving away from islands to city centers and from fishing and agriculture to the manufacturing and service sector industries.

The main data collection was done using stakeholder interviews with the representatives of key stakeholder groups shown in the Figure 2.5 and the perceptions of the general public was captured by questionnaire surveys (Table 2.1 and Appendix I). Interviews were in semi-structured format and combined various elements according to the focused research question (Appendix II). Questionnaire surveys were also comprised of different sub sections in order to capture the requirements of three research questioned focused in this research.

Table 2.1 Summary of data collection

	Interviews / Surveys	Relation with ongoing MRE projects	n*
Interviews	NPO - 'NaMICPA'	Engaging local stakeholders with MRE sector	4
	Local city office / Prefectural government	Promoting MRE sector & information sharing / Policy guidance	3
	Local fishery unions	Key stakeholder in consensus building process	8
	Researchers, Environmental monitoring groups,	Environmental monitoring of pilot MRE projects / EIA for proposed MRE projects	2
	Opponent Groups	Demonstrators against proposed projects	2
	Developers, Utility Co., & Supplier/Pvt. Companies	Potential key supplier in future MRE projects	6
Surveys	Preliminary survey	Local representatives from Nagasaki area	56/200
	Administered Fishery survey	Fishery Union members, General Fishers in Nagasaki, Kitakyushu and other areas	41
	Large scale postal survey	Local community in Nagasaki & Kitakyushu	153/1500

n*= number of valid responses, Source: made by author,

Since the related methodologies were significantly different for each research question, the specific data collection and data analysis methods used to answer each research question will be described separately in the next sections.

2.3 MRE acceptance level, trend and underlying factors (R.Q.1)

2.3.1 Data collection

Intensive semi-structured interviews were conducted to understand the opinion of the specific stakeholder groups regarding the proposed commercial level offshore wind development (and tidal energy pilot project in Nagasaki case study) together with on-site observations. Some interviews were recorded where the permission to record was obtained. Descriptive notes were taken during the interviews, especially for the interviews that didn't receive the permission to record. 25 interviewees from different organizations related to the Nagasaki and Kitakyushu MRE development were selected for the interviews (Table 2.1). The semi-structured interviews were done with the help of guide questions (Appendix II) leading to descriptive discussions on the topics including; what kind of information the informants had heard about the MRE developments in Nagasaki and Kitakyushu case studies before and during the initial pilot projects, what they saw as positive and negative aspects of the MRE projects, were they in favor (or opposition) of the ongoing developments and how their decisions changed over time, how they got information and what led them to their own personal decision, respondents' opinion about the proposed commercial level projects, how they thought the project decision should be made with regards to the further development of the MRE sector and what might be the potential socio-economic impacts for the region etc. Main interview sessions were completed in March 2017 and March 2018.

Since interviewees representing general local community had a very limited knowledge about ongoing work related to the MRE development, we could reach the data saturation point quickly even with a small number of interviewees in terms of underlying decision factors, perceived impacts which construct their current opinion on MRE acceptance. In order to overcome this limited data availability, questionnaire surveys targeting the local fishery and coastal community were conducted because fishery industry has been identified as the most likely to be directly impacted by the MRE project deployments (Yates & Schoeman, 2013).

It is very important to understand the local fisheries perspectives in terms of MRE acceptability specifically in the context of Japan because fisheries has been given a very high prominence in the local socio-economic context. Preliminary survey (Appendix III) was done in Nagasaki case study area in March 2017 by distributing 200 surveys from which we received 56 valid responses. Fishery survey (Appendix IV) was administered in

October 2017 with the fishery union members of Fukue, Naru, Kitakyushu fishery unions. Large scale postal questionnaire survey (Appendix V) was conducted from March 2018 to April 2018 all case study areas. Coastal fishery communities in the Fukue Island and Naru Island, and communities in coastal regions in Nagasaki city representing the Nagasaki case study, and Kitakyushu city, Yasuoka and Shimonoseki areas to represent the Kitakyushu case study were targeted for the large scale postal survey using random sampling.

In order to evaluate the impacts of external information, the large scale postal questionnaire survey participants were allocated to one of three groups using a between-group experiment similar to the survey in (Walker et al., 2014). The first group (G1) was provided with the basic details of MRE projects which are planned in their locality. The second group (G2) was provided data about the possible community benefits which could arise from these MRE projects (if the project co-benefits are shared with the community) in addition to the project information given to G1. The third group (G3) was provided with potential negative impacts and adjustments needed to their current marine practices in addition to the project related information and possible community benefits which was given to G2 (Table 2.2). The information provided for each group is given in Appendix VI. 1500 questionnaires were distributed to the households with a cover-letter and additional information (which constructs the three respondent groups) according to the summary given in the Table 2.2.

Table 2.2 Summary of the between group experiment in the questionnaire survey

Group	Provided Information	Case study		Total
		Nagasaki	Kitakyushu	
G1	Project information + Potential community benefits	250 (53*)	250 (17)	500 (70*)
G2	Project information + Potential community benefits	250 (26*)	250 (16)	500 (42*)
G3	Project information + Potential community benefits + Negative impacts and adjustment needed	250 (29*)	250 (12)	500 (41*)
	Total	750 (108*)	750 (45*)	1500 (153*)

Source: made by author, *(Valid Responses)

Survey questions were same for all three respondent groups and only one set of survey materials was sent to a sample household. Hence the respondents were not aware of the nature of the between-group experiment. The questions were from three main categories i.e. (i). Questions to understand the existing knowledge about the local MRE development, general opinion about national level energy policy and sources of information, (ii) Questions to understand the public acceptability decision towards the local MRE development, underlying factors and sensitivity of those factors, and, (iii) Questions for elucidating demographics of the sample, similar to the previous survey done in the context of USA (Firestone & Kempton, 2007).

2.3.2 Data analysis

The main data analysis method for the first research question was descriptive statistics according to each subtopic as discussed in the results section. For the statistical analysis, all 206 valid questionnaire responses (56 from preliminary survey and 153 from postal survey) were considered and used according to each sub-topic. For the acceptance factor analysis and acceptability prediction, logistic regression was used with the most significant predictors identified from the correlation analysis.

2.4 Options for co-existence between MRE industry and local community (R.Q.2)

Stakeholders' preference depends on perceived pros and cons under various decision criteria. Even though statistical methods can be used to identify potential co-existence options and factors behind preference decisions, those methods have a limited potential to be used as a future scenario evaluation method due to limited availability of data and conflicting nature of decision criteria. Since it is difficult to attain the highest level of satisfaction in terms of each criterion, creating a situation that makes use of synergies and the best compromise among various decision criteria is important to identify the optimum solution.

Multi criteria decision making (MCDM) approach (Kabir et al., 2014; Wang et al., 2009) is a commonly used decision making approach for this type of complex decision making scenarios. There are many types of MCDM approaches such as Analytic Hierarchy Process (AHP), Multi-Attribute Value Function Theory (MAVT), Multi-Attribute Utility Function Theory (MAUT), and Outranking methods, etc. The applicability of each method depends on the data availability, complexity of the problem, available sample size etc. AHP was selected as the basic MCDM approach to evaluate the possible co-existence options in the second research question.

The application of MCDM approach can be summarized into three main steps: (1) identification of potential co-existence options, (2) multi-criteria analysis (MCA) of identified co-existence options and, (3) evaluation of the stakeholder preferences using the selected MCDM approach. Data collection for these three steps was done sequentially using specific data collection methods and tools as explained in the following section.

2.4.1 Data collection

Data for the second research question was obtained from the stakeholder interviews and questionnaire surveys described in the previous section and shown in the Table 2.1. However, a different set of questions and additional data sheets were used during the data collection due to the use of MCDM method.

The first step of identifying potential co-existence options was mainly done through literature review. Expert interviews were used to validate the findings of the literature review. Second step of multi-criteria analysis of identified options was done using the key stakeholder interviews with the support of the MCA sheet shown in Appendix VII. The third step of preference evaluation was done using questionnaire surveys and focus group discussions in which the MCA results were used as additional information. Specific questions used for the third step is shown in Appendix VIII. A total of 77 valid multi criteria evaluations were obtained as shown in the Table 2.3.

Table 2.3 Summary of valid respondents for the multi criteria option evaluation

Stakeholder group	Case study		Total
	Nagasaki	Kitakyushu	
Local fishery	9	6	15
Developers/Construction sector	6	1	7
Civil Servants	14	0	14
Tourism and shipping industry	1	1	2
Health and welfare	3	1	4
Non-profit organizations (NPO), Service sector and others	14	5	19
Not indicated	13	3	16
Total *(Valid Responses)	60	17	77

Source: made by author

2.4.2 Data analysis

The results of the first step, i.e. co-existence options identification by literature review and expert interviews, were summarized by data parameterization.

MCA in the second step was done based on eight sub criteria grouped into three criteria; i.e. economic, environmental and social criteria. These sub criteria were selected based on the importance given by the local stakeholders regarding the option selection.

Economic aspects were considered using three sub-criteria. The project co-benefit criterion measures the extent of the considered co-existence option being a co-benefit of the MRE project. Co-benefit was roughly contextualized as all secondary benefits of the MRE project other than the intended benefit of sustainable renewable energy supply. The second sub-criterion under economic aspects was the measure of variable cost to the developer, i.e., the amount of additional costs the developer has to incur for each additional beneficiary. The lower the variable cost, the lower the project cost. Since the sea area has vague ownership due to the lack of a well-established marine spatial plan, limiting the number of beneficiaries is practically difficult. This is the main reason for the unviability of monetary compensation schemes. The third economic sub-criterion is related to scalability of the solution without adding significant developer costs. Indirectly, it can be described as the ability to provide the same level of service without adding significant fixed costs to the developer.

Impacts to marine environment and greenhouse gas (GHG) emission levels were the main ideas highlighted during the interviews regarding environmental impacts. Social implications were measured by three common social criteria: stakeholder engagement, level of incentives to the stakeholder, and equality. The level of incentives can be an indirect and qualitative measure of the perceived benefit levels. Equality is considered between all the stakeholder groups in the local context.

However, there were not enough data to evaluate each option under each sub criteria quantitatively. The alternative was to evaluate the options based on qualitative information. Even for the qualitative multi-criteria evaluation, all the decision criteria had no common unit of measurement. Hence those qualitative information for each option with respect to the considered criteria was converted to three quantitative measures indicated by ✓ (affirmative / positive impacts), - (not sure), and X (non-affirmative/negative impacts). The number of repetitions (up to three times) of the symbols ✓ and X represents the degree of agreement (tendency to somewhat agree, agree, and strongly agree, respectively) for all the stakeholder interviews considered cumulatively. This level assignment was completed based on the authors' best estimates and based on the characteristics of the interview results such as the frequency of mentioning the considered point and the level of confidence of the interviewee regarding the considered point.

After completing the second step, potential co-existence options were identified with expected impacts based on various criteria. The final step of local preference evaluation by MCDM used the Analytic Hierarchy Process (AHP) and Dempster Shafer Theory (DST).

2.4.2.1 Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) introduced by Saaty (Saaty, 1990) is developed based on the additive synthesis and one of the most widely used MCDM approaches. AHP has been used in many cases from multiple disciplines; such as sea use management (Shiau, 2013), the evaluation of power plants (Chatzimouratidis & Pilavachi, 2007), analysis of Hydrogen based transportation systems (Winebrake & Creswick, 2003) and hydrogen energy technologies (Lee et al., 2008) etc. AHP can be used to select the best decision alternative based on the combination of both qualitative and quantitative criteria. Hence, AHP is commonly used in combination with other data analysis methodologies such as cost benefit analysis, SWOT analysis etc., and other mathematical models such as fuzzy logic (F-AHP), Dempster Shafer Theory (DS-AHP), Mathematical programming such as linear programming etc. (Ho, 2008). Thus there is an increased tendency of using integrated AHP methods in comparison to the original standard AHP. AHP can be roughly described as a three step operation; i.e. hierarchy construction, priority analysis, and consistency verification (Ho, 2008). Basic steps of using AHP in a typical decision making application can be described as follows.

Step 1: Define the problem and the objective of the decision making process.

Step 2: Construct the hierarchy of problem (Figure 2.6) from overall Objective, decision criteria (and sub-criteria in multiple levels of hierarchy) up to the decision options.

Step 3: Pair-wise comparison of criteria, sub criteria or decision options in a hierarchy level with respect to the element in the immediately above hierarchy level and calculating the priority of each set of element in the considered hierarchy level.

Step 4: Complete the consistency test to check the consistency of the judgment.

Step 5: Complete the hierarchical synthesis and develop the overall decision option priority ranking based on the priority of each criterion and its corresponding attributes' priority.

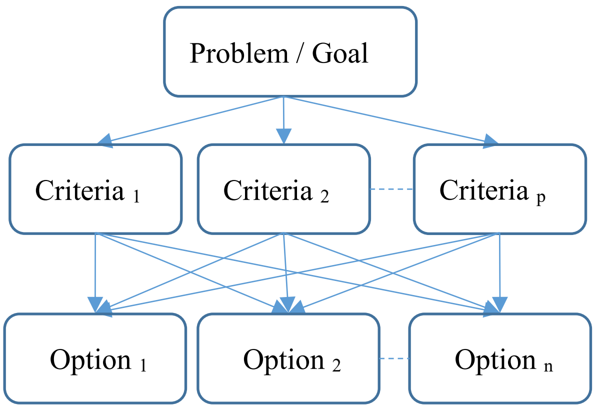


Figure 2.6 Conceptual Decision Hierarchy used in AHP

Source: made by author

The standard AHP process is a straight forward process which is easy to employ in a questionnaire. Further, there are readily available tools to support the related calculations. However, there are few drawbacks of standard AHP method which limits its applicability in this study as follows,

1. Number of pairwise comparisons required increases rapidly with the number of hierarchy levels and number of elements in each hierarchy level. A total of $n(n-1)/2$ comparisons are required per each comparison group with 'n' elements.
2. All the comparisons are mandatory for the final option ranking hence the standard AHP does not allow for decision maker's knowledge limitations and uncertainties.
3. There is a possibility of all the comparisons being irrelevant due to the existence of at least one inconsistence comparison, making the entire decision making process a failure. The risk of having inconsistent comparisons are high in cases where data collections completed before the consistency test (e.g. in the case of data collection through postal questionnaire surveys).

Due to the novelty of the identified co-existence strategies of MRE projects, which is still in its infancy in Japan, the related uncertainties and knowledge gaps are significant. Hence the impact of above mentioned limitations are severe in this study, making the standard AHP impractical. Hence, an improved version of AHP, which uses the Dempster Shafer Theory (DST) of evidence (Beynon et al., 2000), was used to overcome the limitations data unavailability and uncertainties.

2.4.2.2 Dempster Shafer Theory (DST) and DS-AHP method

Dempster Shafer Theory (DST) was originated from the initial works of upper and lower probability estimates by A.P. Dempster (Dempster, 1967, 1968) and further developments added by Glenn Shafer (Shafer, 1976). Since then, DST has been applied in various disciplines such as pattern recognition and artificial intelligence (Hégarat-Mascle et al., 1997; Lee, 2007; Momani et al., 2007; Ranoeliarivao et al., 2013), risk assessment (Sadiq et al., 2006), sustainability evaluations, and environment impact assessments (Wang et al., 2006) etc. DST uses the probabilistic approach to combine evidences to generate the best estimates for the expected outcome. Due to the usage of probabilistic approach, DST can accommodate knowledge gaps and uncertainties up to a certain level. Thus it is commonly used as the basis of the various machine learning applications. The integration of standard AHP and DST as a MCDM approach, also known as the Dempster Shafer Analytic Hierarchy Process (DS-AHP), improved the standard AHP method to a more robust level that can be applied in decision making scenarios with significant knowledge gaps and uncertainties. In DS-AHP method, the pair-wise comparison of criteria (as in the standard AHP) is used for weighting the decision criteria and DST is used for the evaluation of decision options (Beynon, 2002, 2005b, 2005a; Beynon et al., 2001; Beynon et al., 2000).

2.4.2.3 Interpretation of DS-AHP calculation

The basic theoretical background of DS-AHP has been described in previous literature such as Beynon, (2002). However, a very simple interpretation of DS-AHP calculation will be explained in this section based on Kularathna (2016).

Let $\Theta = \{h_1, h_2 \ldots h_n\}$ be a collectively exhaustive and mutually exclusive finite set of *n* hypotheses or propositions, which is also called the frame of discernment. DS-AHP model assigns probability measures to focal elements (e.g. groups of propositions) rather than comparing every possible element pairs within a single hierarchy level like in the standard AHP. It also allows to assign a probability value for the 'set of all the propositions', which is called the 'frame of discernment (Θ)'. The basic probability assignment (*bpa*), is a function m: $2^\Theta \rightarrow [0,1]$ that also satisfies the requirement $m(\phi) = 0$ and $\sum_{A \subseteq \Theta} m(A) = 1$, where ϕ represents the empty set and 2^Θ represents the power set of Θ. The assigned probability of any sub set y of frame of discernment Θ, (i.e.,$y \subseteq \Theta$) is denoted by $m(y)$. So, $m(y)$ represents the exact belief in the proposition depicted by y. The assigned probability for the frame of discernment Θ (i.e., $m(\Theta)$), represents the global ignorance within the basic probability assignment.

A focal element can be an individual decision option or group of decision options with similar level of perceived utility level. A Group of options can be considered as one decision option if the decision maker fails to differentiate their preference levels and if those options can be treated equally with respect to the considered decision criteria. Hence the decision makers have the opportunity to avoid giving a preference rating for the options with limited knowledge or high uncertainty. It also reduces the number of decision maker inputs required. In DS-AHP method, the focal elements are given a criteria-wise preference rating (which represents the degree of favorability) with compared to all possible options (i.e. Θ) (Beynon, 2002). This differs from the standard AHP method that makes pairwise comparisons between individual decision options. Hence DS-AHP method resolves the problems of standard AHP.

Once the focal elements are selected and given a preference rating with respect to the considered criteria, it is converted into a criteria-wise basic probabilities. The criteria-wise *bpa* of a focal element is calculated using equation (1):

$$m_i(y) = \frac{a_y\, W_i}{\sum_{j=1}^{d} a_j\, W_i + \sqrt{d}} \quad \text{and} \quad m_i(\Theta) = \frac{\sqrt{d}}{\sum_{j=1}^{d} a_i\, W_i + \sqrt{d}} \tag{1}$$

where a_y denotes the user preference value (1–7 preference scale from lowest preference 1 to highest preference 7), W_i represents the weight assigned to the considered decision criteria by pair-wise comparison using the standard AHP method (Saaty, 1990) and d represents the number of decision alternatives judged by the decision maker (Beynon, 2005a).

Basic probability assignments are considered as evidences and can be combined using Dempster's rule of combination, provided that information sources are independent. Criteria-wise preference probabilities can be combined and decision maker-wise preferences can be calculated using Dempster's rule of combination in equation (2):

$$m_{i\oplus j}(y) = \begin{cases} 0 & ; y = \phi \\ \dfrac{\sum_{A_p \cap A_q = y} m_i(A_p)\, m_j(A_q)}{1 - \sum_{A_p \cap A_q = \phi} m_i(A_p)\, m_j(A_q)} & ; y \neq \phi \end{cases} \tag{2}$$

where $m_{i\oplus j}(y)$ denotes the combined preference probability with respect to decision criteria i and j. This combination rule is used again to aggregate the individual decision maker's preference levels to derive the group preference, taking each decision maker as a criteria (Beynon, 2005a).

Belief level, denoted by $Bel(y)$ represents the confidence or exact support for the proposition y or the confidence level that hypothesis y is true. Plausibility level, denoted by $Pls(y)$, represents the possibility of support for proposition y or the maximum amount of confidence that could be placed on y. Both belief and plausibility are functions: $2^{\Theta} \rightarrow [0,1]$ and constitute the interval of support for the considered proposition y. The two functions are related to each other by $Pls(y) = 1 - Bel\,(\bar{y})$ where $\bar{y}$ represents the complement of y. The interval between belief and plausibility levels represents the decision option-wise uncertainty level because $[\,Bel(y), Pls(y)\,]$ represents the lower and upper bounds of the probability by which the considered proposition y is supported (Awasthi & Chauhan, 2011; Shafer, 1976). The final belief level and the plausibility levels are calculated by equations (3) and (4) respectively.

$$Bel(S) = \sum_{B \subseteq S} m(B) \quad \forall S \subseteq \Theta \tag{3}$$

$$Pls(S) = \sum_{B \cap S \neq \emptyset} m(B) \quad \forall S \subseteq \Theta \tag{4}$$

The individual stakeholder-wise decisions were combined to aggregate to a group decision using the equally weighted decision makers approach, where individual decision makers of the considered group are considered as equally weighted decision criteria according to the DS-AHP group decision methodology (Beynon, 2005a). Decision option-wise uncertainty level reduces significantly with the number of decision makers contributing to the group decision. The maximum plausibility level was used to identify the extent of this uncertainty level. Maximum plausibility level of the group decision was calculated by adding the averaged value of decision maker-wise uncertainty levels of the considered option to the belief level of that option in the group decision. Overall DS-AHP process can be summarized as follows;

Step 1: Define the problem, objective, and the decision hierarchy (Figure 2.7(a)) similar to standard AHP.

Step 2:.Calculate the criteria weights by pairwise comparisons using the 9 scale relative importance indicator. Consistency test should be done in this step similar to standard AHP.

Step 3: Identify and group the alternatives which can be given a preference value with respect to the each considered criteria (creation of criteria wise focal elements).

Step 4: Identify the preference value for each focal element using the 1-7 preference scale with respect to the considered criteria.

After completing the step 4, decision maker-wise combined bpa values as well as decision maker-wise belief and plausibility levels can be obtained from equations (1) to (4). Step 5 and onwards is required to aggregate the decision maker-wise preference decisions to come up with the group decision.

Step 5: Select the decision makers who needs to be considered for the group decision.

Step 6: Combine their bpa values of each decision option, (considering decision maker-wise final bpa as the criteria-wise bpa as shown in the Figure 2.7(b)), using the equation (2).

Overall DS-AHP process can be shown as Figure 2.7.

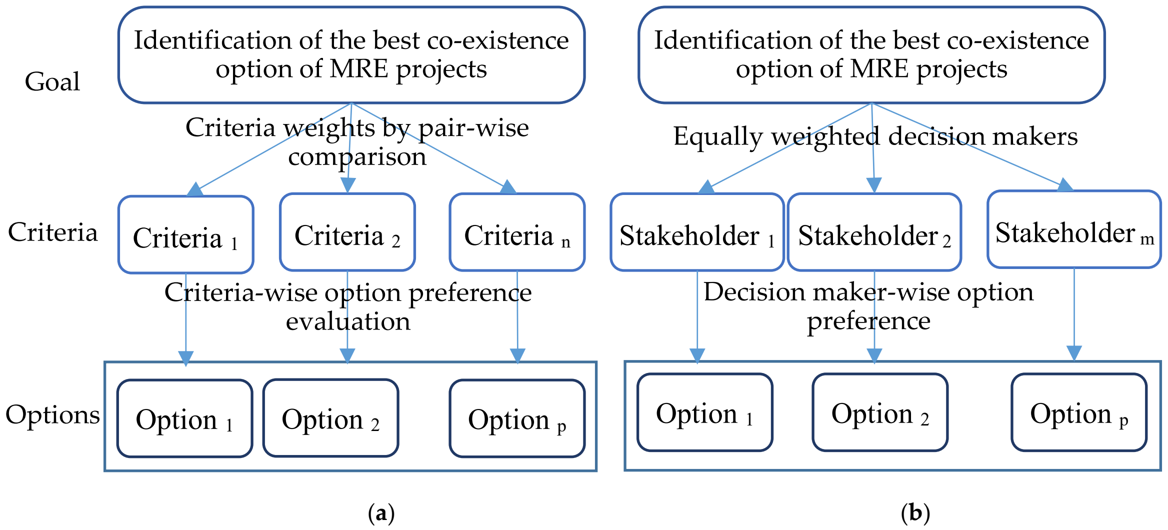


Figure 2.7 Dempster Shafer Analytic Hierarchy Process (DS-AHP) decision hierarchy: (a) stakeholder-wise decision and (b) group decision

Source: made by author

2.4.2.4 DS-AHP software development

Unlike in the standard AHP method, the number of calculations / iterations involved in the DS-AHP method depends on the number of evaluated focal elements, the number of decision options attributed to the focal element evaluated, and the number of decision makers considered for the group decision. Hence the calculation steps are dynamically changing making the manual calculation process impractical. Since there were no available tools to simplify this process, a new software tool was developed using C# programing language based on the .Net framework. This DS-AHP software can weigh the decision criteria using the pairwise comparison (Figure 2.8), support the criteria wise focal element creation and calculate the decision maker-wise option '*bpa*'s based on the given criteria-wise preference levels (Figure 2.9), and select decision makers (Figure 2.10) to generate the group decision (Figure 2.11). A comprehensive description of the implementation of the DS-AHP software has been described in Appendix X.

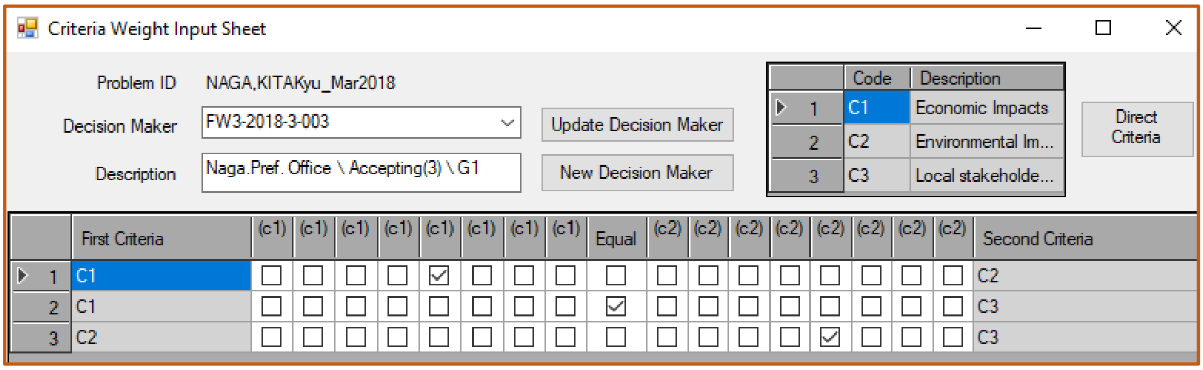


Figure 2.8 Screenshot of the pairwise comparison of Criteria

Source: made by author

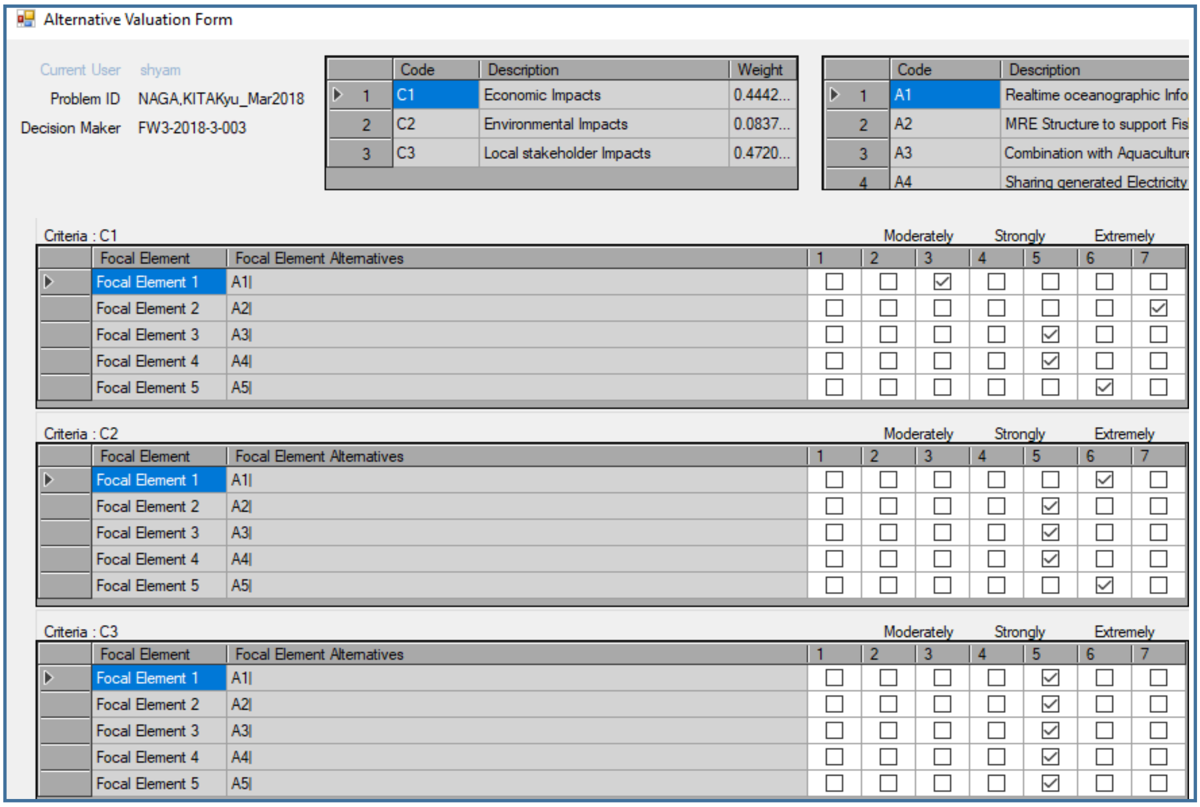


Figure 2.9 Screenshot of the criteria wise focal element creation and preference input

Source: made by author

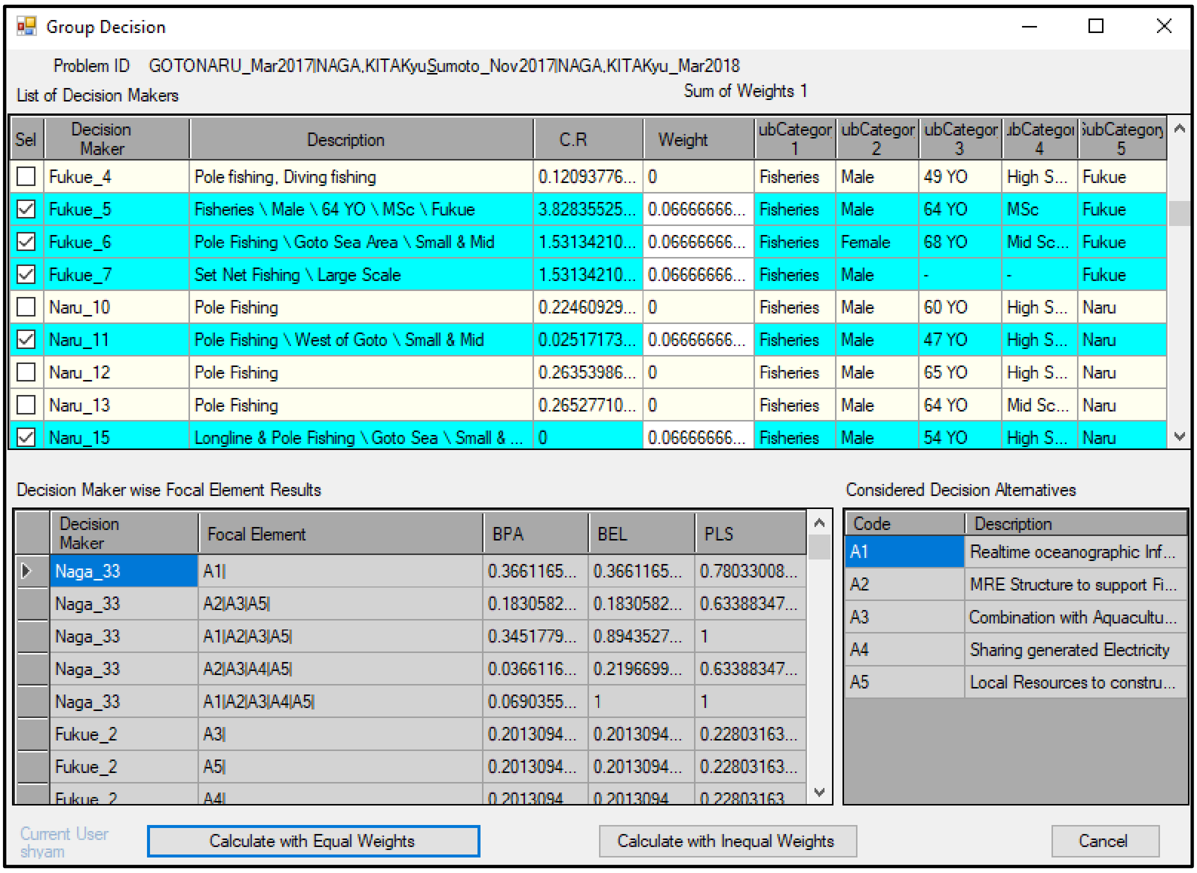


Figure 2.10 Screenshot of the decision maker selection for the group decision

Source: made by author

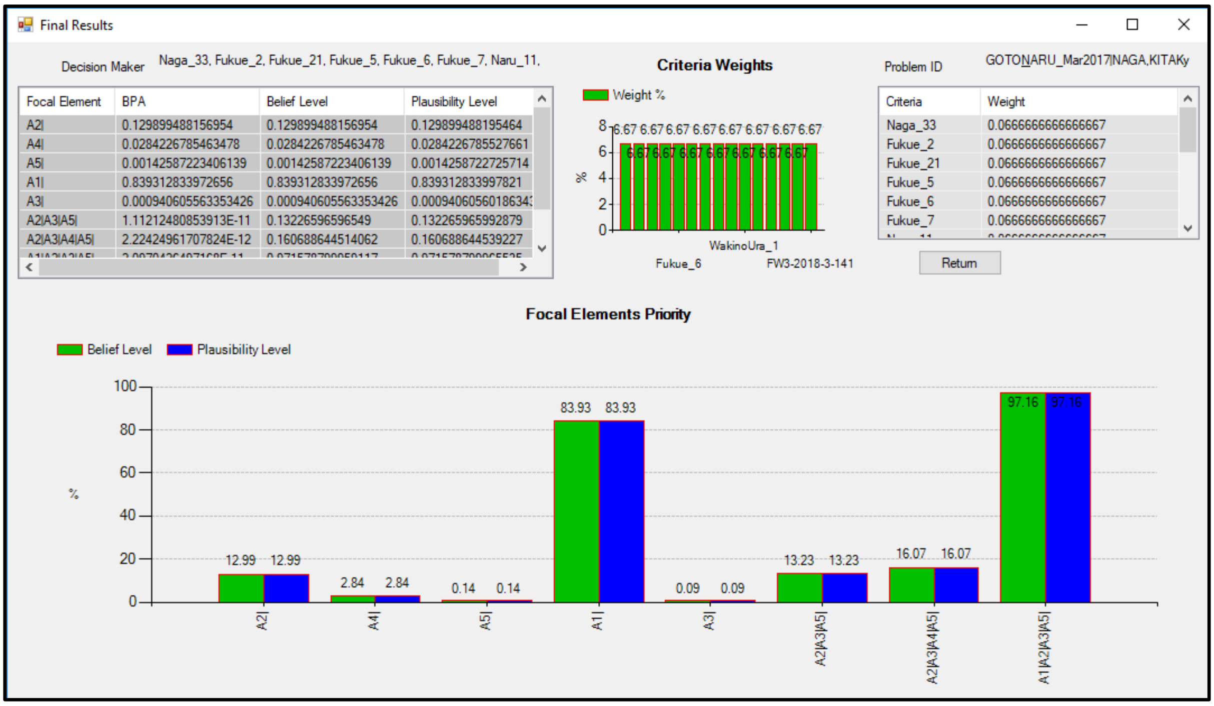


Figure 2.11 Result display screen

Source: made by author

2.5 Feasibility of the preferred co-existence strategy: Sharing real-time in-situ ocean information MRE to other marine users (R.Q 3)

From the first two research questions, it was identified that the option of "sharing real time ocean information from MRE projects to the local marine users"; is the most preferred option by the local fishers; who are the most prominent stakeholder in the consensus building process and who had the most knowledge and experience on marine activities among other local stakeholders. Due to the stakeholder preference as well as the novelty of the solution, sharing real-time in-situ ocean information option was selected as the co-existence strategy that should be further analyzed for the feasibility. To evaluate the feasibility of ocean information sharing option, following questions were focused in this study.

a) What ocean information parameters are required by the stakeholders?
b) What ocean information parameters are currently available for the stakeholders?
c) What ocean information parameters can be generated by the plant's Condition Monitoring System (CMS) / Supervisor Control and Data Acquisition (SCADA) system?
d) What are the expected incremental costs and benefits of employing this option to the stakeholders?

2.5.1 Data collection analysis methods

Data collected by the author (Primary Data) as well as the data from existing data sources and literature (Secondary Data) have been considered when answering the above questions. Specific data collection and analysis methods used for each research question are as follows.

2.5.1.1 Stakeholders' ocean information requirement

Local stakeholders' ocean information requirement was elucidated from key informant interviews. The document shown in Appendix IX, which is based on the EuroGOOS Requirement Survey (ERS); a similar type of stakeholder requirement survey (Fischer & Flemming, 1999), was used as a guide document during the stakeholder interviews. ERS is one of most comprehensive studies conducted in late 90s covering almost all potential ocean information users by means of an open-ended survey. (Fischer & Flemming, 1999).

Despite the comprehensiveness, the exact replication of ERS in this study was not practical due to the limitations such as, lack of stakeholder expertise, local fishermen's unfamiliarity with the technical terms used in the ERS, differences of commonly used terms to represent the ocean information parameters even among different stakeholder groups etc. Hence a simplified version of ERS was used as a guide document during the interviews. This simplified ocean information requirement survey was used in our previous studies in the context of ocean current power project in Wakayama prefecture (Kularathna, 2016; Kularathna & Takagi, 2017). The results of that previous survey was also validated in this study.

The original results of the ERS, specifically the ocean information requirements of the 'researchers, transport, environment monitoring, and food' sector stakeholders were used as secondary data to validate the primary data collected. Parameterization was done to the validated data at the end of analysis of the stakeholder's ocean information requirements.

2.5.1.2 Ocean information currently available for local stakeholders

Questions were included in the same guide document (Appendix IX) in order to identify the current ocean information availability. This data is then validated with the available data sources such as online data portals. Parameterization was done to identify the gap between the ideal ocean information demand and the current ocean information availability for local stakeholders.

2.5.1.3 Information generation capacity of the CMS / SCADA of the MRE farm

CMS and SCADA systems of the MRE power plant monitors the critical operational parameters inside the power take off devices (e.g. temperature, vibration levels, noise levels, oil pressure etc.) as well as the ambient conditions of the environment outside the MRE devices which are related to the performance and the safety of the power plant (wind profile, wave profile, current velocities, temperature etc.). All these parameters monitored via in-situ sensors are then transmitted to the control center located onshore via subsea fiber optic communication lines. Additional parameters can also be monitored via the CMS or SCADA systems since the basic infrastructure is already developed for the MRE project. Thus the potential of the CMS/SCADA to generate the required ocean information is dependent of the design specifications of the CMS/SCADA. Since the technical specifications for the proposed MRE projects have not been finalized yet, interviews and consultations with project development team were used to confirm the technical feasibility of having different CMS/SCADA configurations to satisfy different ocean information requirements. Further, generic CMS and SCADA system design specifications were also used as supporting data to analyze the potential information supply.

In addition to these primary data received from interviews and generic CMS/SCADA system specifications, data from existing ocean observation systems and user specific ocean data acquisition systems were referred as the secondary data to validate the potential ocean information supply from MRE power plants. Parameterization was then conducted to summarize the ocean information supply potential of the CMS/SCADA of the MRE plant.

2.5.1.4 Economic feasibility of the proposed ocean information sharing scheme

Economic feasibility of the proposed ocean information sharing system was done by estimating the net incremental costs and benefits considering all the related stakeholders. The standard cost benefit analysis methods (Boardman et al., 2006) and sensitivity analysis were used to improve the economic feasibility analysis. The total incremental cost of the proposed information sharing system was estimated from the data elucidated from the interviews with project developers and available market data. After the technical requirements (e.g. type of sensors, data transmission requirements etc.) were confirmed by the project designers, total additional development cost is estimated by consulting equipment suppliers and conducting an online price survey. Due to the limitations such as lack of accurate cost estimates for the proposed local MRE projects and uncertainties of exact additional requirements etc., the worst possible cost scenarios were considered for the cost estimates with the assumptions made from the secondary costing data available from previous studies such as the costing data from similar ocean observation systems and cost benefit analysis done for the Mediterranean Forecasting System Towards Environmental Predictions (MFSTEP) (Chiabai & Nunes, 2006).

The total incremental benefits of the proposed information sharing system is relatively difficult to estimate by direct valuation methods, due to the lack of prior experience of having such a rapid technological transition in recent history and the inherent uncertainty of matching the local benefits with the improved information supply. Hence, only the fishers' direct benefits were considered to estimate the potential benefits and the estimation was done by the contingent valuation method of Willingness to Pay (WTP) study based on the qualitative improvements identified. In addition to the WTP value, other indirect indicators such as fishers' current expenditure levels on available ocean information etc. were also used for the validation of the expected stakeholder benefits levels. Sensitivity analysis was done based on fishers' average financial data to test the reliability of the identified WTP value.

The expected costs and benefits were compared for several possible information sharing levels from which the optimum feasible scenarios were identified according to the other limiting factors such as the number of fishers in the case study area etc.

2.6 Summary

With the data collection and analysis methods, the complete research flow can be summarized as the research framework diagram in the Figure 2.12.

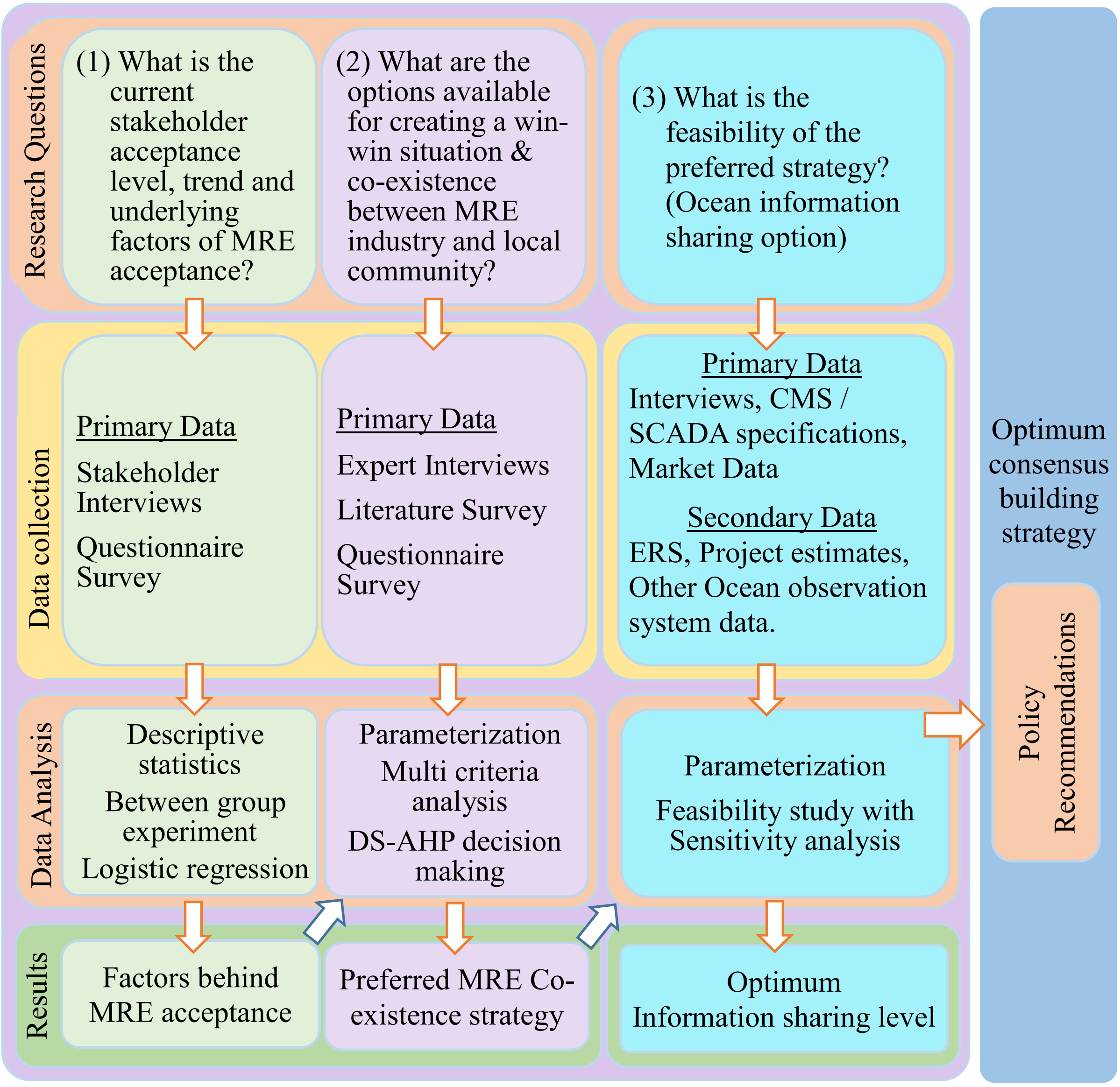


Figure 2.12 Research Framework and Methodology

Source: made by author

Chapter 3 (pp. 50 to 83) of this doctoral thesis has not been made public on the internet because a part of this chapter is scheduled to be published as a journal paper.

4 OPTIONS FOR CO-EXISTENCE

4.1 Literature on co-existence of MRE with community

This chapter is focused on the second research question: "What are the options available for creating a win-win situation & co-existence between MRE industry and local community?" according to the requirements identified by the previous chapter.

From the analysis of local acceptance behavior in the previous chapter, it was identified that local stakeholder acceptance decision for MRE projects is highly dependent on project information sharing level, impacts to local industries such as fisheries, tourism and related businesses, and costs/benefits to the local community than the other factors mentioned in the literature like visual impacts and NIMBY effect. It was also identified that inclusivity of public authorities also help improving the local acceptance. Thus, MRE projects directly involved with local community under government supervision is the preferred co-existence strategy by the local stakeholders.

The motive behind this search for co-existence options is supporting the process of consensus building among local stakeholders and thereby improving public acceptability of MRE projects. In order for those co-existence options to be sustainable, satisfying the basic requirements such as 'being an incentive to stakeholders', 'maintaining the fairness, inclusivity and respect towards local requirements', 'encouragement of stakeholder engagement' etc. is necessary. These factors have been identified as effective in terms of building local acceptance from the experiences of developing onshore wind projects in Europe (IEA Wind, 2013; Jobert et al., 2007). A brief summary of strategies used for improving stakeholder acceptance for renewable energy projects (mainly onshore wind projects) has been shown in Table 4.1.

Table 4.1 Summary of the strategies used for stakeholder acceptance from literature

Main type	Description	Examples
Monetary incentives	Profit sharing schemes, Tax benefits	Denmark (Morthorst, 1999) UK (Brunt & Spooner, 1998) France/Germany (Jobert et al., 2007), Sweden (Devlin, 2005) Netherland (Wolsink, 2007a)
	Creating opportunity for local investments	
	Sharing ownership (shareholders of wind turbines / Private and co-operative ownership)	
	Financial compensation for use of territory and adverse project impacts	
Non-monetary incentives	Use of 'built infrastructure' to support other local activities	Combined visits for tourists. (Jobert et al., 2007)
	Creating local job opportunities, alternate supply of cheap energy, development of other local infrastructure	Discounted electricity supply (Devlin, 2005), Investments on other local infrastructure (Aitken, 2010)
Stakeholder engagement	Project information dissemination	Communication (Krohn & Damborg, 1999)
	Public participation in the project planning process	Site selection (Bosley & Bosley, 1988), decision making (Wolsink, 2007a)
	Capacity development	Denmark (Morthorst, 1999)
	Involvement of local, public or third party stakeholders / authorities	France and Germany (Jobert et al., 2007)
Policy guidance, Political and legislative support	Long term national policy set up	Long term policy in Germany (Jobert et al., 2007), Netherlands, England, Germany (Breukers & Wolsink, 2007)
	Long term agreements with local governments	
	Introduction of new laws	'Feed laws' in Denmark and Germany (Canton & Linden, 2010)
	Political lobbying	France (Jobert et al., 2007)
Other	Minimizing impacts and interactions to the community, isolating and dividing opposing stakeholders	Selecting sites allocated for less attractive land use such as dumping sites (Jobert et al., 2007)
	Various other strategies has been identified in Aitken, (2010); IEA Wind, (2013); Jobert et al., (2007a),	

Source: made by author based on cited other references

In contrast to onshore developments, the legal and geographical boundaries of MRE developments in open ocean areas are unclear. Hence it is difficult to identify the important stakeholder groups that should be incentivized by the considered consensus building strategies. This situation also leads to a difficulty of limiting the number of beneficiaries which is an inherent and unique problem of MRE projects in comparison to other onshore renewable energy projects. The severity of this problem is aggravated when there is no marine spatial plan established for the development area. Hence, in addition to the above criteria, 'use of multi-functional properties of the developed infrastructure or being a co-benefit of the project', is also an important factor when selecting the possible co-existence options.

The basic problem of creating local community benefit schemes is that it normally refers only to additional voluntary measures provided by the developers, which leads to additional costs to already expensive MRE projects. Most monetary benefit creation strategies lead to higher project costs that is directly proportional to the number of beneficiaries (Reilly et al., 2016). Due to the difficulty of limiting the number of beneficiaries, the proposed solutions must not have the same financial impacts of monetary benefit schemes in order to be viable. Rather, the additional developer costs (if there is any) should not be proportional to the number of beneficiaries, to be acceptable by the developers.

Previous studies have shown that conventional type of community benefit creation strategies are unlikely to increase local stakeholder support when bribery perceptions are salient (Cass et al., 2010). Further institutionalizing community benefit schemes has the potential to reduce bribery perceptions (Aitken, 2010). Empirical results from a potential offshore wind farm in the United Kingdom suggested that local stakeholder support is greater if the community benefits result from an institutionalized policy guidance in comparison to the community benefit schemes created as a voluntary act by the project developers (Walker et al., 2017). Further, developers have to manage a variety of stakeholder groups and are generally not equipped to balance all other stakeholders' requirements. Hence, it is of utmost importance to evaluate options to create local project benefits and a win-win situation among all local stakeholders of MRE projects.

Due to these factors, MRE project developers in Japan are in dire need to find solutions to satisfy these requirements. However, there are no previous examples in the Japanese MRE context and a little work has been published even in European context on potential co-existence strategies that can be used to create local benefits from MRE projects, even though providing community benefits can increase levels of local support through improving individual perceptions of MRE projects (Walker et al., 2014).

Local fishery industry is the most likely to be directly impacted stakeholder group by the MRE project deployments (Yates & Schoeman, 2013). Since MRE project structures are usually built away from the community, the related social interactions as well as potential benefit creation strategies tend to deviate from onshore renewable energy projects. The second aspect of this problem is the lack of knowledge and experience as local MRE sector is still in the technology readiness phase. The Research Institute of Ocean Economics (RIOE) in Japan has proposed some options to create benefits for local fisheries from offshore wind projects (RIOE, 2013). However there is very limited literature available on those identified co-existence strategies as summarized in the Table 4.2.

As described in the section 2.4, MRE co-existence option evaluation is a three-step process: (1) identification of potential co-existence options, (2) multi-criteria analysis (MCA) of identified co-existence options and, (3) evaluation of the stakeholder preferences using the DS-AHP MCDM method. This literature review serves the basic requirements for accomplishing the first step of identifying the potential options. However, in-order to confirm the local relevance of the identified options, key stakeholder interviews were conducted from which a refined set of co-existence options were selected for further analysis as described in the next section.

Table 4.2 Summary of co-existence strategies applicable for MRE

	Options proposed by RIOE (2013)	Key findings from other literature
1	Providing in-situ ocean information in real-time	Japanese marine users receive ocean information from satellite observations, buoys, and other user specific monitoring platforms (Kinoshita, 2010; RIOE, 2013). Stakeholders have different ocean information demands (Fischer & Flemming, 1999). Direct economic valuation and cost benefit analysis of ocean information is impractical (Chiabai & Nunes, 2006). Marine energy is mostly harvested in murky and high energetic places where conventional data acquisition techniques are impractical (Francisco & Sundberg, 2019).
2	Use MRE structures as artificial reefs for nurseries/fishing	Constraints, opportunities, and perceptions of co-locating offshore wind farms and fisheries (Hooper et al., 2015; Hooper & Austen, 2014), mitigation agenda for fishing effort displacement (de Groot et al., 2014).
3	Using MRE structures to support fishery gears	Potential for co-location of passive gear fisheries with offshore wind (Stelzenmüller et al., 2016). Potential for and limitations of co-locating fisheries inside offshore wind farms (Blyth-Skyrme, 2011).
4	Co-location with aquaculture facilities (e.g., fish, oyster, and algae)	Co-locating offshore wind farms and aquaculture facilities (Buck & Langan, 2017; Buck et al., 2004; Gimpel et al., 2015; Hooper et al., 2015; Mackinson et al., 2006). Device placement has many other technical requirements (Wang, 2019).
5	Co-location with leisure facilities (e.g., diving, recreational fishing etc.)	Potential for limited entry recreational fishery in wind farms (Fayram & de Risi, 2007), snorkeling, tourism(Westerberg et al., 2013), angling, and yachting (Mackinson et al., 2006; RYA & CA, 2004).
6	Use of electricity generated to power fishery port facilities and electric boats	Proposal for using wind energy to power fishery ports (MAFF, 2012), harbors (Cascajo et al., 2019), desalination plants (Clayton et al., 2014).
7	Project participation by using fishery boats for construction and maintenance of the power plant	Use of fishing vessels for offshore energy projects (FLOWW, 2008). Availability of crew and vessels is an important factor influencing the planning and cost of maintenance of MRE. Laws and regulations also influence MRE operation and maintenance (O&M) (Nachimuthu et al., 2019; Seyr & Muskulus, 2019).
8	Project participation by providing investment opportunities in MRE business	Creating business investment opportunities as an acceptance improvement measure (OES - IEA, 2015). Local ownership or financial participation contribute to the acceptance of MRE projects (Gao et al., 2019).

Source: made by author based on cited other references

4.2 Step 1: Identification of potential co-existence options

The local relevance of MRE co-existence options proposed by RIOE (2013) were analyzed by systematically understanding the real project stakeholders' perceptions of each proposal via key stakeholder interviews. Stakeholder interviews were conducted in a semi-structured format that focused on the expected potential impacts, related costs and benefits, and the related risks and limitations of the proposed co-existence options.

Table 4.3 provides a summary of the key information provided by the key stakeholders during the interviews. After identifying the potential and the applicability, the proposed co-existence options were categorized into five main options: (O1) sharing real time, in-situ ocean information, (O2) using MRE structures as artificial reefs and support structures for fishing, (O3) co-location with other industries such as leisure and tourism, aquaculture, (O4) sharing generated electricity for local users at a subsidized rate, and (O5) use of local resources to construct and operate the power plant, creating business involvement opportunities.

From experiencing the pilot project developments in the area, local stakeholders have understood that MRE devices can create positive benefits if their multi-functional properties are utilized for creating additional value for the community. According to the industrial practices, potential benefits and additional investments required, certain options proposed by RIOE (2013) was combined to a single co-existence strategy. For example, 2nd and 3rd options in Table 4.2 were combined into option O2 in Table 4.3 since adjustments needed in terms of MRE project owners are almost similar. Similarly, co-location of aquaculture and leisure industry (4th and 5th options in Table 4.2) was treated similarly in option O3 in Table 4.3 since industrial activities such as travel planning, deciding the location (fixed location in these cases etc.) is similar. Finally 7th and 8th options in Table 4.2 were combined into option O5 in Table 4.3 due to the similar nature of stakeholder engagement and required adjustments.

Table 4.3 Summary of stakeholder interviews on expected impacts, related costs and benefits, risks and limitations of proposed options

Co-existence option		Expected impacts, related costs and benefits, risks and limitations
O1	Sharing real-time, in-situ ocean information from MRE farms	• Real-time in-situ ocean information is valuable to the marine users for travel cost reductions, risk reductions, and improvements in commercial marine industries such as fisheries (by efficient fishing ground selection, stock estimations, etc.) and navigation (improvements in safety, route planning, etc.) • Can be identified as a co-benefit of the MRE projects since most commonly-required ocean information can be generated from the Condition Monitoring System (CMS) / Supervisory Control and Data Acquisition (SCADA) system of the project. • Stakeholder engagement can be improved since many stakeholders directly or indirectly use ocean information. • The additional cost to developers is insignificant (if there is no ocean monitoring equipment to be installed in addition to the power plant's standard CMS/SCADA) and not proportional to the number of beneficiaries due to the existence of cheap information dissemination infrastructure. • Equality and scalability can be improved if the governance of information sharing is well-maintained. • There is a risk of stakeholder conflicts due to the exposure of marine information that is considered trade secret (such as fishing grounds). Information about the marine environment can lead to better eco-system management or unsustainable exploitation of marine resources (such as over fishing) unless there is proper governance of shared ocean information.
O2	Using MRE structures as artificial reefs and support structures for fishing	• Artificial reef effect and resulting positive spillover effect to the surrounding fishing grounds can be considered a co-benefit of MRE projects. • Use of sub-structures to support fisheries can be a benefit if there is no significant additional cost to the developer and fishing gears do not adversely interact with the MRE devices.(Subsea support structures are expensive to setup for fishers) • Only certain types of fishers can benefit since many fishing methods are being used in the case study areas. • Scalability is directly dependent on the size of the MRE farm. • There is a high possibility of increasing the initial construction costs as well as O&M costs if MRE structures are used as support structures for fishing operations. Impact to the overall Levelized Cost of Energy (LCOE) and the net benefits to the fishery industry should be considered when conducting a detailed cost-benefit analysis for this option. • Artificial reef effects caused by bio-fouling as well as fishing operations near MRE devices can pose significant operational risks and unforeseen problems.

O3	Co-location with other industries such as leisure, tourism, and aquaculture	• Aquaculture is one of the best co-location options. However, it depends on how fishing gears can be used with MRE structures. With the combination of reef effects and remote monitoring facilities (e.g., detection of fish within MRE farms (Francisco & Sundberg, 2019)), aquaculture facilities combined with MRE farms is an attractive solution. • Local tourism can be improved by having visible MRE projects as well as organizing boat excursions to the power farm areas. Reef effect creates an environment conducive for snorkeling and diving. • There should be a practical method of regulating the interactions to maintain the safety and efficiency of both industries. • Due to the nature of operations, such as travel planning, aquaculture facilities (specifically seaweeds culture) and leisure facilities have the same characteristics that differ from typical large-scale fishing. • Activities in marine environments near MRE farms can pose significant risks to MRE devices and involved personnel. • LCOE can be impacted by additional construction or O&M costs due to co-location attempts.
O4	Sharing generated electricity for local users at a subsidized rate	• Local fishery harbors and fish processing plants can be the best candidates for receiving subsidized electricity. • Under current regulations, it is illegal for the utility company to differentiate the electricity rates based on other factors. Hence, limiting the number of beneficiaries is difficult unless clear policy-level guidance is introduced. • Additional costs are directly proportional to the number of beneficiaries, thus limiting scalability and economic viability. • Offshore charging points for electric boats (like charging stations for electric vehicles on land) can be created in the future. However, those technologies are too uncertain and impractical given existing costs. • LCOE can be impacted by additional costs due to potential additional requirements of local electricity grid management.
O5	Use of local resources to construct and operate the MRE plants, creating business opportunities	• Shipping vessels can be used for logistic purposes during the environmental impact assessment, construction, as well as maintenance phase of the power farm. Local fishers can be recruited for monitoring purposes in the offshore area. • If the local fishery union can invest in the project, the sense of ownership can lead to a better performance of fishers as guards of the power farm. However, the local capacity within fisheries is limited and legal regulations have to be adjusted. • Local ports, steel industry in Kitakyushu, and ship building industry in Nagasaki can be strategic partners of MRE projects. • LCOE can be positively impacted by using local resources from already established sources and industries. However, LCOE can be adversely impacted if the initial MRE projects have to invest in capacity building of the local sources to make them qualified and competent enough to be involved with the MRE projects.

Source: made by author based on the key stakeholder interviews

4.3 Step 2: Multi-Criteria Analysis of identified co-existence options

Since most of the suggested co-existence strategies have not yet been experienced by the local stakeholders, it was important to describe and define the proposed options. Project benefit information described in Appendix VI provides the summary of the proposed co-existence strategies.

After the interviews, key stakeholders were asked to estimate the net impacts of each co-existence option (with the help of MCA sheet in Appendix VII). Since it was difficult for most of the stakeholders to estimate the impacts in quantitative measures, provided qualitative data was converted into a three scale indirect quantitative measure as explained in the methodology section 2.4.2.

The results of the multi criteria analysis is summarized in the Table 4.4. The main limitations of the considered co-existence options identified during key stakeholder interviews are shown in the last row of Table 4.4. For example, the main concerns mentioned regarding the ocean information sharing option were 'how the shared information will be used in the context of competitive fishing ground selection', 'who will be given the information because some fishery groups maintain knowledge about fishing grounds as a local trade secret and fishers from outside areas also have the possibility to use the same fishing area', and 'if the new information will cause sustainable stock management or over exploitation of fishery resources'. All these concerns have to be handled by establishing good governance for using the shared information.

Only a certain type of fishers can benefit from the second option of using MRE structures as artificial reefs or support structures for fishing gear. Hence, unequal cost-benefit distribution and limitations of scaling the benefits to other stakeholders were mentioned as limitations of the second option.

Since there are no prior examples of combining aquaculture or leisure facilities with other offshore activity, there is a significant uncertainty for the feasibility of the third option, even though the possibility was recognized by the stakeholders.

Local utility company representatives indicated that they are legally bound to maintain equality in terms of pricing the electricity for their customers, so the electricity rate for different customers or stakeholder groups cannot be significantly differentiated. Further, Japanese utility companies use the 'total cost method' as the basis of electricity bill calculation.

Table 4.4 Multi-criteria analysis (MCA) of co-existence options

Key criteria		Co-existence Option				
		O1. Sharing real-time, in-situ ocean information from MRE farms	O2. Using MRE structures as artificial reefs and as fishery support structures	O3. Co-location with industries like leisure, tourism, and aquaculture	O4. Sharing generated electricity for local users at a subsidized rate	O5. Use of local resources & create business involvement opportunities
C1.Economic impacts	Project co-benefits	✓✓✓	✓✓	✓✓✓	x	✓✓✓
	Cost not proportional to the number of beneficiaries	✓✓✓	x	✓	xx	✓
	Scalability	✓✓✓	-	-	x	✓
C2.Environmental impacts	Marine environment	-	-	✓	-	✓
	Emissions	✓	✓✓	-	✓✓	✓
C3. Social impacts	Stakeholder engagement	✓✓	✓✓	✓✓	✓✓✓	✓✓✓
	Stakeholder incentives	✓✓	✓	✓	✓✓✓	✓✓
	Equality	✓✓	-	✓	-	✓
Main limitations		Lack of information sharing governance	Limited scalability and unequal cost benefit distribution	Uncertainty on economic feasibility with the adjustments required	Legal barriers and limiting number of beneficiaries	Limited local capacity

Note:✓: Affirmative/positive impacts, -: Not sure, x: Non-affirmative/negative impacts. The number of repetitions (up to three times) of the symbols ✓ and x represents the degree of agreement (tendency to somewhat agree, agree, and strongly agree, respectively) for all the stakeholder interviews considered cumulatively. Source: made by author based on the key stakeholder interviews.

Fishery union representatives and the developers identified the limitations of the fifth option as the requirement of specialized skills and other resources to become involved with the MRE sector. For example, even though the fishery vessels can be used as power plant monitoring resources (at a certain distance), they might not be capable of being used as a logistic means to reach or repair the MRE devices. The limitations of local capacity were identified as the main limitation of the fifth co-existence option of using local resources to construct, maintain, and operate the power plant and creating business involvement opportunities.

4.4 Step 3: Preference of identified co-existence options

The next step in the co-existence option evaluation is the multi-criteria decision making with the MCA results obtained in the previous section to select the optimum solution. The decision hierarchy for the DS-AHP multi-criteria decision making (as explained in the methodology and Figure 2.7) is updated according to the selected set of criteria and options as shown in Figure 4.1.

Consensus building normally happens among the stakeholder groups and their representative associations. The members of these discussion group are generally comprised of stakeholders who are working in the same field and have same level of livelihood (e.g. Fishery unions, health and welfare groups, environmentalist groups). The responses were grouped based on the stakeholders' occupation considering the prominence assigned to the stakeholder group as well as the unique characteristics of their responses.

Out of 77 valid results obtained for the DS-AHP analysis, 6 main stakeholder groups could be formed according to the similarity of the mentioned occupation (Table 2.3). Thus the stakeholder group preference was calculated with respect to the fishers, construction sector respondents / developers, civil servants, tourism and shipping industry respondents, health and welfare sector respondents and NPO/service sector or other type of stakeholders. The respondents who have not indicated their occupation were not considered for the stakeholder group-wise analysis discussed in the next section.

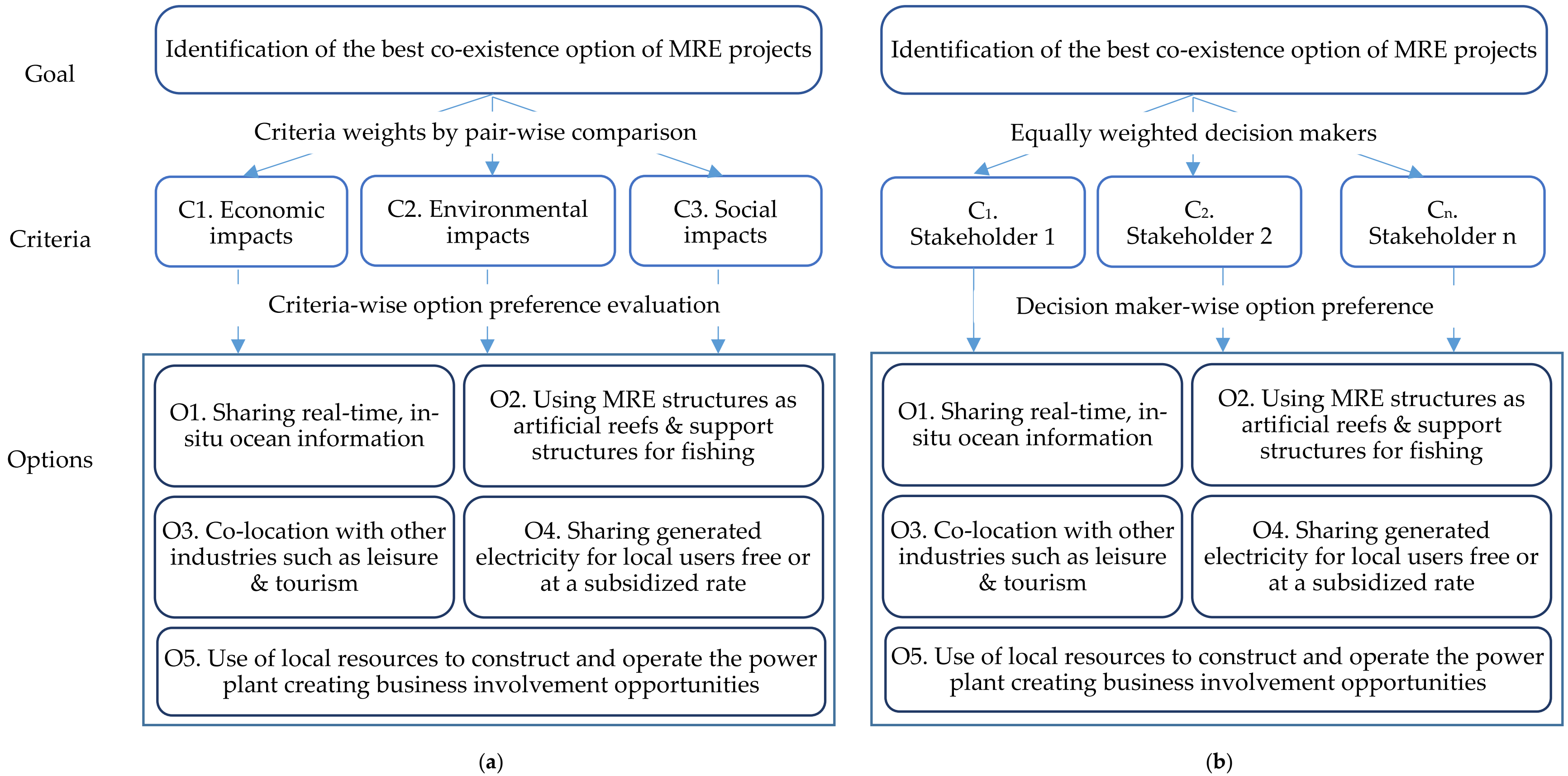


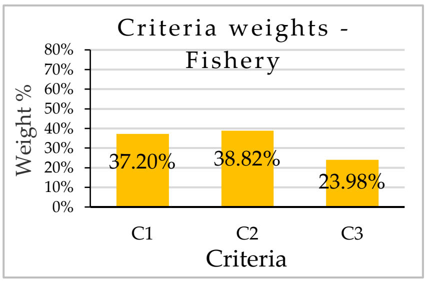
Figure 4.1 DS-AHP decision hierarchy: (a) stakeholder-wise decision and (b) group decision hierarchy

Source: made by author based on selected set of decision criteria and decision options. Group decision was made by equally weighted decision-maker method (Beynon, 2005a)

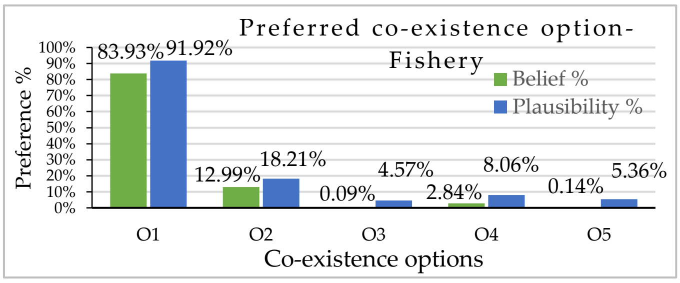
4.4.1 Stakeholder group-wise preference decision

Figure 4.2 to Figure 4.7 indicate the criteria weights (obtained by pair-wise comparison as in AHP method) of the selected criteria (in the left column), and the final belief and plausibility levels of support for the considered co-existence options (in the right column) for both case study areas according to the stakeholder group.

Figure 4.2 indicates the DS-AHP results summary of the fisheries. According to the criteria weighting results in Figure 4.2 (a), respondents representing the local fisheries assigned a higher weight to economic and environmental impacts (C1 and C2, respectively) than the social impacts (C3).



(a)



(b)

Figure 4.2 Stakeholder group-wise preference decision (a) average criteria weights and (b) option preference of fisheries.

Source: made by author based on the DS-AHP MCDM results

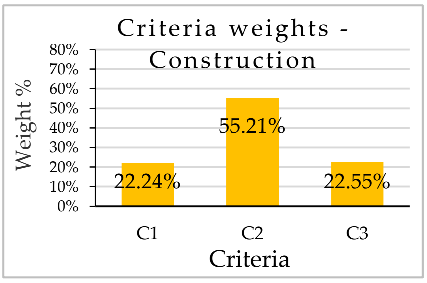
The fisheries are the main stakeholder group who frequently require ocean information for their daily industrial activities. Interviews with fishery unions indicated the value of subsea information for estimating fish stock, fishing ground, viable catch, and the safety of marine activities. All these factors support their preference of considering ocean information as the best option (Figure 4.2 (b)).

Even though they were interested in the fifth option, fishers also raised the question about the real potential of being involved with the MRE project developments and operation, because they have a better understanding of what is required to work in offshore conditions based on their experience. Interviews with fishers showed that fishing vessels can be used for logistic purposes during the environmental impact assessment phase and maintenance phase of the power farm. The potential of recruiting local fishers for monitoring purposes of the power plant was also mentioned. However, fishery union leaders identified that the vessels used for local fishing may not be suitable for MRE projects and the ageing fishery community may not be willing to accept new challenges related to MRE projects. However, this type of interaction with fishery and the MRE industry may attract the younger generation to the fishery industry. In addition to the above factors, the low weight assigned to the social impacts contributed to not selecting the fifth option as a preferred option.

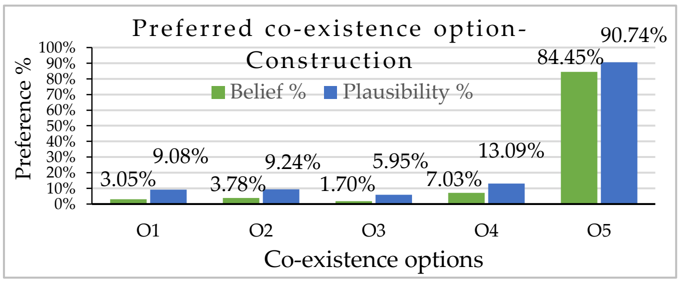
The second best alternative for fishers was the second option. However, its preference level was significantly lower than that for the first option. Fishers identified that they can benefit from the artificial reef effects, which have a spillover effect on the surrounding fishing grounds. Fishers indicated that they can reduce costs related to their fishing gear setups (such as fixed nets) if they receive structural support from the MRE structures.

The value of real-time in-situ ocean information was again highlighted when the fishers discussed their fishing methods and fishing gear, such as the ability of local fishers to protect their fixed net setups and aquaculture setups, in the events of sudden ocean currents, commonly known as Kyucho in Japan (Ishidoya, 2002; Matsuyama et al., 1999). Another advantage of in-situ ocean information is the ability of fishers to predict the ocean conditions and decide if the fishing gear is suitable before travelling to the area. Further analysis of fisheries preference is discussed in a separate section due to their importance to the stakeholder group among all other stakeholders as well as their unique decision behavior.

Figure 4.3 (a) and (b) indicate the criteria weights assigned by and the final preference of the respondents from the construction industry. These respondents are expected to be involved with the MRE projects during its development phase. These results can generally represent the opinion of future MRE project developers.



(a)



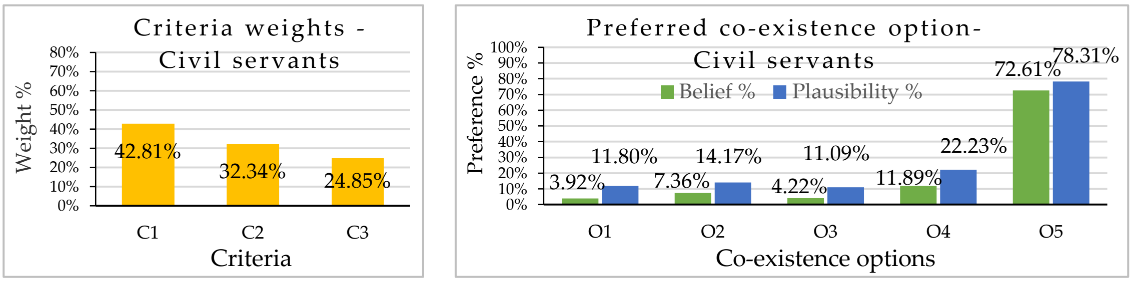
(b)

Figure 4.3 Stakeholder group-wise preference decision (a) average criteria weights and (b) option preference of construction sector respondents.

Source: made by author based on the DS-AHP MCDM results

They assigned the highest weight to the environmental impacts. However, the environmental impacts of most of the considered co-existence options are either not known or insignificant (Table 4.4). Hence the high weight assigned to environmental impacts is not represented in the final preference results where the highest preference was for the fifth option. Interviews with the project developers indicated that there is a high possibility of involving local fishers through the local fishery union for the initial stages of MRE project development, such as using their fishing vessels to conduct surveys and environmental impact assessment. The fifth option is the only option that can be directly employed for project development so the developers directly benefit from it. According to the project developers, there can be long term benefits in terms of improving LCOE due to the use of local resources and developing local supply chain industries, even though additional initial investments could be required for building local capacities to meet the requirements of the MRE industry.

Figure 4.4 (a) and (b) indicate the criteria weights assigned by and the final preferences of the respondents from the civil service sector. They assigned the highest weight to the economic impacts criterion. They selected the fifth option as the best option among the options. Interviews conducted with local government officers and other civil servants like school teachers indicated that they have no direct involvement with the marine affairs. We separately analyzed the results from the health and welfare sector respondents due to unique characteristics that will be explained later. The group of civil servants considered in Figure 4.4 (a) and (b) can be approximated to the inland urban communities that have a vague idea that MRE projects may result in high energy costs and the local community should be given the opportunity to improve their economy.

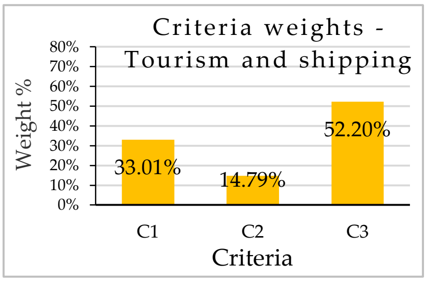


(a) (b)

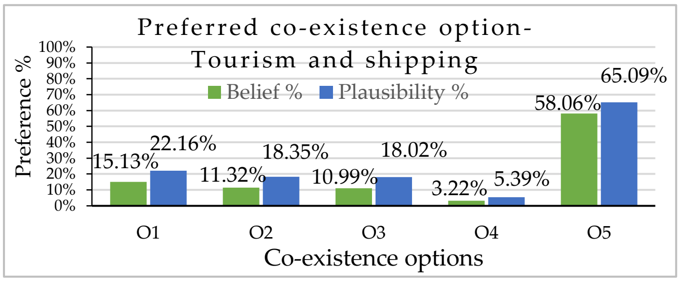
Figure 4.4 Stakeholder group-wise preference decision (a) average criteria weights and (b) option preference of civil servants.

Source: made by author based on the DS-AHP MCDM results

Respondents involved with the local tourism industry and shipping industry assigned a significant weight to the social impacts criterion (Figure 4.5(a)) which is comprised of stakeholder engagement, incentives, and equality. The most preferred option was the fifth option, using local resources for MRE project development and creating business involvement opportunities (Figure 4.5 (b)).



(a)



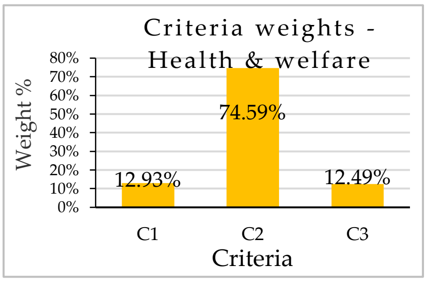
(b)

Figure 4.5 Stakeholder group-wise preference decision (a) average criteria weights and (b) option preference of tourism & shipping industry respondents.

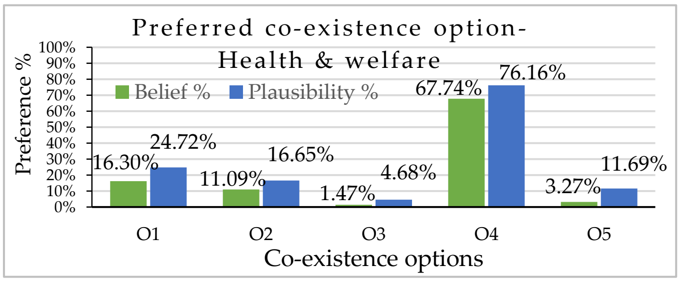
Source: made by author based on the DS-AHP MCDM results

The literature as well as key stakeholder interviews indicated the potential for collaborating with these sectors according to both the third and fifth options. However, local respondents had no experience with how MRE projects can collaborate with local tourism industry as indicated by the third option. The high weight assigned to the social impact aspects with the current level of perception might be the reason for their preference for the fifth option over the third option.

Figure 4.6 (a) and (b) indicate the criteria weights assigned by and the final preferences of the respondents from the health and welfare sector.



(a)



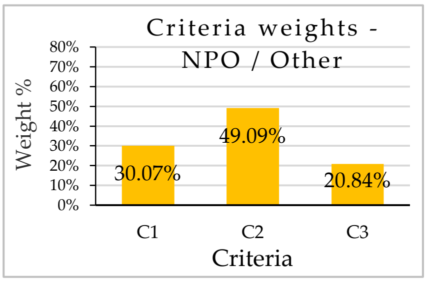
(b)

Figure 4.6 Stakeholder group-wise preference decision (a) average criteria weights and (b) option preference of health and welfare sector respondents.

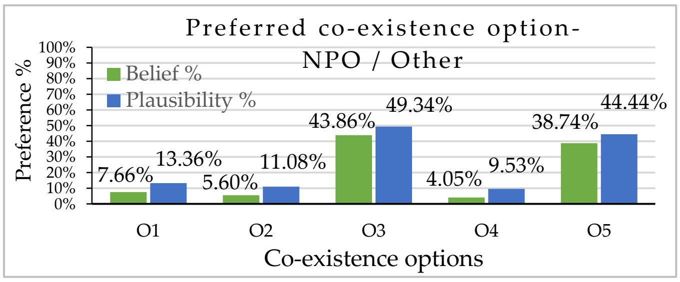
Source: made by author based on the DS-AHP MCDM results

The respondents from health and welfare sector had a unique perception of MRE options, even though they can be considered as civil servants in general. This group had in-depth knowledge and experience with human health impacts compared with other civil servants, as indicated by the high weight assigned to the environmental impacts criteria (74.59%), which was the highest amongst all three criteria weightings for every other stakeholder group (Figure 4.6(a)). They can represent the general inland communities given the minimum interaction with marine affairs. Interviews with representatives indicated their concerns about possible low frequency noise and its impact on human health. However, there is no evidence about the impact of low frequency noise from the onshore wind turbines currently installed in their locality. More justifiable reasons for the selection of the fourth option, i.e., sharing generated electricity as the best option as indicated in Figure 4.6(b), would be the expectation that it will reduce the dependency on conventional non-renewable energy sources (like coal), which would reduce GHG emissions and the expectation of reducing the current economic burden caused by the high electricity demand.

Figure 4.7 (a) and (b) indicate the criteria weights assigned to and final preference of the respondents from local nonprofit organizations and other community organizations. This group indicated environmental impacts as the most important criterion but selected both the third and fifth options as the preferred options. Since most of these respondents were working closely for the revitalization of the local economy, they expected positive impacts from business involvement opportunities with the new MRE sector. According to the discussions with local hotel owners, they expected to revitalize the local tourism industry via future MRE projects. They indicated that there has been a slight improvement in their businesses due to external people visiting the remote islands because of these project developments.



(a)



(b)

Figure 4.7 Stakeholder group-wise preference decision (a) average criteria weights and (b) option preference of NPO and other respondents.

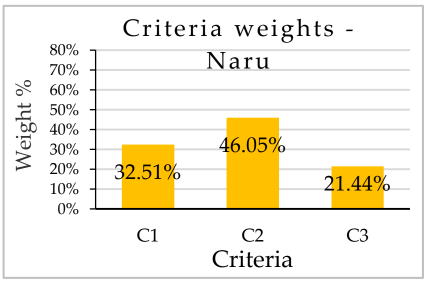
Source: made by author based on the DS-AHP MCDM results

From the results of the stakeholder group-wise option preferences shown in the Figure 4.2 to Figure 4.7, no solution clearly meets the preferences of all the stakeholder groups. Stakeholder preferences were significantly related to the expected individual costs and benefits as well as the level of knowledge and interaction with the marine activities. Hence, it was important to further analyze the local preferences according to other factors such as geographical area.

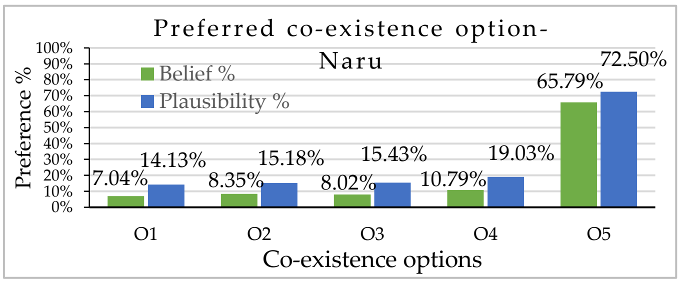
4.4.2 Geographical area-wise group decision

Figure 4.8 to Figure 4.13 indicate the criteria weights (obtained by pair-wise comparison as in AHP method) of the selected criteria (in the left column), and the final belief and plausibility levels of support for the considered co-existence options (in the right column) of the respondents grouped according to the geographic areas in the two case studies. Location of these regions are shown in the case study map in Figure 2.2. The area-wise analysis results show that there is no significant preference identification for certain areas. Few area-specific factors were identified related to these area-wise preference decisions. Further, the analysis of the stakeholder groups included within the area-wise preference analysis group shows that, more the diversity of stakeholders within area-wise analysis group, the lesser the variation of the preference trend. Hence, it can be suggested that the preference behavior was more dependent on the stakeholders' occupations than area-specific factors.

Figure 4.8 (a) and (b) indicate the criteria weights assigned to and final preference of the respondents from Naru Island. Naru Island respondents have identified environmental criterion (C2) as a high priority criteria over the economic and social criteria and selected the fifth co-existence as the preferred option.



(a)



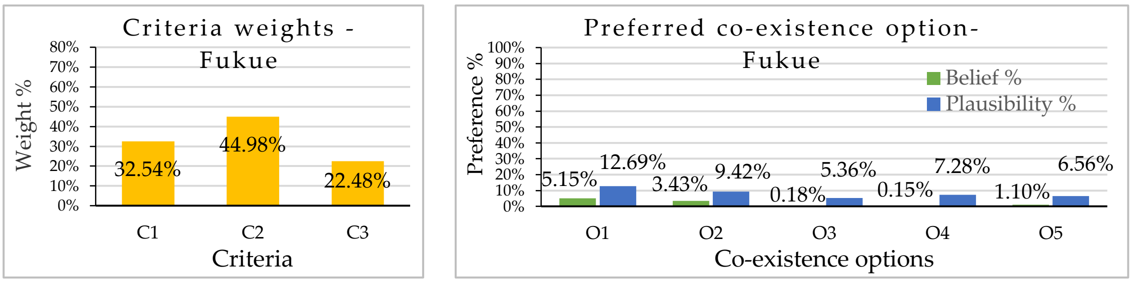
(b)

Figure 4.8 Case study area-wise preference decision (a) average criteria weights and (b) option preference of respondents from Naru.

Source: made by author based on the DS-AHP MCDM results

The fishery industry, which is the main traditional industry on Naru Island (near the proposed tidal energy project in Nagasaki case study area), is declining rapidly due to the ageing society and inability to attract the younger generation towards the fishing industry. Interviews with the Naru fishery union representatives also mentioned that there are almost no fishing efforts in the Naru strait due to the high tidal current velocity. Hence, they do not expect to interact much with the tidal energy project. Fishers from Naru Island acknowledged that their fishing efforts could benefit from real-time in-situ ocean information provided according to the first option, by estimating the high tidal current conditions that are unique to their area. Naru fishers identified that they could extend their fishing grounds to the high tidal current areas in the Naru strait if they know the exact conditions of the tidal velocity. Such benefits can be provided even with the second option where MRE structures could help fishing in high velocity tidal streams. However, they do not expect much benefit in terms of fishery due to the diminishing nature of the local fishery industry. Despite most of the Naru respondents being fishers, their preferred strategy was the fifth co-existence option, which was using local resources to construct and operate the power plant, creating business involvement opportunities as shown in Figure 4.8 (b).

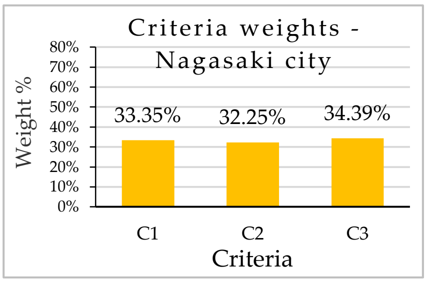
Figure 4.9 and Figure 4.10 show the decision of the respondents from Fukue Island and Nagasaki city area respectively. However, it is difficult to estimate the final preferences of these two groups due to the mix of respondents within the group.



(a) (b)

Figure 4.9 Case study area-wise preference decision (a) average criteria weights and (b) option preference of respondents from Fukue.

Source: made by author based on the DS-AHP MCDM results



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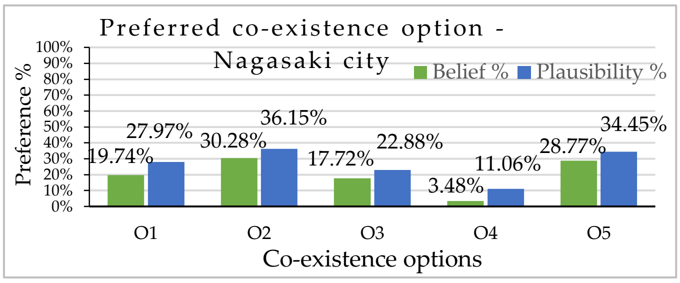
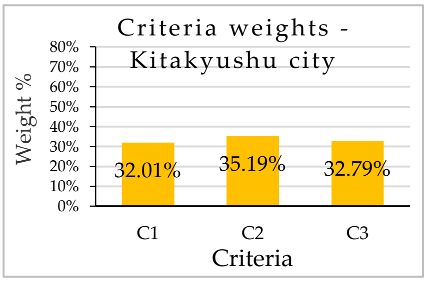


(b)

Figure 4.10 Case study area-wise preference decision (a) average criteria weights and (b) option preference of respondents from Nagasaki city.

Source: made by author based on the DS-AHP MCDM results

However, the respondents from Kitakyushu city area have a relatively clear preference decision where the preferred co-existence is the first option of sharing ocean information (Figure 4.11 (b)). Most respondents from Kitakyushu were from the fishery industry. Hence it was expected to have a similar preference trend between the fishery group (Figure 4.2) and Kitakyushu group (Figure 4.11). Kitakyushu harbor is also a powerful stakeholder in the area. Perception of the existence of the local harbor, which also values the ocean information, might have contributed to the preference decision of selecting first option as the best option.



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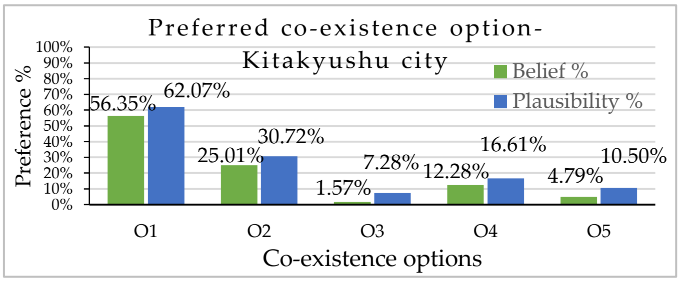
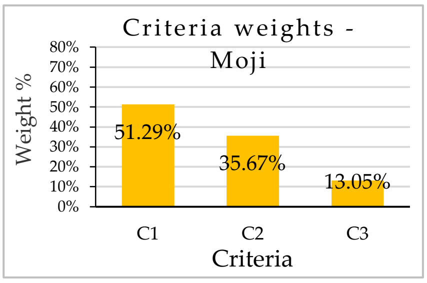


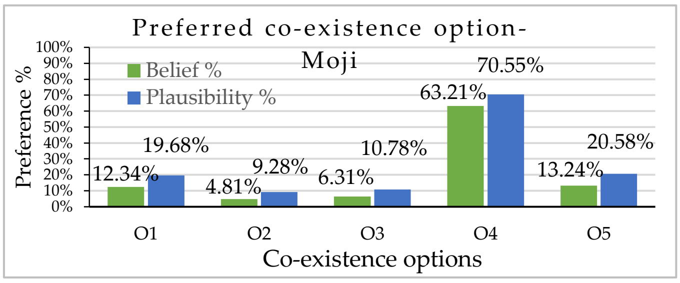
(b)

Figure 4.11 Case study area-wise preference decision (a) average criteria weights and (b) option preference of respondents from Kitakyushu city.

Source: made by author based on the DS-AHP MCDM results

The respondents from the Moji area (in the Kitakyushu case study but away from MRE project sites) preferred the fourth option of sharing generated electricity at a subsidized rate (Figure 4.12 (b)). Their preference decision can be supported by the fact that the electricity supply could be the only direct impact of MRE projects located away from their dwellings.



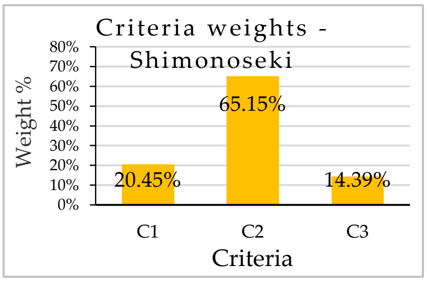


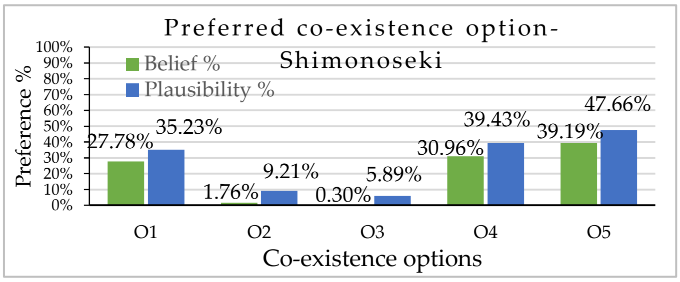
(a) (b)

Figure 4.12 Case study area-wise preference decision (a) average criteria weights and (b) option preference of respondents from Moji.

Source: made by author based on the DS-AHP MCDM results

Figure 4.13 shows the acceptance decision of the respondents from the Shimonoseki area. Considerable amount of these respondents represent the health and welfare group, and fisheries group (whose highest preference was for the fourth option of sharing electricity as per the Figure 4.6 and first option of sharing ocean information as per the Figure 4.2). Hence the Shimonoseki respondents show a mix of preferences for the first, fourth as well as fifth options. However, due to the lack of clear difference between those option preference levels, it is difficult to conclude a clear final decision for the Kitakyushu respondents.





(a) (b)

Figure 4.13 Case study area-wise preference decision (a) average criteria weights and (b) option preference of respondents from Shimonoseki.

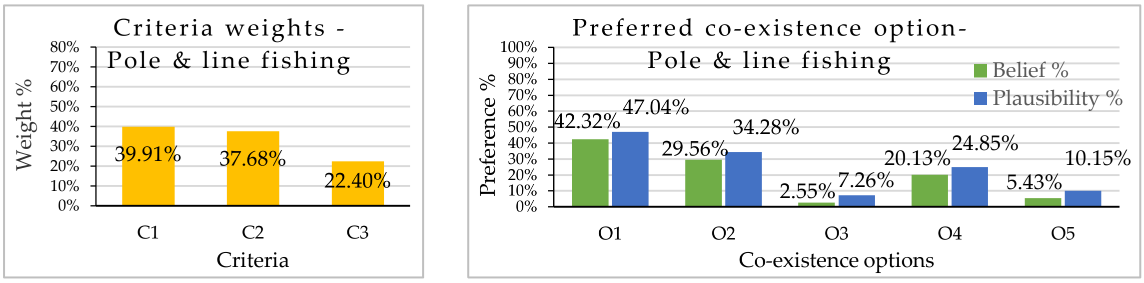
Source: made by author based on the DS-AHP MCDM results

4.4.3 Fishers' preference according to fishing methods and scale

Fisheries preference was further analyzed due to their unique decision behavior in preferring the first option of sharing ocean information. Fisheries are the most prominent stakeholder group in local consensus building process as well as the most impacted local industry from the introduction of MRE projects. Interviews with fishery unions indicated that the impacts of the proposed options highly depend on their fishing methods, fishing grounds and scale.

In this analysis, grouping based on fishing method and fishing scale were highly inter-dependent. Most of the small and medium-scale fishers were using the pole and line fishing method, whereas all respondent fishers who were grouped under the large-scale fisher category were using net fishing and longline fishing as the main fishing methods. Due to this equality of data sets, preference patterns of large-scale fishers and longline and net fishing fishers were exactly the same. Fishers usually use more than one fishing method. The most frequently used fishing method was considered for this grouping. Fishing method was significantly dependent on the fishing area. Most of the local fishers in Fukue and Naru Islands were small-scale fishers mainly using pole and line fishing. Fishers in Kitakyushu area mostly used large-scale fishing methods such as bottom draw nets and set nets.

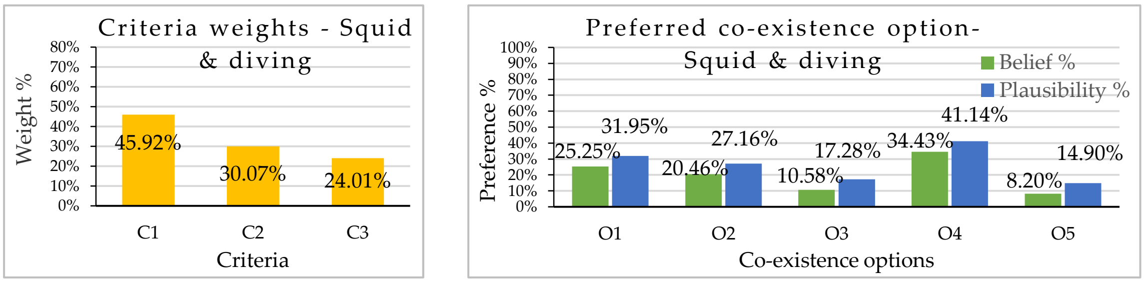
Figure 4.14 to Figure 4.16 show the final preference results of the fishers according to their main fishing method. Figure 4.17 and Figure 4.18 show the final preference results of fishers according to their fishing scale. From the interviews with fishers, it was identified that the small-scale fishers who use pole and line method or nearshore fishing methods, such as diving, could benefit from the artificial reef effect and the fish gathering effect created by the subsea MRE structures. Hence, they preferred to have many small-scale MRE devices or structures in the area rather than a few large-scale MRE devices or structures. However, they acknowledged the technical factors that developers have to consider when designing the MRE device layout.



(a) (b)

Figure 4.14 Fishers' option preference according to fishing method and scale: (a) average criteria weights and (b) option preference of pole and line fishing fishers.

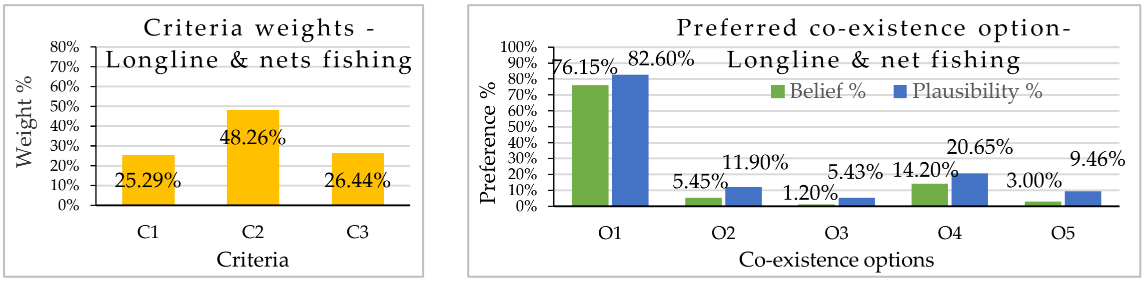
Source: made by author based on the DS-AHP MCDM results



(a) (b)

Figure 4.15 Fishers' option preference according to fishing method and scale (a) average criteria weights and (b) option preference of squid fishing and diving fishers.

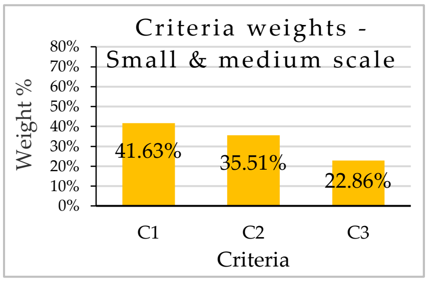
Source: made by author based on the DS-AHP MCDM results



(a) (b)

Figure 4.16 Fishers' option preference according to fishing method and scale (a) average criteria weights and (b) option preference of longline and net fishing fishers.

Source: made by author based on the DS-AHP MCDM results



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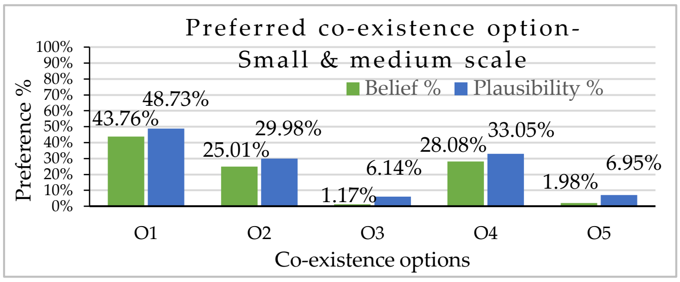
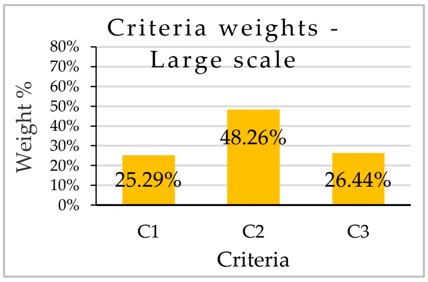


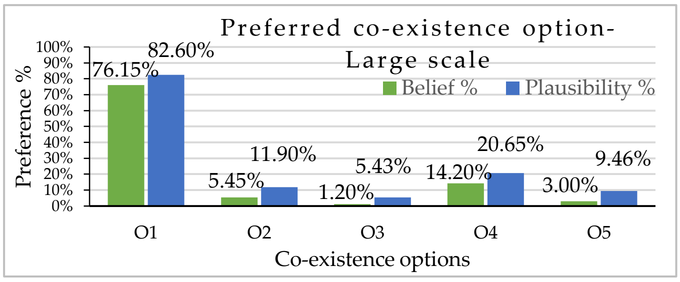
(b)

Figure 4.17 Fishers' option preference according to fishing method and scale (a) average criteria weights and (b) option preference of small and medium scale fishers.

Source: made by author based the DS-AHP MCDM results



(a)



(b)

Figure 4.18 Fishers' option preference according to fishing method and scale (a) average criteria weights and (b) option preference of large scale fishers.

Source: made by author based on the DS-AHP MCDM results

In contrast to small-scale fishers, large-scale fishers who use fishing methods which need a large sea area to operate like longline, trawling and net fishing, prefer to have the least amount of MRE devices to minimize their fishing effort displacement. Since they use large sea area, real-time ocean information is vital to decide the travel plans and fishing grounds. Finally, large-scale fishers tend to be financially stronger than the small-scale fishers. Hence, large-scale fishers are more focused on the continuity of the industry and less willing to change the current practices, whereas small-scale fishers tend to prioritize different alternatives that provide more financial incentives. Interviews with fishers on Naru Island revealed that they prefer the benefit of having under water structures to support their fishing gears, specifically in the areas with strong tidal currents because, currently, they cannot use their fishing gear most of time due to the high tidal current velocity.

Large-scale fishers tended to prioritize the second criterion, environmental impacts, whereas small-scale fishers tended to prioritize the first criterion, economic impacts. This behavior can be explained by the current financial stability of the particular fishery groups. Generally, all the fishery groups tended to prefer the first option of sharing ocean information. However, in contrast with the large-scale fishers who use longline and net fishing methods, small and medium-scale fishers who mostly use pole and line fishing indicated a significant preference for the second option of using MRE structures as artificial reefs and support structures for fishing gear. All these factors identified from key stakeholder interviews support the fisheries' preference shown in the above Figure 4.14 to Figure 4.18.

4.5 Factors that can impact the decision of preferred co-existence strategy

The main reason for limiting this study to qualitative multi criteria analysis (rather than quantitative analysis) is the unavailability of data and significant uncertainties associated with the available data. The main reason for these uncertainties are the lack of empirical data from real MRE projects (there are no clear project specifications even on the proposed commercial MRE projects yet). However, it was identified from the interviews that stakeholders' decision might be impacted with the availability of new data, especially the net impacts and feasibility of each proposed options in the real MRE project context etc. Factors which have the potential to impact the stakeholders' preference decision is discussed under several topics as follows.

4.5.1 MRE project characteristics

The co-existence strategy is dependent on the MRE technology. Certain types of co-existence options are compatible only with certain types of MRE projects. For example, providing ocean information is feasible with most of the MRE projects. However, the quality of data and the available parameters might be different from offshore wind projects in comparison to tidal energy projects with fully submerged devices. The second option in this study, using MRE structures as artificial reefs and support structures for fishing gear, is more compatible with offshore wind energy projects than the tidal energy projects. However, tidal energy projects generally create less spatial conflict with fisheries because local fisheries generally do not use strong tidal current areas for fishing activities. Tidal energy projects require different skills and equipment, even for routine maintenance checks. However, some co-existence options can be used independent of the MRE technology used, such as the fourth option in this study; sharing generated electricity.

Project siting is also a significant factor which can affect the net impact of considered co-existence options. Nearshore MRE projects are more visible to the coastal communities. Hence, interactions between them are common. There is limited ocean space available in the nearshore area for specific marine activities such as shipping and transportation, docking fishery, and other commercial vessels. However, if the visual impacts are considered to be positive and used in a co-existence option, such as in the case of third option in this study, nearshore MRE projects are more preferred than the offshore MRE projects. Going further offshore can enhance the power takeout of the power plant, but increases the construction and operation costs. However, going offshore can create less congestion in the most competitive nearshore areas. So, location of the MRE project itself can decide the feasibility of co-existence strategies which needs co-location of different marine activities such as co-locating with aquaculture. Other project characteristics such as number of MRE devices, area of MRE farm, other marine uses of the MRE farm area, design specifications (mooring techniques, sub-sea structures etc.), operational and maintenance requirements, are also important MRE project characteristics which determine the effectiveness of the proposed co-existence strategies.

4.5.2 Cost of co-existence options

The 'Levelized Cost Of Energy' (LCOE), which represents the costs of electricity for an MRE installation over an assumed financial life and duty cycle (Soukissian et al., 2017), is significantly impacted by the installation costs and operation and maintenance (O&M) costs (Allan et al., 2011; Myhr et al., 2014). Limited information exists about the LCOE of Japan's MRE projects. However, from the literature on the European MRE industry (Astariz et al., 2015; Lerch et al., 2018; OES - IEA, 2015), the initial commercial MRE projects in Japan are estimated to have a significant LCOE. Confidence in the ability of the MRE industry to deliver a competitive LCOE in comparison to other forms of power generation in an acceptable timeframe is essential for continued investment in the sector (Weller et al., 2015). Hence, project developers were deeply concerned about managing the project costs to maintain a competitive LCOE with respect to other energy generation options. Hence, it is important to analyze the potential economic impacts of the proposed co-existence strategies, since those options may significantly impact the LCOE and overall economic sustainability of the projects.

The MCA results, in terms of the economic impacts (Table 4.4), show that stakeholders expect a positive overall impact from the proposed co-existence options except for the fourth option of sharing generated electricity at a subsidized rate. LCOE dynamics for various renewables depend on various factors that could be directly impacted by employing the identified co-existence options. For example, project developers may have to incur additional construction costs if options O1, O2, or O3 are employed. Conversely, using local resources according to O5 may reduce O&M costs. All these co-existence options may indirectly generate positive impacts on LCOE if they lead to a higher local acceptance level.

4.5.3 Non-monetary co-existence options vs. monetary compensation

An alternative to the identified non-monetary co-existence strategies is the monetary compensation or benefit creation scheme where the developers allocate funds to the local community with the mediation of local government, local authority, or some other responsible community body. Developers can benefit from the mediation of a local authority because they tend to have a higher trust among local communities, and higher expertise in assessing the local priorities which is vital when disbursing funds for the needs of the community. However, this kind of monetary benefit creation scheme worsens the developer costs and indirectly affects the LCOE. (This situation is worsen in Japan due to the lack of MSP making the monetary compensation schemes unviable as described in introduction section). However, the existing conditions might change with the introduction of new MSP, rules and regulations in the future. In such a case, developers may be able to benefit from monetary compensation scheme, if the LCOE impact of the proposed non-monetary co-existence strategies is worse than that of monetary benefit creation schemes.

4.5.4 Knowledge, perceptions and values vs. option preference

Acceptance and preference depend on the decision makers' knowledge about the context and the perceived impacts of different decision alternatives. Previous literature also highlights the impact of personal values and beliefs on MRE acceptance decision (Bidwell, 2017). The best examples of this from the results of this study are the health and welfare group decision (Figure 4.6 (b)), and the group decision of the Moji area residents. (Figure 4.12 (b)). The health and welfare group perceived noise pollution and prioritized the environmental impacts over economic or social impacts and finally preferred the fourth option of having subsidized electricity. Most of those respondents have experienced nearby onshore wind turbines. The significant concerns about the low frequency noise pollution of offshore wind turbines indicate that they have a different belief about offshore wind turbines in comparison to onshore wind turbines. In contrast, Moji respondents prioritized economic impacts over environmental or social impacts, but still preferred the fourth option, which indicates that preference is highly correlated with personal economic gains.

The probability assigned for the frame of discernment (i.e., $m(\Theta)$), indicates the global ignorance level (GIL) in the DS-AHP as explained in the section 2.4.2.3. Since only the consistent responses were considered for the DS-AHP analysis (CI<10%), average GIL of the DS-AHP analysis was only about 6.13%, which is insignificant in terms of the belief levels of the most preferred options. However, GIL can roughly represent the overall reliability of the group decision. Figure 4.19 shows the summary of the GIL analysis which indicates that uncertainty is highest among respondents from health and welfare sector and Shimonoseki area.

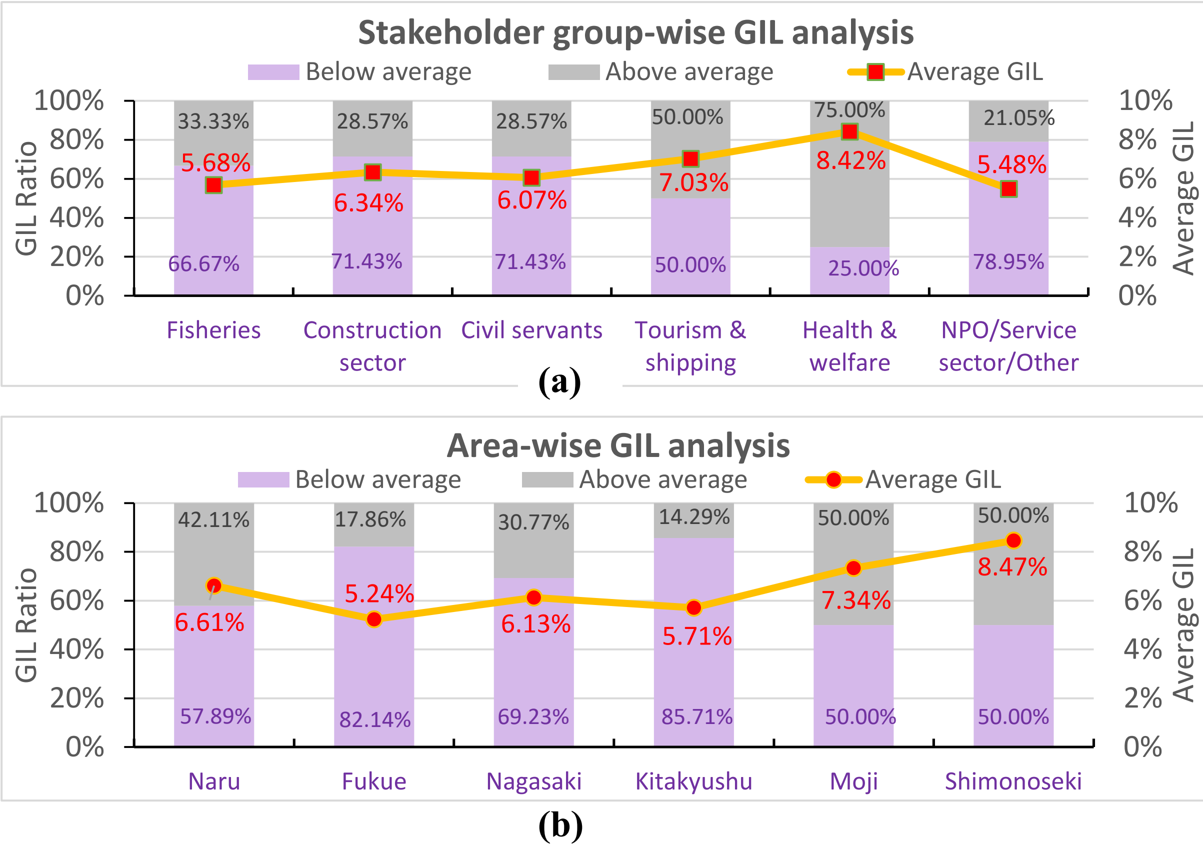


Figure 4.19 GIL analysis

The unique preference decision of the fishers is mainly due to their knowledge (by experience) and individual benefits which can be obtained from the ocean information. As indicated by fishery respondents, they doubt the real capacity of local resources to be involved with the MRE sectors as proposed in the fifth option because they know (much better than other stakeholders who have less interaction with marine activities) the real risks and capacities required to be involved in marine activities. Thus the stakeholders' existing perception and preference may change with the availability of new information and knowledge even though their values are less likely to change.

4.6 Summary

When answering the first research question, it was identified that creating strategies for MRE projects to directly combine with local community and create local benefits lead to a higher acceptance according to the results of third chapter. Hence the fourth chapter was focused on the second research question “What are the options available for creating a win-win situation & co-existence between MRE industry and local community?”

Multi criteria decision making (MCDM) process was used to evaluate the potential options by using the three step process; (1) identification of potential co-existence options, (2) multi-criteria analysis (MCA) of identified co-existence options, and (3) evaluation of the stakeholder preferences using the DS-AHP MCDM method.

From the 1st step, five potential co-existence options were identified as; (O1) sharing real time, in-situ ocean information, (O2) using MRE structures as artificial reefs and support structures for commercial fishing, (O3) co-location with other industries such as leisure and tourism, aquaculture, (O4) sharing generated electricity for local users at a subsidized rate; and (O5) use of local resources to construct and operate the power plant, creating business involvement opportunities. These options were evaluated using criteria which were grouped into three main categories; (C1) Economic, (C2) Environment, and (C3) Social. Final preference was evaluated based on stakeholder groups, area, and fishing methods and scale within the fishers group.

Figure 4.20 and Table 4.5 show the summary of stakeholder group-wise preference decision while Figure 4.21 and Table 4.6 show the summary of stakeholder area-wise preference decision. From anlyzing the combined results, it was identified that preference decision is highly dependent on the individual impacts. In this case, individual impacts are dependent on the stakeholders’ occupation than other area specific characteristics. Hence the most suitable co-existece option should be decided according to the occupational requrements of the majority of stakaholders. The identified common trend was that the stakeholders who had experience and good knowledge about marine activities (mostly fishers in this study) prefer the first option of ocean information sharing. The respondents who had less interaction with ocean and vague idea about marine activities (mostly the stakeholders other than fishers) tend to prefer the fifth option of using local resources to construct and operate the power plant, thereby creating business involvement opportunities. Stakeholders who were interacting with the marine areas tended to know the real potential and limitations of the proposed co-existence options.

The preference evaluation in this study was conducted considering the identified co-existence options independent to each other. However, there can be synergies among those identified co-existence options if employed together. Hence, it is possible that an integrated co-existence strategy, i.e. a combination of several identified options, to be the optimum strategy. However, these types of integrated co-existence strategies have not been evaluated in this study due to the high uncertainties and lack of data on their potential synergies.

Table 4.5 stakeholder group-wise preference level

Decision maker	Co-existence option	Preference level	
		Belief	Plausibility
Fisheries	O1- Sharing real-time, in-situ ocean information	83.93%	91.92%
	O2- Using MRE structures as artificial reefs / support structures	12.99%	18.21%
	O3- Co-location with industries like tourism, and aquaculture	0.09%	4.57%
	O4- Sharing generated electricity at a subsidized rate	2.84%	8.06%
	O5- Use of local resources & create business opportunities	0.14%	5.36%
Construction sector	O1- Sharing real-time, in-situ ocean information	3.05%	9.08%
	O2- Using MRE structures as artificial reefs / support structures	3.78%	9.24%
	O3- Co-location with industries like tourism, and aquaculture	1.70%	5.95%
	O4- Sharing generated electricity at a subsidized rate	7.03%	13.09%
	O5- Use of local resources & create business opportunities	84.45%	90.74%
Civil servants	O1- Sharing real-time, in-situ ocean information	3.92%	11.80%
	O2- Using MRE structures as artificial reefs / support structures	7.36%	14.17%
	O3- Co-location with industries like tourism, and aquaculture	4.22%	11.09%
	O4- Sharing generated electricity at a subsidized rate	11.89%	22.23%
	O5- Use of local resources & create business opportunities	72.61%	78.31%
Tourism & Shipping	O1- Sharing real-time, in-situ ocean information	15.13%	22.16%
	O2- Using MRE structures as artificial reefs / support structures	11.32%	18.35%
	O3- Co-location with industries like tourism, and aquaculture	10.99%	18.02%
	O4- Sharing generated electricity at a subsidized rate	3.22%	5.39%
	O5- Use of local resources & create business opportunities	58.06%	65.09%
Health & Welfare	O1- Sharing real-time, in-situ ocean information	16.30%	24.72%
	O2- Using MRE structures as artificial reefs / support structures	11.09%	16.65%
	O3- Co-location with industries like tourism, and aquaculture	1.47%	4.68%
	O4- Sharing generated electricity at a subsidized rate	67.74%	76.16%
	O5- Use of local resources & create business opportunities	3.27%	11.69%
NPO / Other / Service sector	O1- Sharing real-time, in-situ ocean information	7.66%	13.36%
	O2- Using MRE structures as artificial reefs / support structures	5.60%	11.08%
	O3- Co-location with industries like tourism, and aquaculture	43.86%	49.34%
	O4- Sharing generated electricity at a subsidized rate	4.05%	9.53%
	O5- Use of local resources & create business opportunities	38.74%	44.44%

Source: made by author based on the area-wise DS-AHP MCDM results

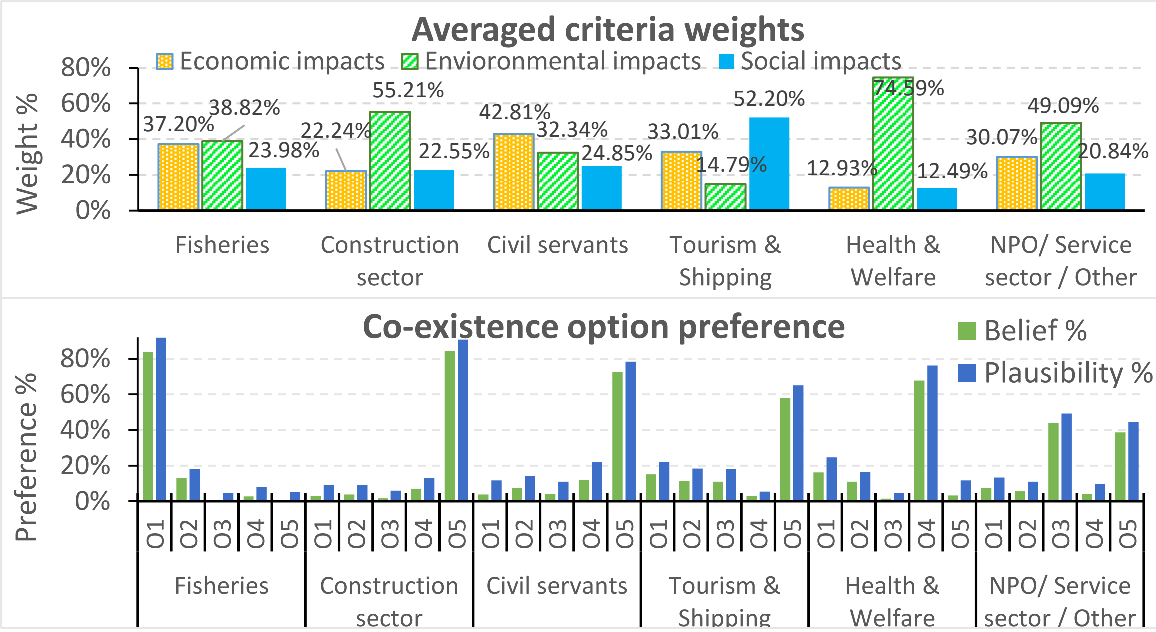


Figure 4.20 Summary of stakeholder group-wise preference decision

Source: made by author based on the stakeholder group-wise DS-AHP MCDM results

Table 4.6 Case study area-wise preference level

Area	Co-existence option	Preference level	
		Belief	Plausibility
Naru	O1- Sharing real-time, in-situ ocean information	7.04%	14.13%
	O2- Using MRE structures as artificial reefs / support structures	8.35%	15.18%
	O3- Co-location with industries like tourism, and aquaculture	8.02%	15.43%
	O4- Sharing generated electricity at a subsidized rate	10.79%	19.03%
	O5- Use of local resources & create business opportunities	65.79%	72.50%
Fukue	O1- Sharing real-time, in-situ ocean information	5.15%	12.69%
	O2- Using MRE structures as artificial reefs / support structures	3.43%	9.42%
	O3- Co-location with industries like tourism, and aquaculture	0.18%	5.36%
	O4- Sharing generated electricity at a subsidized rate	0.15%	7.28%
	O5- Use of local resources & create business opportunities	1.10%	6.56%
Nagasaki	O1- Sharing real-time, in-situ ocean information	19.74%	27.74%
	O2- Using MRE structures as artificial reefs / support structures	30.28%	36.10%
	O3- Co-location with industries like tourism, and aquaculture	17.72%	22.88%
	O4- Sharing generated electricity at a subsidized rate	3.48%	10.88%
	O5- Use of local resources & create business opportunities	28.77%	34.41%
Kitakyushu	O1- Sharing real-time, in-situ ocean information	56.35%	62.07%
	O2- Using MRE structures as artificial reefs / support structures	25.01%	30.72%
	O3- Co-location with industries like tourism, and aquaculture	1.57%	7.28%
	O4- Sharing generated electricity at a subsidized rate	12.28%	16.61%
	O5- Use of local resources & create business opportunities	4.79%	10.50%
Moji	O1- Sharing real-time, in-situ ocean information	12.34%	19.68%
	O2- Using MRE structures as artificial reefs / support structures	4.81%	9.28%
	O3- Co-location with industries like tourism, and aquaculture	6.31%	10.78%
	O4- Sharing generated electricity at a subsidized rate	63.21%	70.55%
	O5- Use of local resources & create business opportunities	13.24%	20.58%

Shimonoseki	O1- Sharing real-time, in-situ ocean information	27.78%	35.23%
	O2- Using MRE structures as artificial reefs / support structures	1.76%	9.21%
	O3- Co-location with industries like tourism, and aquaculture	0.30%	5.89%
	O4- Sharing generated electricity at a subsidized rate	30.96%	39.43%
	O5- Use of local resources & create business opportunities	39.19%	47.66%

Source: made by author based on the area-wise DS-AHP MCDM results

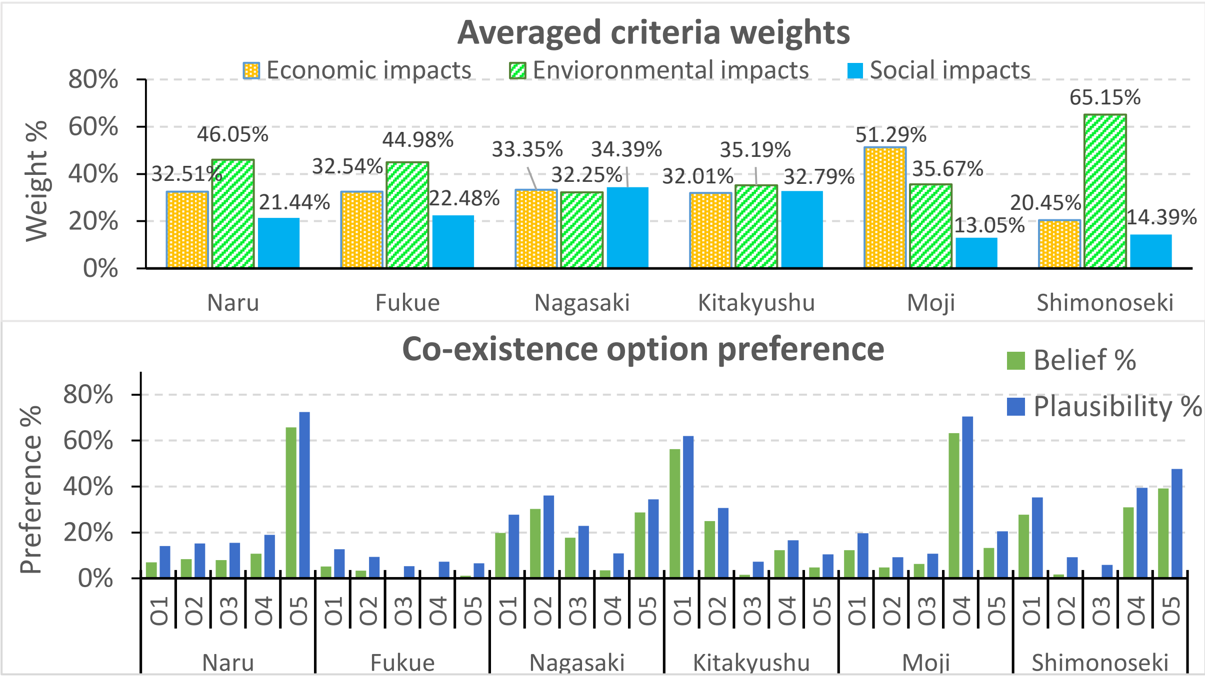


Figure 4.21 Summary of area-wise criteria weightings and option preferences

Source: made by author based on the area-wise DS-AHP MCDM results

Fishers being the most prominent stakeholder group, their preference was further analyzed according to the fishing method and scale. Figure 4.22 and Table 4.7 shows the summary of criteria weightings and co-existence option preferences made by fishers according to their fishing methods and scale. There was a clear preference to the ocean information sharing option across all fisher groups except for the squid fishing and diving fisher group, which represented a minority in our sample. Smale scale fishers who use pole and line fishing tended to prefer the second option. Underlying factor for small scale fishers prefering the second option is that they could benefit from the artificial reef effects and its spill-over effect more than the large scale fishers. High travel requirements, use of large sea areas etc. can be the reasons for large scale fishers to prefer the ocean information than the small scale fishers.

Table 4.7 Fishing method and fishing scale-wise option preference levels

Fishery group	Co-existence option	Preference level Belief	Preference level Plausibility
Pole & Line fishing	O1- Sharing real-time, in-situ ocean information	42.32%	47.04%
	O2- Using MRE structures as artificial reefs / support structures	29.56%	34.28%
	O3- Co-location with industries like tourism, and aquaculture	2.55%	7.26%
	O4- Sharing generated electricity at a subsidized rate	20.13%	24.85%
	O5- Use of local resources & create business opportunities	5.43%	10.15%
Squid fishing & Diving	O1- Sharing real-time, in-situ ocean information	25.25%	31.95%
	O2- Using MRE structures as artificial reefs / support structures	20.46%	27.16%
	O3- Co-location with industries like tourism, and aquaculture	10.58%	17.28%
	O4- Sharing generated electricity at a subsidized rate	34.43%	41.14%
	O5- Use of local resources & create business opportunities	8.20%	14.90%
Longline, Set net, Bottom &Trawl net	O1- Sharing real-time, in-situ ocean information	76.15%	82.60%
	O2- Using MRE structures as artificial reefs / support structures	5.45%	11.90%
	O3- Co-location with industries like tourism, and aquaculture	1.20%	5.43%
	O4- Sharing generated electricity at a subsidized rate	14.20%	20.65%
	O5- Use of local resources & create business opportunities	3.00%	9.46%
Small & Medium	O1- Sharing real-time, in-situ ocean information	43.76%	48.73%
	O2- Using MRE structures as artificial reefs / support structures	25.01%	29.98%
	O3- Co-location with industries like tourism, and aquaculture	1.17%	6.14%
	O4- Sharing generated electricity at a subsidized rate	28.08%	33.05%
	O5- Use of local resources & create business opportunities	1.98%	6.95%
Large	O1- Sharing real-time, in-situ ocean information	76.15%	82.60%
	O2- Using MRE structures as artificial reefs / support structures	5.45%	11.90%
	O3- Co-location with industries like tourism, and aquaculture	1.20%	5.43%
	O4- Sharing generated electricity at a subsidized rate	14.20%	20.65%
	O5- Use of local resources & create business opportunities	3.00%	9.46%

Source: made by author based on the area-wise DS-AHP MCDM results

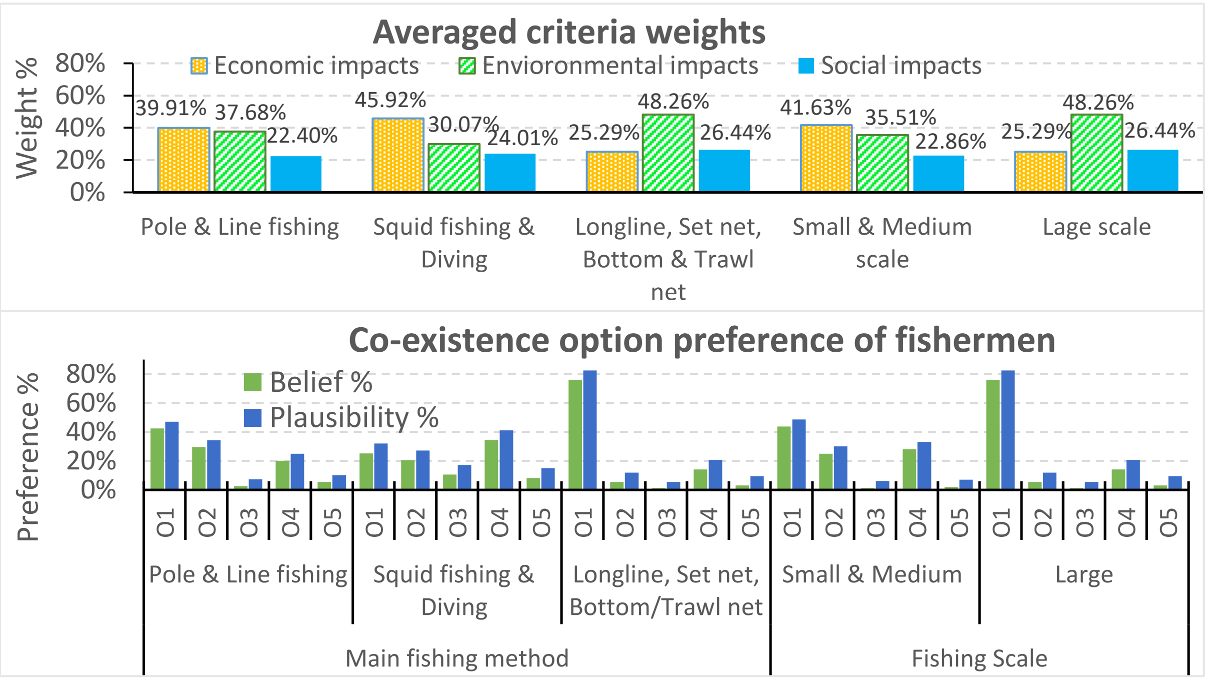


Figure 4.22 Summary of fishing method and fishing scale-wise option preferences

Source: made by author based on the fishing method/scale DS-AHP MCDM results

5 FEASIBILITY OF SHARING REAL-TIME IN-SITU OCEAN INFORMATION FROM MRE PROJECTS TO OTHER MARINE USERS

According to the results of the fourth chapter, it was identified that the stakeholders' preference over potential MRE co-existence strategies show a highly polarized decision where fishers' chose the ocean information sharing option as the best co-existing option while the other stakeholders preferred the option of using local resources to construct and operate the power plant, thereby creating business involvement opportunities. As explained earlier, this preference is highly dependent on the knowledge and experience on marine activities. In depth analysis of fishers' (who are the most prominent stakeholder in the local consensus building process) preference decision also indicates that ocean information sharing option is the preferred option in almost all the cases.

We have done a preliminary study in the context of proposed Ocean Current Power (OCP) project in Wakayama (Kularathna, 2016; Kularathna & Takagi, 2017) from which we identified the potentials and limitations of the proposed ocean sharing scheme. Apart from our preliminary study, there have not been other studies focused on the feasibility of ocean information sharing from MRE projects to other marine users. Hence this chapter focused on the feasibility of the proposed ocean information sharing system and validation of our previous results in the context of general MRE projects using the key stakeholder interviews done in Nagasaki and Kitakyushu case studies.

5.1 Concept of the proposed information sharing system

Ocean information refers to wide range of parameters which can be used to describe or forecast the marine conditions in different perspectives according to the respective discipline. Ocean information is required by persons who directly use marine areas for resource extraction, policy implementation, regulation controlling of marine space usage, monitoring and assessing the anthropogenic impacts to marine eco-system and estimating the future global level impacts such as climate change. Hence, ocean information directly or indirectly affect most of the population.

There are different ocean information sources such as autonomous ocean monitoring platforms like buoy systems, remote sensing using dedicated satellites, user-specific ocean monitoring systems in different industries like weather forecasting, commercial shipping, fishery etc. However, it is practically impossible to satisfy all the ocean information demands due to many reasons such as the limited cover, significant variety in information demand from the users from different disciplines, very high cost of ocean observations and lack of information sharing especially across the industries. A pragmatic approach to fill this gap is to share the information among different users as in the shared information systems such as 'Global Ocean Observation System'("GOOS)",and 'Common Information Sharing Environment' (CISE (2010)) project in Europe etc. MRE plants have separate sub systems to monitor the operation condition of turbines to control the operating parameters remotely to suit the ambient environment conditions. These systems are generally called condition monitoring systems (CMS) and Supervisory Control and Data Acquisition (SCADA) systems. The in-situ ocean information captured by the CMS/SCADA of the power plant can be transmitted to the onshore operators since the devices are connected by submarine cables. Hence, ability to generate and transmit ocean information can be considered as a co-benefit of MRE projects if these information can be shared with other users for their activities as indicated in the Figure 5.1.

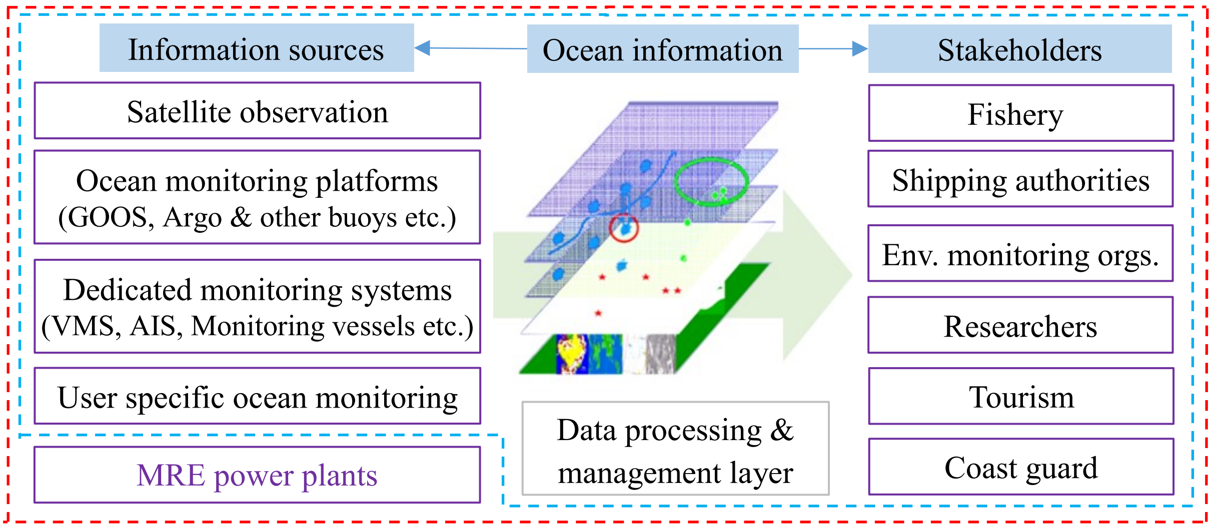


Figure 5.1 Concept of ocean information sharing scheme

Source: made by author

In order for this proposal to success as a co-existence option, it should satisfy an existing ocean information gap of the local stakeholders in an economically viable manner. Hence main questions focused in this chapter are;

(a) What ocean information parameters are required by the stakeholders?

(b) What ocean information parameters are currently available for the stakeholders?

(c) What ocean information parameters can be generated by the plant's CMS/SCADA?

(d) What are the expected incremental costs and benefits to the stakeholders?

5.2 Stakeholders' ocean information requirements

The oceanographic and meteorological parameters in the Table 5.1 have been identified as the most desired set of ocean information from the interviews with the key stakeholders, especially the fishery union leaders and under water observation and diving company representatives.

Table 5.1 Ocean information parameters in demand

	Parameter	Ideal requirement	Other remarks
1	Sea surface temperature	10 km spatial resolution, covering the main fishing grounds	Temperature is the key indicator used for selecting fishing grounds
2	Depth-wise temperature distribution	At least 50 m depth-wise resolutions in the fishing grounds	
3	Tidal and current velocity	10 m depth-wise resolution in the current streams	Real-time data as well as forecasts are useful
4	Wave profile	10 km spatial resolution, covering the main fishing grounds	Real-time data as well as forecasts are useful
5	Wind profile		
6	Plankton levels, marine growth rates	Specially in the fishing grounds and the areas affected with sea-desertification phenomena	Useful for fish stock predictions and ongoing sea grass cultivation projects etc.
7	Underwater video / Fish count	Specially around fixed net setups, aquaculture facilities and other sub-sea structures etc.	Real-time information which is useful for estimating the catch
8	Marine mammal observation / passive acoustic monitoring & under water noise levels	Near the sub-sea structures	Mainly for the impact monitoring
9	Mean sea level	Hourly values	-
10	Coastal bathymetry	Coastal and shelf regions	-

Source: made by the author based on the interviews

Even though the specific requirements such as fish migration patterns, fish egg count, suspended sediments, nitrate and oxygen levels etc. were mentioned in the Wakayama case in our previous study, those parameters were not highlighted in this study. The main reason for our previous study to identify such parameters was the existence of Wakayama prefecture fishery research and experiment station as a main interviewer. On the other hand, private ocean monitoring and construction company representatives (who were involved in local marine projects) were interviewed in this study. Their local activities such as monitoring pilot MRE projects' marine impacts, sea-grass cultivation projects etc. make them the closest match to fishery research and experiment station in our previous study. Similar to research on fish migration in Wakayama case, Nagasaki stakeholders are studying on the sea desertification; a phenomena unique to the local area. There have been attempts to re-introduce sea-grass into the area and successful results have been obtained so far from those attempts. Due to the influence of this type area specific characteristics, ocean information requirements also become different. Hence the priority given to the parameters such as plankton levels, marine growth rate etc. became higher in Nagasaki with respect to Wakayama.

New parameters were also identified according to the local conditions. For example, researchers identified that marine growth rate and bio fouling characteristics are of special interest in Nagasaki due to ongoing MRE project related studies. Kitakyushu respondents did not highlight any unique requirement in terms of ocean information parameters. However, they were concerned about the potential marine accidents such as collisions which had happened in the past. Since they expected an increase of collision risk after MRE devices are placed, it was indicated that any additional information to mitigate such risk would be valuable.

EuroGOOS Requirement Survey (ERS) (Fischer & Flemming, 1999), which is the basis of this demand survey, serves the purpose of validation of the results of this study. The closest application sectors in the ERS results to the stakeholder groups of this study are, 'Research', 'Transport', 'Environment', and 'Food' sectors. Table 5.2 shows the top 20 requirements of those sectors in comparison to primary data.

Table 5.2 Top 20 variables of each application sector in ERS results

	Research	Transport	Environment	Food
1	Sea surface temperature*	Current direction*	Nitrate	Current direction*
2	Sea surface salinity	Current velocity*	Phosphate	Current velocity*
3	Current direction*	Hourly mean sea level*	Chlorophyll	Sea surface temperature*
4	Current velocity*	Sea surface temperature*	Oxygen	Wave direction spectrum*
5	Sea surface wind stress*	Sea surface wind stress*	Silicate	Waves Hs*
6	Upper ocean salinity	Wave direction spectrum*	Iron	Sea surface wind stress*
7	Bathymetry*	Wave period*	Current direction*	Wave period*
8	Surface currents*	Wave spectrum*	Current velocity*	Suspended sediments
9	CTD sections*	Wave swell*	Sea surface temperature*	Oxygen
10	Phytoplankton*	Waves Hs*	Sea surface wind stress*	Aquatic toxins
11	Wave direction spectrum*	Oceanic tides*	Coastline map	Wave spectrum*
12	Waves Hs*	Air, sea, ice temperatures	Coastal bathymetry*	Wave swell
13	Wave spectrum*	Coastline map	Hourly mean sea level*	Coastline map
14	Coastal bathymetry*	Sea surface salinity	Sea surface salinity	Coastal bathymetry*
15	Nitrate	River runoff	Phytoplankton*	Surface currents
16	Chlorophyll	Sediment transport	Sediment transport	Phytoplankton*
17	Suspended sediments	Sound velocity profiles	Meteorological forcing	Human health risks
18	Precipitation	Fresh water transport	Pathogens	Pathogens
19	Wave period*	Ice motion	Trace metals	Pesticides & herbicides
20	Coastline map	Bioluminescence	PAHs	-

* Compatible parameters with primary data. Source: pg. 35 of ERS (Fischer & Flemming, 1999)

5.3 Ocean information availability and information gap

It was identified that most surface level information such as sea surface temperature, forecasts about wind and wave conditions etc. are available from the existing sources. For example, local fishery union gets the satellite information from JAXA and NOAA and more general information and warnings from meteorological department and coast guard services. But the limitation of these data is that mostly those are remote sensing data and resolution is not sufficient in comparison to users' ideal requirements. There are very limited in-situ monitoring in the area. Hence the sub-sea parameters are almost not available.

Table 5.3 shows the comparison of available data and the top 10 data requirements according to the local stakeholders. The most important sub-sea parameter the fishers sought after is the depth-wise temperature distribution. According to an experienced fisherman, if the depth-wise temperature is available at a 10 m resolution, it is possible to estimate the fish catch up to 10 km with that information itself. Hence it was identified that experienced fishers use traditional methods (such as using a rope) to get this information.

Table 5.3 Comparison of information demand and supply

	Parameter	Data availability	Gap
1	Sea surface temperature	Available from satellite data	Resolution is not good and accuracy is not ideal due to lack of in-situ monitoring
2	Depth-wise temperature distribution	Not available from commercial data providers	Accuracy of user specific methods is too low
3	Tidal and current velocity	Available in limited data points	Coverage and availability of real-time data are limited
4	Wave profile		
5	Wind profile		
6	Plankton levels, marine growth rates	Almost no commercial data available	Coverage and accuracy of manual and user specific data collections are low
7	Underwater video / Fish count	No information exists	
8	Marine mammal observation / passive acoustic monitoring & under water noise levels	No information exists	
9	Mean sea level	Available with limited data quality	Mostly from user specific in-situ observations and limited other data points
10	Coastal bathymetry	Available mostly from user specific in-situ observations and archived data	

Source: made by author based on the interviews

Most full time fishers have their own equipment to observe the position (GPS) and depth, and some fishers even have more advanced equipment such as sonar fish finders. However these existing equipment are useable only in real-time in-situ monitoring. These existing self-owned data acquisition systems help on commercial outputs such as navigational safety and even fishing ground selection etc. However, it rarely improves the transit requirements.

5.4 Information generation capacity of the CMS/SCADA

CMS and SCADA systems are integral sub systems of MRE devices which monitor the condition of the devices as well as the operating ambient conditions. Generally condition of the device itself is monitored by in-built sensors and usually these sensors can be categorized to several types such as condition monitoring based on vibration, oil quality, acoustic emission, strain measurements, electrical output parameters etc. (Coronado & Fischer, 2015; Lian et al., 2019; Watson & Xiang, 2006). SCADA system monitors the overall operating parameters of the turbine which include the driver parameters such as wind, tidal, ocean current speed, direction and deviations as well as the output parameters such as rotor speeds, temperatures, etc.(Lian et al., 2019).

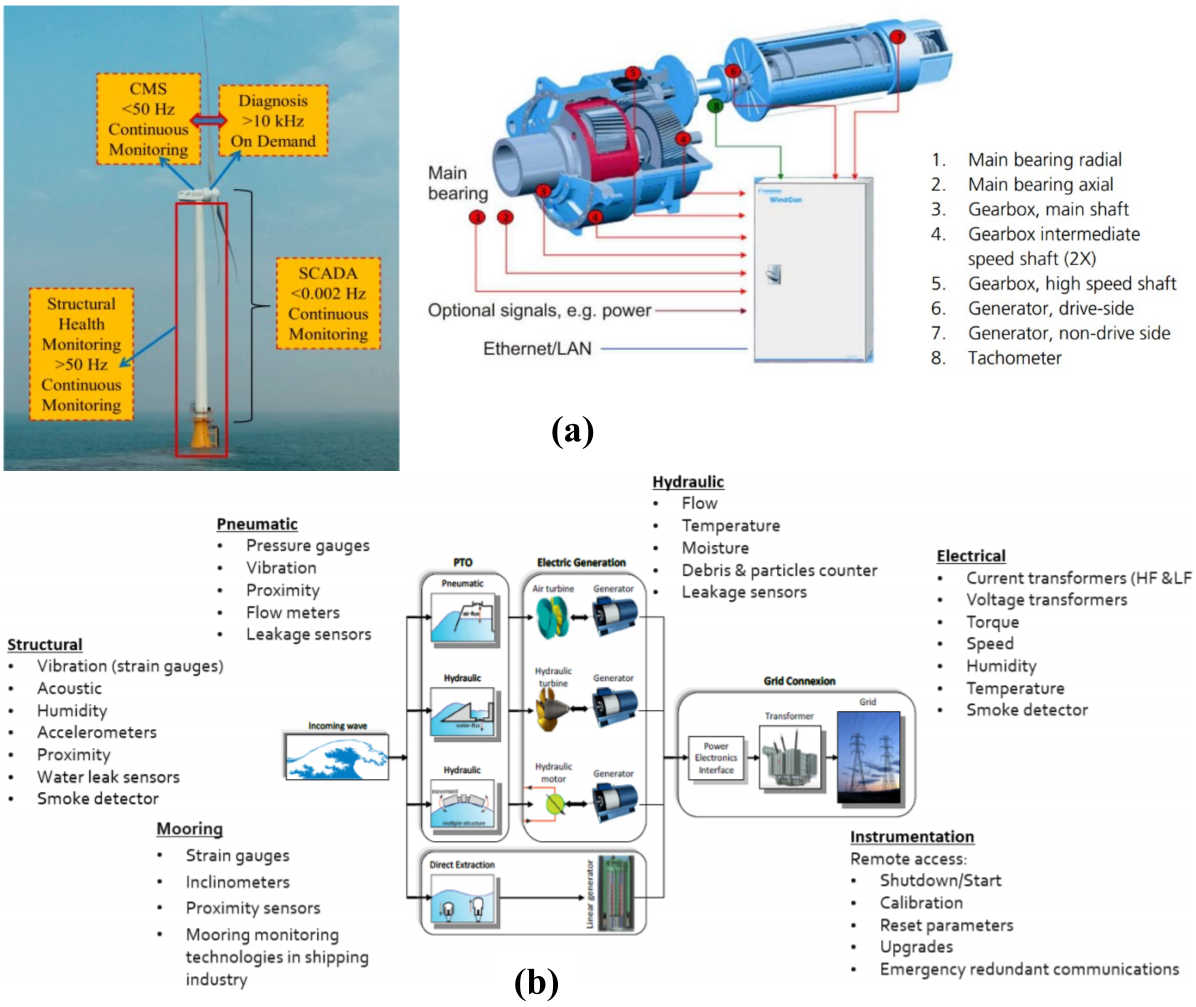


Figure 5.2 CMS/SCADA of (a) wind turbines and (b) wave energy converters

Source: (Coronado & Fischer, 2015; Lian et al., 2019; Mountassir, 2018)

The monitored parameters and quality of data depend on the configuration of the MRE power farm's CMS/SCADA systems. However, the specification of CMS/SCADA of the proposed commercial level offshore wind farms and pilot tidal project have not been confirmed yet. Alternatively, the potential information supply was estimated by consulting the project developers and related researchers. Validation was done referring to the literature. Table 5.4 shows the summary of potential information supply from the MRE power plants' CMS/SCADA systems.

Table 5.4 Information supply potential of the CMS/SCADA of the MRE power plant

Monitoring area		Monitoring parameters	Attributable parameter
Turbine / Rotors / Nacelle		Ambient temperature	Water / air temperature at an average hub level - offshore wind turbines(OWT) (~ 80-120 m height) tidal, current turbines (~ 40-50 m depth), floating wave energy converters (WEC) (at surface level)
		Turbine rotation speed	Indirect indication of wind speed (from OWT), ocean current or tidal current velocity at hub level (from tidal current turbines), indirect measure of wave height/length/period (from WEC).
		Nacelle positioning and control systems	Indirect measure of the direction, gusts, and other variables of the flow (wind, current or wave)
		Electromagnetic outputs	Can be an indirect measure of flow conditions
Direct measurements by sensors on the	**Support structure**	ADCP, DVL, EM velocity meter	Direct measurement of current and tidal velocity
			Wave height by ADCPs
		Strain sensors/ position sensors & other elongation measurements	Can be an indirect indication of the flow conditions (wind, wave, tidal and ocean currents depending on the type and design of the device)
		Marine growth on the devices	Indirect measure of biofouling rate & other related biochemical parameters
		Micro-fouling Macro-fouling	
		Video camera, passive acoustic monitoring, fish detectors or fish finders, Hydrophones and ADCPs	Marine mammal observation (dolphins & whales)
			Underwater noise
			Underwater video
			Fish species and fish count
	Mooring, sinkers and anchors	Strain sensors/ position sensors & other elongation measurements	Can be an indirect indication of the flow conditions (tidal and ocean currents depending on the type and design of the device)
		Marine growth	Marine growth (sea bed)
		Micro fouling Macro fouling	Indirect measurement of biofouling rate & related biochemical parameters
		ADCP, DVL, EM velocity meter	Direct measurement of current and tidal velocity
		Underwater video	Fish and Crustacea detection

Source: made by author based on the literature (Coronado & Fischer, 2015; Lian et al., 2019; Mountassir, 2018) and expert interviews

The quality of data is dependent on the configuration of the MRE devices in the power farm, technical specifications of the CMS/SCADA system and the data processing and modelling techniques used to estimate the parameter in consideration. The most important factor identified with respect to the parameter requirement is the ability to use the infrastructure developed for basic CMS/SCADA system; such as the electrical supply, support structures, data transmission facilities such as subsea fiber cables or radio links etc. to have additional sensors and customize the monitoring capability according to the requirements.

The initial MRE projects are anyway subjected to rigorous monitoring due to the existence of significant uncertainties associated and public perceptions on potential risks. Thus the potential to monitor from the CMS/SCADA of the initial MRE projects would be up to the highest technical capabilities of the developer. However, these factors are yet to be finalized with respect to the actual planned MRE project in the area. Hence, the exact details of the monitoring capability is still unknown. However, the summary in Table 5.5 can be identified as the possible data quality levels and limiting factors according to the interviews and literature on CMS/SCADA systems.

According the interviews, most of the stakeholder information requirements can be monitored by improving the standard CMS/SCADA (by adding more sensors). There are previous studies that prove the correlation between CMS/SCADA data of offshore wind farms and the standard monitoring data from meteorological masts (Mittelmeier et al., 2016). Further, monitoring equipment such as sensors and communication infrastructure, are almost similar in CMS/SCADA systems of MRE projects and existing ocean observation systems such as met masts, buoys and other floating monitoring platforms. Hence the monitoring capacity of the CMS/SCADA system of the MRE power farm can be estimated by analyzing existing ocean observation system specifications. However, design limitations of the power plant should also be considered when comparing ocean monitoring potential of the power plant's CMS/SCADA systems with the existing ocean monitoring systems. The monitoring capacities of the well-established ocean monitoring platforms such as FINO research platforms in North and Baltic Sea (https://www.fino-offshore.de/en/), and existing popular ocean information data portals such as JAMSTEC (http://www.jamstec.go.jp/e/database/ocean.html), Copernicus Marine Environment Monitoring Service (http://marine.copernicus.eu/training/education/observation/) were considered as secondary data for the information supply potential estimation.

Table 5.5 Data quality levels and limiting factors of CMS/SCADA

Information quality	Maximum potential data quality / limiting factors
Coverage	Depends on the coverage area of the power plant. E.g., the estimated plant area of the Kitakyushu offshore wind project is approximately 2700 ha, covering the entire marine area which belongs to the port authority (First deployment). A large scale 100 device project generally can cover 3 km × 10 km area.
Product type	Depends on the type of sensors, data processing and management strategy. Row data as well as processed data for some parameters may be available. Data transmission capacity also limits the data availability. For resource intensive data sets, only the processed output can be delivered from devices to onshore.
Accuracy	Depends on the type of sensors used.
Spatial resolution	Depends on the layout of the sensors within the power plant. Spatial resolution up to 1 km should be possible.
Vertical resolution	Depends on the depth and power plant configuration. Parameters around 50 m depth and sea bed level are possible
Temporal resolution	Depends on the type of sensors used
Forecast period	Depends on the type of sensors and forecast models used
Latency	Real time communication between the power devices and onshore control room is possible. Latency of the parameters depends on the data acquisition methods used.
Delivery medium	Depends on the data management strategy. Most probable delivery medium would be internet. Quality and availability of data is limited by the data transmission capacity.

Source: made by author based on expert interviews

According to these other monitoring platforms, and data portals, meteorological and oceanographic parameters such as wind strength, wind direction and turbulence, measurements of wave height and wave propagation, measurements of the strength of sea currents, and seabed subsurface conditions can be monitored commercially. Well established monitoring stations like FINO also monitor other ecological and industrial parameters such as the data on benthic communities, bird strikes, and environmental damages associated with the vessel collisions etc. (https://www.fino-offshore.de/en/) as required by many other stakeholders. According to the secondary data analysis on ocean information supplying potential, it is evident that most of the parameters in high demand with a significant gap in demand and supply (Table 5.3) are being monitored commercially, except for few parameters such as marine growth, plankton levels, underwater video and marine mammal observation. However, most of these parameters are being monitored for research purposes in other contexts. Thus the technical feasibility of providing the requested parameters were confirmed within the limitations of MRE power plant designs.

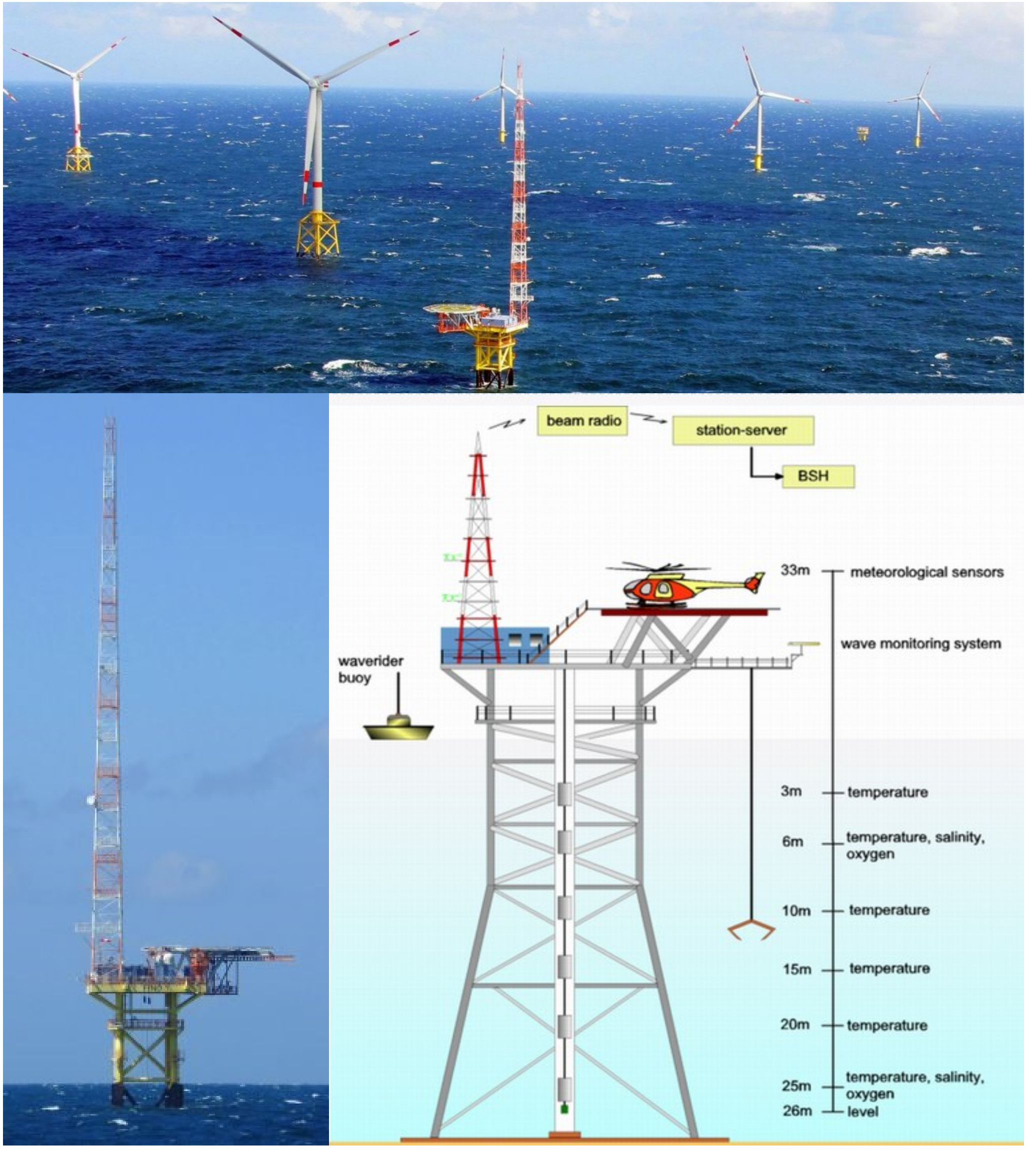


Figure 5.3 Siting of FINO1 in an offshore wind farm and its ocean monitoring methods

Source: https://www.fino1.de/en/

Table 5.6 shows the summary of the local ocean information demand and the potential supply according to identified technical feasibilities. The last column includes additional requirements to satisfy the ideal requirements of the stakeholders.

Table 5.6 Summary of the stakeholders' information demands, information gap and potential information supply

	Parameter in demand	Information gap	Potential information supply	
			Basic CMS / SCADA system	With additional sensors
1	Sea surface temperature	Resolution is not good and accuracy is not ideal due to lack of in-situ monitoring	Temperature around nacelle and support structure	Direct measurements not available if support structures do not reach surface level. Need additional sensor setups in this case
2	Depth-wise temperature distribution	Not available from existing sources. Accuracy of user specific methods is too low	Available	Additional sensors may be required if the required resolution is not met with the standard sensor setup
3	Tidal and current velocity	Coverage and availability of real-time data are limited	Available from MRE projects other than wind projects	Additional sensors may be required for the offshore wind projects
4	Wave profile			
5	Wind profile	Coverage and availability of real-time data are limited	Available from wind projects and other MRE projects with over the surface structures	Additional sensors may be required for the projects with only sub-surface structures
6	Plankton levels, marine growth rates	Coverage and accuracy of manual and user specific data collections are low	Marine growth on sea bed will be monitored in tidal and ocean current projects	Additional sensing equipment can be supported
7	Underwater video / Fish count	Not available	Acoustic monitoring may be available. Underwater video not available	Additional sensors can be supported. Image processing algorithms are required for fish detection
8	Marine mammal observation / passive acoustic monitoring & under water noise levels	Not available	Noise levels and acoustic monitoring are available	Additional sensors can be supported. Image processing algorithms are required for fish detection
9	Mean sea level	Mostly from user specific in-situ observations and limited other data points	Available	Additional sensors may be required
10	Coastal bathymetry	Available mostly from user specific in-situ observations	Not available	Not available

Source: Made by the author

5.5 Economic feasibility of the proposed information sharing scheme

It was identified from the previous three sections that there is a gap in terms of ocean information supply and demands with respect to local stakeholders like fishers in the MRE development areas. Further, according to the experts and other related secondary information sources, it was identified that it is technical feasible to generate ocean information from the CMS/SCADA systems and share those data with other marine users. Hence the technical feasibility of the proposed information sharing scheme is confirmed. However, there is not enough evidences to prove its economic viability.

Cost benefit analysis is the direct method of evaluating the economic feasibility. Costs and benefit levels of the proposed option are highly dependent on the level of information sharing (number of parameters and data quality of those information) from MRE project to the other stakeholders. Due to the existence of data sharing platforms and internet based information provider systems, it can be assumed that the cost of sharing information is negligible. However, the incremental cost of data generation is significant if additional ocean monitoring infrastructure has to be built in order to satisfy stakeholders' information demands. Likewise, the benefit levels are also dependent on how the provided information can be used for stakeholders' industrial and other requirements.

Due to the lack of prior experiences, the monetary values of incremental costs and benefits are very hard to obtain from the stakeholders. Therefore estimation methods and other indirect indicators have been used based on the qualitative data obtained from the stakeholder interviews combined with the secondary data available from the literature and other sources.

5.5.1 Local benefits of ocean information and willingness to pay

In order to do a cost benefit analysis, the benefits of the ocean information have to be comparable with the cost estimates which are usually done in monetary terms. However, as Kaiser and Pulsipher (2004) pointed out, it is difficult to estimate the potential benefits of ocean information (or improved ocean observation system) due to the uncertainty of the commercial value of the existing ocean information, difficulty to establish a direct link between the improved ocean information supply and the resultant benefits such as cost savings or revenue improvements, and the difficulty to estimate which set of information is optimum or which combinations add value to the existing system the most.

Hence indirect methods and indicators such as qualitative reasoning and factor identification, prevailing cost of information, and WTP (Boardman et al., 2006) for the new information have been used in this study to estimate the benefit levels. Qualitative analysis of ocean information can be summarized as follows.

i. Efficient fishing ground and fishing method selection

The most important local benefit of an improved ocean information supply is for the fishers since their output is directly combined with the efficient fishing ground selection, and it is done based on the knowledge on the local marine areas. Traditionally this knowledge on fishing ground selection is based only on the fishers' experience. However even with traditional knowledge or with modern estimation methods, fish catch estimation is dependent on the condition of ocean. Water temperature (of surface level as well as below surface water layers) has been identified as the single most important parameter used for estimating fish stock and selecting the fishing ground. As explained in the previous section, there is a significant information gap in terms of ocean temperature parameter itself.

Local fishers use various types of fishing methods. Used fishing method is also dependent on the fish stock estimation as well as the condition of the sea. Fishing method and fishing ground characteristics are unique to the coastal region. In most of the cases, traditional knowledge on these factors are being kept as a highly guarded trade secret within local fishers. Use of fishing gear is also dependent on the characteristics of sea area selected as the fishing ground. Another advantage of in-situ ocean information is the ability of fishers to predict the ocean conditions and to decide if the fishing gear is suitable before travelling to the area. There are unique benefits of ocean information such as the ability to expand the available fishing area even into ocean areas which are not considered as fishing areas due to unfavorable ocean conditions like high currents. If the fishers know the exact condition of ocean area real time, they could decide the time periods when the usual unfavorable condition is minimum. All these factors ultimately contribute to the fish catch.

ii. Operational cost reduction by reduced transit requirements

Fishers have to travel to the sea area to decide if a particular site is suitable as a fishing ground unless they cannot estimate the sea conditions beforehand. On average, about 20% of the fishers' operating costs is fuel cost which is directly related to the travel requirements to find a suitable fishing ground (MAFF, 2016). Transportation requirements can be reduced if fishers can get accurate in-situ, real-time data remotely, i.e. without visiting the area. Additionally, improved knowledge about the sea conditions can result in efficient and safe route selections for reaching most efficient fishing grounds. For example, vessels can utilize the currents to reduce the fuel cost.

iii. Efficient fish stock management

Fish stock management is an important aspect of Japan's fishery industry due to the trend of high consumption while reducing the stock. Nagasaki prefecture is the second largest fishery supply in terms of quantity, and the first in rank based on the fish variety in Japan (Nagasaki prefecture Fisheries Association, 2018). Lack of understanding of the fish breeding and migration patterns is said to be a main barrier to do an effective and sustainable fishing in the area. Improved ocean information (such as temperature variances, current velocities, and plankton levels) helps local fishermen to understand the fish breeding and migration patterns. However, in most of these studies, data collections are conducted using manual sample collection and oceanographic parameter monitoring methodologies done during field surveys which is resource intensive thus limit the coverage and data availability. Therefore improved ocean information, ideally an automated data acquisition system which can be derived from this ocean information sharing scheme, is beneficial for researchers as well as local fishers in the long term.

iv. Improving safety of marine activities and damage risk reduction

Another main benefit of ocean information is the risk reduction of marine activities. Offshore areas are inherently a dangerous work environment. Unexpected weather condition in the sea (including subsea, surface level and atmospheric conditions) is the main operational risk and major contributor to human and property damages. Lack of environmental monitoring parameters (with the required quality levels) and inaccuracies of the existing weather prediction models are the main reasons of failing to forecast the weather conditions. Hence improved ocean monitoring is very useful to forecast marine conditions using the existing weather prediction models.

Rough sea conditions are a significant threat to fishers as well as their fishing gears such as fixed net set ups. Since ocean is a very dynamic environment, sea conditions can change rapidly, making it very difficult for fishers to adjust unless there are weather warnings given with sufficient lead time. Improved ocean monitoring is very useful for providing weather forecasts accurately and in timely manner. One of the major property damages are caused by rapid currents also known as 'Kyucho'. According to the researchers and the literature, ocean current parameters are essential for predicting Kyucho events (Isobe et al., 2012; Matsuyama et al., 1999). And the prediction of Kyucho can save the fishing infrastructure such as aquaculture facilities and fixed net setups that worth millions. According to the interviews, the set nets / fixed nets deployed generally cost around 3-10 million US dollars thus fisheries perceived value of reducing the damages to these set nets is significant. The incremental value of reducing human risks by improving the accuracy of the weather prediction is also highlighted as a main benefit of the proposed information sharing scheme.

v. Improving the effectiveness of the environmental impact monitoring

Environmental monitoring is vital for assessing the impacts of marine projects such as MRE and other offshore constructions, emission levels and production enhancement projects etc. For example, fishers value the observation data of the impact of MRE pilot projects done in their fishing grounds and other ongoing projects such as sea-grass cultivation project etc. These information are currently acquired through labor and resource intensive manual data collection methods as shown in the Figure 5.4. According to researchers working on related research topics, there are research related benefits from the proposed information sharing scheme such as the availability of additional parameters, improving the quality of existing parameters, and improving the efficiency of data acquisition methods. These benefits have the potential to enhance their research outcomes as well as sea condition prediction capabilities significantly.

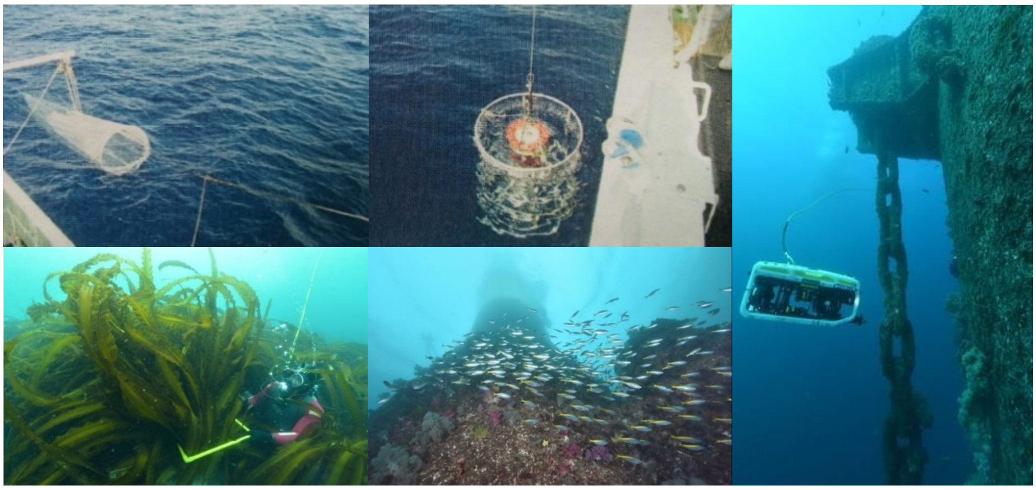


Figure 5.4 Manual and resource intensive data collection on marine studies

Source: Fisheries Experimental Station, Wakayama Prefecture, Shibuya Diving Co.

vi. Other indirect benefits by improving existing data sets

Possibility to automate the data acquisition of certain oceanographic parameters which are currently being collected by manual methods, has been proposed as a future benefit of sharing the monitoring capabilities and other related infrastructure of the MRE projects. For researchers, MRE projects can be considered as a built infrastructure (such as MRE subsea structures as structural support, power supply and data communication media) for their sensor setups (Figure 5.5). It was identified that the availability of more ocean information can lead to other types of spillover effects, such as the possibility of having regional forecasting businesses, and attracting younger generation to traditional as well as new marine industries.

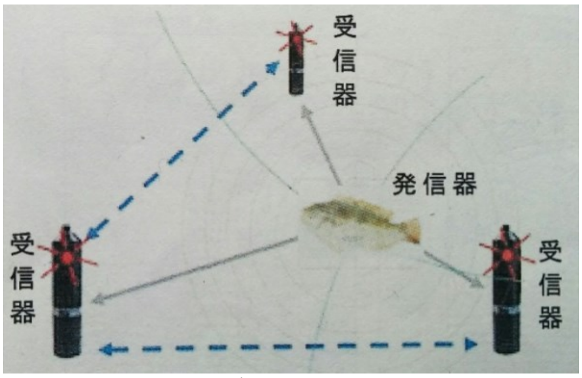


Figure 5.5 An example sensor setup which needs to be mounted on subsea structures

Source - Fisheries Experimental Station, Wakayama Prefecture

Even though a lot of benefits have been identified for different stakeholders, only the fishers' direct benefits were used for further analysis since it was difficult to estimate the other stakeholders' benefit levels with an acceptable accuracy. Fishers' benefits can be estimated by other indicators with a higher level of accuracy, because commercial fishers tend to match their costs in terms of fish catch improvements. Further, fishers have a better knowledge on how to use the ocean information for commercial activities.

Fisheries benefit levels could be estimated by two indirect indicators; i.e. their current expenditure level for acquiring the ocean information and their WTP for the information from the MRE projects.

From our previous studies, it was identified that fishers have commercial options to receive regional forecasts and limited amount of ocean data from existing sources for about 20,000 yen per year. According to the fishery union, about 20 million yen has been already invested cumulatively for ocean information acquisition systems which can be estimated to about 25,000 yen per fishermen.

WTP is an indirect method used to estimate the benefit levels of a future product or service based on the perceived benefits. WTP has been used in lot of studies (Boardman et al., 2006) to evaluate potential values of future products which are difficult to evaluate using other methods. Fishery union representatives have indicated that fishers may be willing to pay on the range of 100,000 – 500,000 yen annually depending on their fishing scale, fishing area and fishing methods. It was also revealed that certain fishers who do large scale fishing, have already invested for millions worth of ocean observation equipment to enhance their output. However, there are small scale fishers who have not invested in such type of infrastructure based on their fishing requirements. Thus the WTP amount of fisheries have a significant variation. But given their average current cost of information and investments made, which can sum up to about 50,000 per fisherman annually, annual WTP of 100,000 per fisherman can be a conservative estimate based on the improvements which can be made to the current information availability by the proposed information sharing scheme.

5.5.2 Incremental cost of sharing information

According to the basic proposal, which is sharing ocean information obtained by the CMS/SCADA of the MRE power plant, the only additional cost is the 'cost of data sharing' from MRE projects' onshore facilities to external users. This type of information sharing can be done at a very low cost due to the existence of Information and Communication Technology (ICT) infrastructure even in the remote islands of Japan. According to the original proposal of RIOE (2013), the estimated cost of information sharing is about 50,000 per month based on the existing internet based platforms regardless of the number of data receivers. This is an insignificant additional cost in terms of actual cost of data acquisition and related operating costs. However, these data acquisition cost cannot be considered as incremental cost of proposed information sharing scheme since those information will be monitored anyway for the operation of the MRE power plant. Hence in the base case, where the information obtained by the power plants' standard CMS/SCADA system is shared with other stakeholders, the incremental cost can be estimated to 600,000 yen per year regardless of the number of beneficiaries.

RIOE (2013) also estimates the initial cost of ocean monitoring if it is done by small buoys which is about 20-30 million yen per buoy. This gives an indication of the significant cost of ocean observation in comparison to cost of information sharing.

According to the results of the initial research questions, it was identified that there is an opportunity to improve the standard monitoring capacity of the MRE power farm so that a higher level of stakeholders' ocean information requirements can be satisfied by the proposed information sharing scheme. The potential returns of such an additional investments is clearly indicated by the significant change of the fishers' WTP amount. Hence, incremental changes to the CMS/SCADA that result additional information availability is considered as the 'extreme cost case' in the incremental cost estimation.

Estimation of the additional cost based on the 'extreme cost case' was done based on certain assumptions made on the relevant literature on cost benefit analysis of ocean information systems. Chiabai and Nunes (2006) have given a comprehensive cost breakdown estimation of the 'Mediterranean Forecasting System Towards Environmental Predictions (MFSTEP)' as shown in Figure 5.6. According to the analysis of cost structure of a typical ocean monitoring system, it can be assumed that about 50% of the initial cost is related to labor costs and only about 30% of initial costs are attributable to sensor and other equipment cost. In terms of maintenance, equipment replacements would attribute to about 20% of total cost while more than 55% of annual recurrent cost is attributable to labor costs.

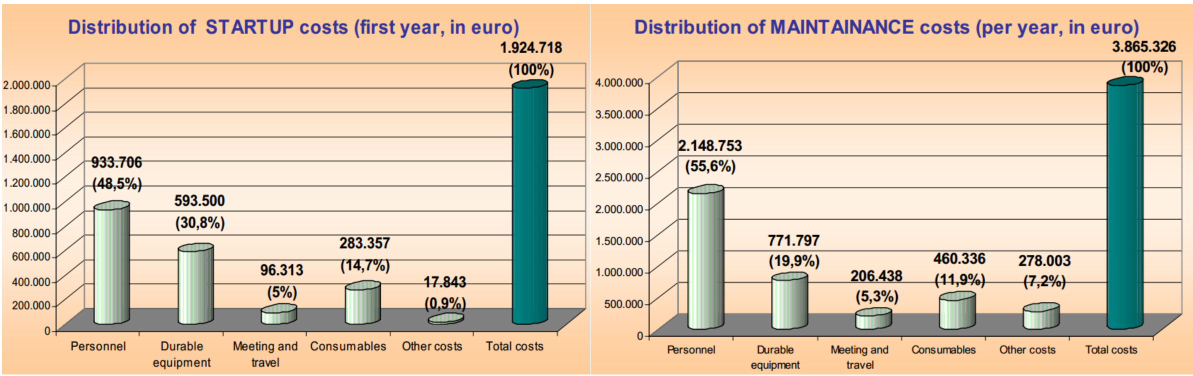


Figure 5.6 Summary of cost estimates of MFSTEP

Source: Chiabai & Nunes, (2006)

By comparing the initial costs and annual maintenance cost from the second year onwards, it can be assumed that the entire system should be replaced (in terms of financial estimates) every 6 months since the annual maintenance cost is almost double the initial cost. However, that 100% cost increment of maintenance cost is basically from the costs other than the equipment costs. According to comparison of equipment costs, it can be seen that annual maintenance cost slightly overruns the initial equipment cost. The initial cost as well as the running cost of this system is significantly higher than that of a typical

CMS/SCADA system of an offshore MRE power farm. The main reason is the quality of sensors used for scientific research oriented ocean observation systems is higher than that of sensors of commercial CMS/SCADA systems. Another reason is that this type of research oriented ocean observation systems work as standalone systems typically not connected to onshore facilities continuously. Hence those equipment store data for a predetermined time period and then the operators have to fetch those data after its intended service period. So generally, sensors get changed or updated every year. However, this is not the case for general CMS/SCADA of a MRE project where life span of equipment is much longer and they can work for a longer time without any intervention.

Since the maintenance of the ocean monitoring systems are also carried out as a part of MRE maintenance activities, related labor and other costs cannot be considered as additional cost of the proposed information sharing scheme. However, equipment costs should be considered for initial costs as well as annual maintenance cost if additional equipment has to be included to the standard CMS/SCADA system (as suggested in the 'extreme cost case').

According to a cost estimate of another MRE project (with hundred 2 MW ocean current energy convertors deployed in 50 km offshore at about 1000 m depth range) total capital expenditure on equipment has been estimated to 1,268 million Euros and about 3.4% of those costs (42.8 million Euro) have been attributable to CMS/SCADA of the power plant (Kularathna, 2016). If it is assumed to have same ocean monitoring equipment for the proposed commercial MRE projects considered in this study, the cost of CMS/SCADA of the MRE project can be approximated to 5,225 million yen (42.8 million Euro at an exchange rate of 122 yen/Euro).

Over 5 billion yen worth of sensing equipment (in a 100 device MRE farm) suggests a significant ocean monitoring capacity available from the MRE farm. Further, if the stakeholders need additional data and it requires an improvement to the ocean monitoring capacity of the MRE farm, with 1% cost increase (1%-2% probably be acceptable range for a MRE developer considering the future value of those data even to power farm operators), that means more than 50 million yen worth of additional investment.

Likewise, the upper limit of the additional cost for the proposed information sharing scheme can be estimated as a percentage of cost of CMS/SCADA of the power plant. However, this type of costing is based on business decisions rather than actual cost of additional monitoring requirements. A thorough technical analysis is required to estimate the additional equipment requirement more accurately. Since the proposed commercial

MRE projects are still in the basic planning stage, the data availability is minimum for such a thorough technical analysis at this stage. However, a preliminary cost estimation can be done by considering the additional sensor requirements and their market values as shown in the Table 5.7. The upper bound of initial cost can be estimated to be less than 200 million yen for a hundred device MRE farm as shown in the Figure 5.7.

A limitation of this cost estimate is the assumption of the technical similarities between ocean observation systems meant for scientific research (like FINO) or forecasting services (like MFSTEP) and CMS/SCADA of a typical MRE project. Generally, the equipment used for scientific ocean monitoring is significantly expensive and require frequent replacement than the equipment meant for condition monitoring on MRE devices. However, since the exact details of the CMS/SCADA systems are not yet available, and since the extreme cost case is focused in this context, the market data for high quality ocean monitoring equipment were used for the additional sensor cost estimation in Table 5.7.

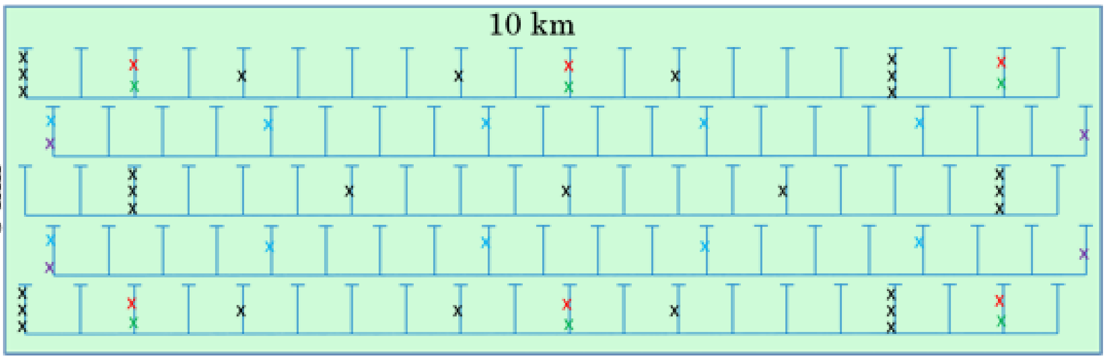


Figure 5.7 Additional sensors required to satisfy the highest information demand

Source: (Kularathna, 2016) based on stakeholders' information requirement and Ocean current power project details from IHI Corporation

x =CTD, x =ADCP
x =Video cameras and hydrophones
x =Fish detectors
x =Bio-chemical sensors

Table 5.7 Additional sensor cost estimation

Sensor (generic type)	Unit cost (¥) (highest range of pricing data)	Units required	Total cost (¥ millions)
CTD (Conductivity, Temperature & Depth)	700,000 - 1,000,000	27	18.9 – 27.0
ADCP (Acoustic Doppler Current Profiler)	5,000,000 - 7,500,000	6	30.0 – 45.0
Underwater video systems	1,000,000 - 1,500,000	6	6.0 – 9.0
Hydrophone, passive acoustic monitoring equipment	500,000 - 700,000	6	3.0 – 4.2
Fish detector	250,000 - 300,000	10	2.5 – 3.0
Biochemical sensors (Chlorophyll A, sampler, particle counter)	1,500,000 - 2,000,000	4	6.0 – 8.0
Connectors and other equipment	Assuming 100% of the sensor costs		66.4-96.2
			132.8 – 192.4

Source: Created by the author based on the developer interview results and market data.

5.5.3 Sensitivity of economic estimates

The economic estimations in the previous section are based on very limited data, hence the final values incorporate a high level of uncertainty. However those costing estimates can represent the worst cost scenario, and benefit estimated by means of WTP can represent a more conservative estimate even though the minimum WTP mentioned is about twice of their current expenditure for the available information. Due to the limitation of these economic estimates, sensitivity analysis is required on estimated values to improve the reliability.

In order to validate the fishers' WTP amount, it is necessary to analyze the economic condition. Figure 5.8 shows the average business financials of coastal fishery households with fishing vessels. Most of the local fishers referred in this study fall under this category and the rest are commercial fishery companies and recreational or part time fishers.

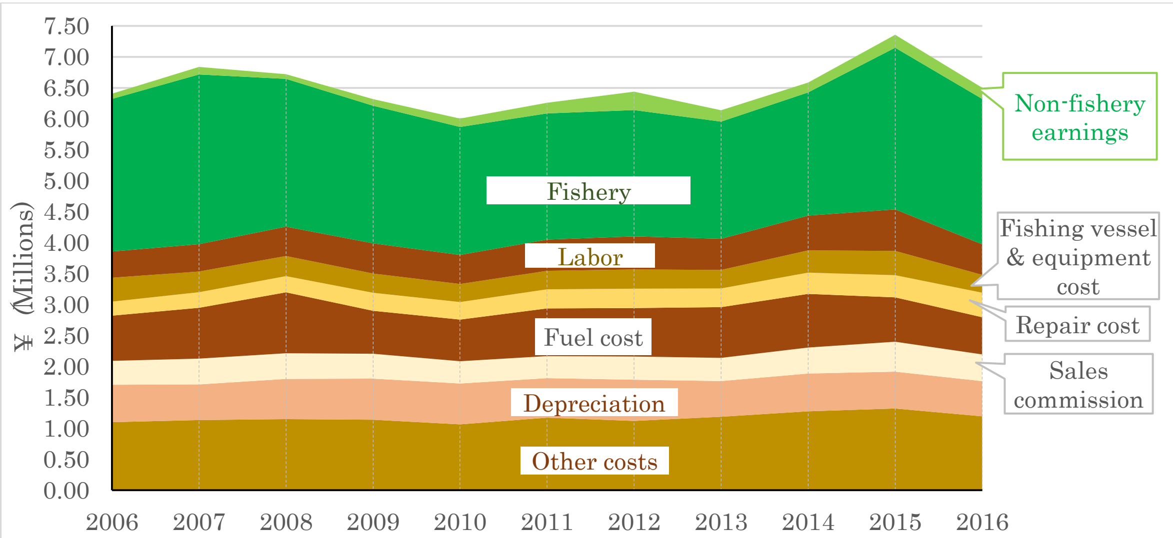


Figure 5.8 Average financials of coastal fishery households with fishing vessels

Source: created by author based on information from the MAFF, (2016)

Kaiser & Pulsipher, (2004) provided an example of estimating the potential value of ocean information for different marine uses such as fisheries, and maritime transportation. According to Kaiser & Pulsipher, (2004), ocean information can increase the fishers' income by "extending commercial activity and by increasing the number of days at sea". Similarly, maritime transportation can benefit from ocean information since it can optimize transit times and minimize the exposure to severe weather conditions. Vessel operators also depend on wave and fog conditions for planning activities in harbors where better information can lead to cost savings and risk reductions. Due to these risk reductions both insurance and damage costs (and depreciation in the long run) can be reduced.

Table 5.8 shows the 10 year average financials of fishers in Japan. The items that can be impacted by a better ocean information supply have been indicated in the last column.

Table 5.8 Average financials of fishers and items that can be impacted with better ocean information supply

	2006-2016 Average values		Potential to have an impact*
	¥ (in millions)	% of fishery income	
Fishery income	**6.984**	100%	✓
Fishery costs	**4.503**	**64.48%**	
Labor cost	0.556	7.97%	✓
Equipment cost	0.360	5.15%	x
Repair cost	0.334	4.78%	✓
Fuel cost	0.846	12.11%	✓
Sales commissions	0.442	6.33%	x
Depreciation	0.680	9.74%	✓
Others	1.284	18.39%	✓
Fishery net earnings	**2.481**	**35.52%**	
Non fishery net earnings	0.173		
Total business earnings	2.653		

Source: Made by the author based on MAFF, (2016)

Main indicator of fishery income is the number of fishing days. According to the interviews, local fishers achieve 150-160 fishing days per year on average. However, out of these fishing attempts, about 10-15 days become inefficient on average. Fishers expect that this number of inefficient fishing days can be reduced with the availability of ocean information such as water temperature in different fishing grounds. These improvements can benefit in multiple ways such as the reduction of unprofitable travel requirements, better fishing ground selection, and thereby increasing the number of efficient fishing days. According to the interviews, fishers expect that the number of inefficient fishing days can be reduced at least by half with new information. That is, on average, a 3.33% (5 days for 150 total fishing days) to 4.38% (7 days for 160 fishing days) improvement of fishing days. Hence, at least 3%-5% improvement of fishery income can be expected by the improvement of the fishing days since it is directly related with the fish catch. If it is assumed that fuel cost is solely from the travel requirements in search of fishing grounds, it can be expected to have the same percentage of improvement for the fuel costs by reducing the avoidable (No good fishing ground found) inefficient fishing trips. However, fuel cost reductions are from more than efficient fishing ground selections. Significant amount of fuel can be saved by selecting the safest and most fuel efficient path to the identified fishing area. Even though it is hard to estimate an improvement percentage, this type of fishery improvements can indirectly save a significant amount from labor costs, insurance costs, and even depreciation amounts.

Figure 5.9 shows the sensitivity of net benefits of fishers within potential ranges of income improvement, fuel cost savings, and a combination of labor, repair, depreciation and other costs, decided based on the above evidences.

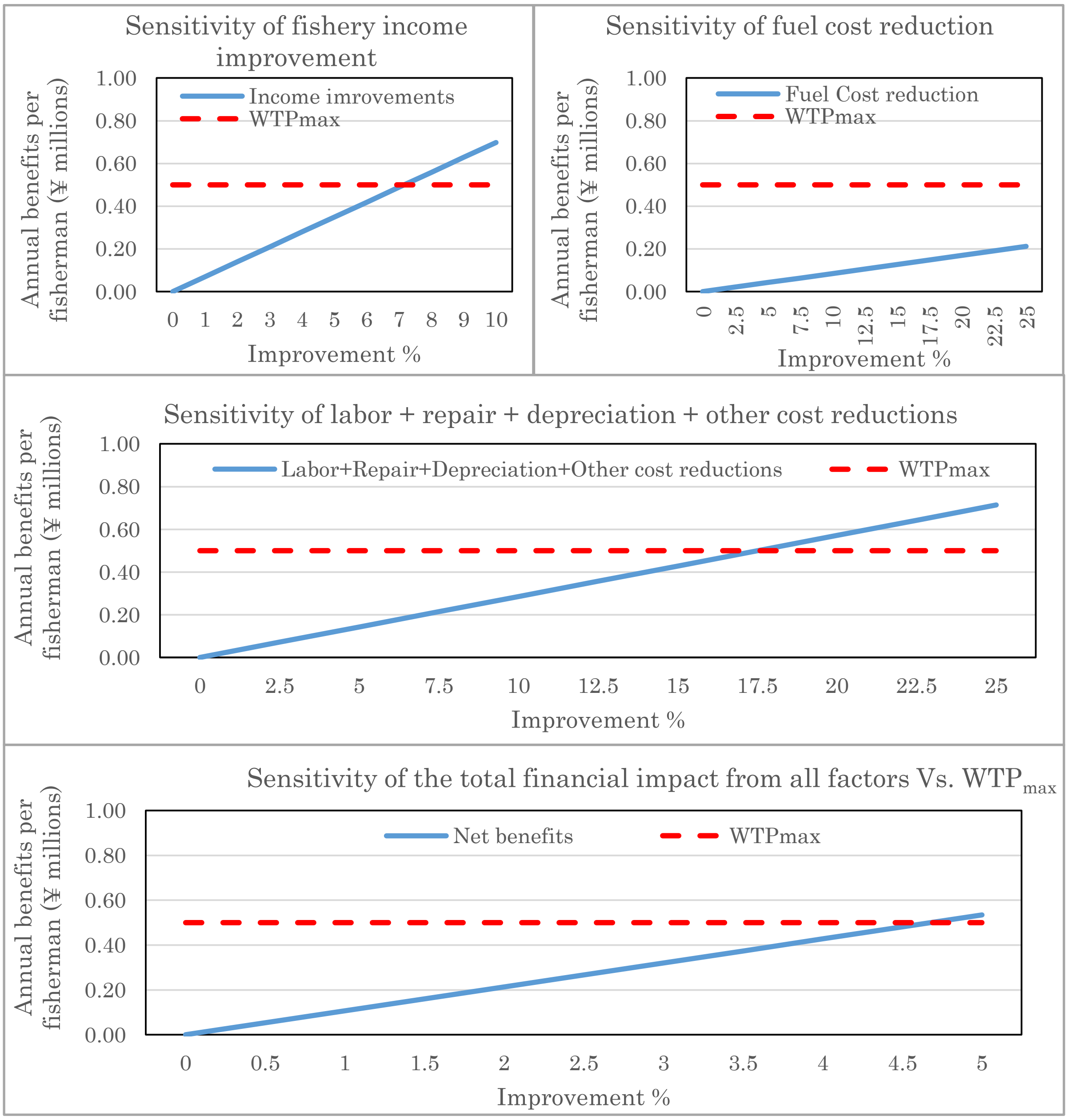


Figure 5.9 Sensitivity of net benefit levels

Source: made by author

According to the basic sensitivity analysis, the maximum WTP of 500,000 yen per fisherman can be reliable if there is a 5% improvement of all the financial factors which were identified to have potential to improve with better ocean information supply.

Estimated cost level also depends on the level of information sharing. Table 5.9 shows the summary of cost estimates with respect to the different information sharing levels according to additional sensor cost breakdown of Table 5.7, and the minimum number of fishers (who is willing to pay for information) required to cover the additional costs.

Figure 5.10 shows the number of fishers required to pay in order to breakeven the additional cost of data sharing. Main scenarios are the data sharing levels indicated in the Table 5.9 and the upper and lower bounds of the WTP of fishers.

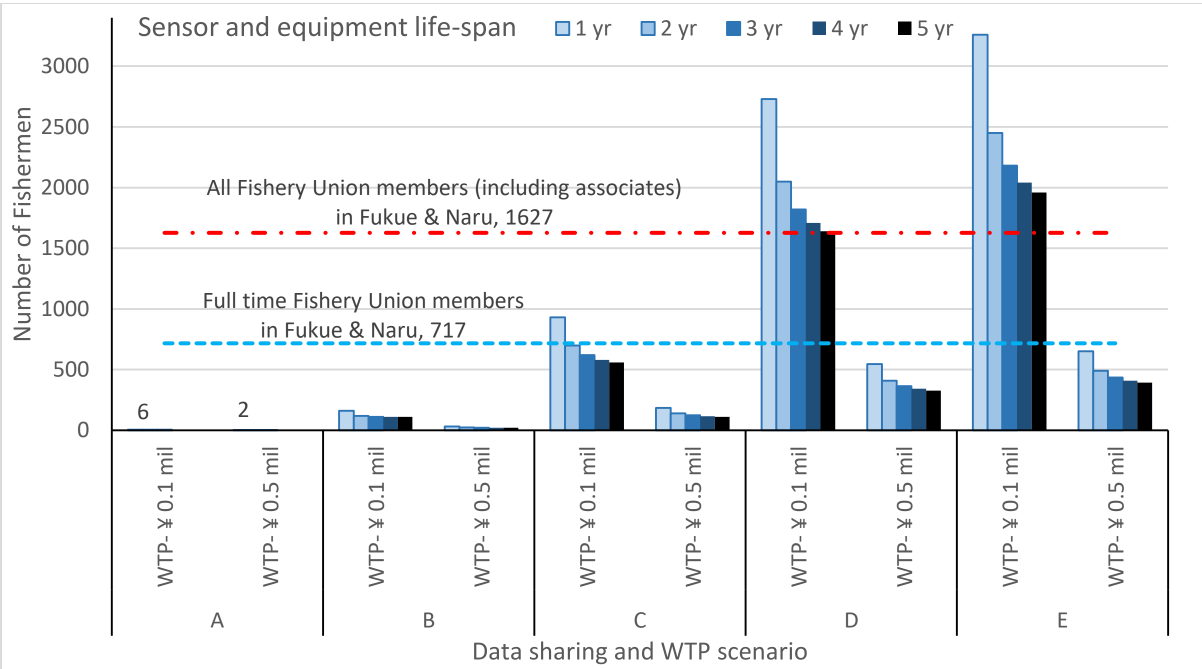


Figure 5.10 Required number of fishermen to breakeven the cost with respect to equipment lifespan, WTP and data sharing level

Source: made by the author based on the sensitivity data on the Table 5.9

Table 5.9 Sensitivity of cost estimations and required number of fishers to break-even

Information sharing level	Factors behind additional costs	Additional cost (¥ millions)			Number of fishers required	
		Initial cost	Operation cost/year	Annualized cost	@ WTP=0.1	@ WTP=0.5
No information sharing	-	0	0	**0**	**0**	**0**
(A). Sharing the parameters of basic CMS/SCADA	Cost of data sharing from MRE to other stakeholders	0	0.6[*1]	**0.6**	**6**	**2**
(B). Sharing the parameters of basic CMS/SCADA + Additional buoy[*2]	Data sharing cost + Buoy maintenance cost	5-7.5 [*2]	0.6[*1] + (5.5 ~11)[*2] = 8.85	8.85 + [(6.25)[*2] /5] **≈ 10**	**100**	**20**
(C). Sharing the parameters of basic CMS/SCADA + Temperature (Only CTDs)[*3]	Data sharing cost + Cost of additional CTDs[*3]	18.9 – 27.0 (+ 100% sensor cost for other items) [*3]	0.6[*1] + (18.9+27)[*3] = 46.5	46.5 + [(45.9)[*3] /5] **≈ 56**	**560**	**112**
(D). Sharing the parameters of basic CMS/SCADA + CTD + ADCP + Under water video[*3]	Data sharing cost + Cost of additional sensors[*3]	54.9 – 81.0 (+ 100% sensor cost for other items) [*3]	0.6[*1] + (54.9+81)[*3] = 136.5	136.5+[(135.9)[*3] /5] **≈ 164**	**1640**	**328**
(E). Sharing all demanded information by adding sensors to basic CMS/SCADA[*3]	Data sharing cost + Cost of additional sensors[*3]	66.4 – 96.2 (+ 100% sensor cost for other items) [*3]	0.6[*1] +(66.4+96.2)[*3] = 163.2	163.2+[(162.6)[*3] /5] **≈ 196**	**1960**	**392**

*1 based on RIOE, (2013) , *2 based on (Kaiser & Pulsipher, 2004), *3 based on (Chiabai & Nunes, 2006), *4 assuming 5 year equipment life-span and zero discounting rate

5.6 Optimum information sharing level

Figure 5.10 indicates that the required number of payees to breakeven the additional cost increases exponentially with every attempt to improve the ocean monitoring capability of the basic CMS/SCADA, due to the exponential increase in the cost. However, according to the cost and WTP estimates, it can be seen that it is financially feasible to develop the CMS/SCADA with additional ADCPs, CTDs and under water video equipment (Scenario D) if the equipment replacement cycle is assumed to be 5 years with the lower bound of the WTP, (which is 100,000 ¥ per fisherman annually). However, if all the full time fishery union members are willing to pay 500,000 ¥ per fisherman annually, even the best information sharing level is feasible, even with 1 year equipment replacement cycle.

Thus it can be seen that financial feasibility of the proposed ocean information sharing level is significantly dependent on the level of information sharing, WTP and equipment replacement cycle. According to the benefit estimation based on qualitative reasoning and WTP analysis, it was evident that the most important oceanographic parameter is the temperature. Meteorological information is available even though the quality of data is not up to the ideal requirement. Hence the incremental benefits become lower for other specific parameters or data quality improvements beyond the parameters available from the basic CMS/SCADA systems. However, incremental cost grows exponentially with each attempt made to improve the data quality and availability beyond the availability and quality of CMS/SCADA systems' data. Hence, it is important to consider which information really add value to the fishers. This in-depth financial feasibility analysis further consolidates the results of our previous study on stakeholders' preference of the level of information sharing (Figure 5.11) where most of the stakeholders preferred to set the sharing level only to information captured by the basic CMS/SCADA of the MRE power plant (Kularathna, 2016; Kularathna & Takagi, 2017).

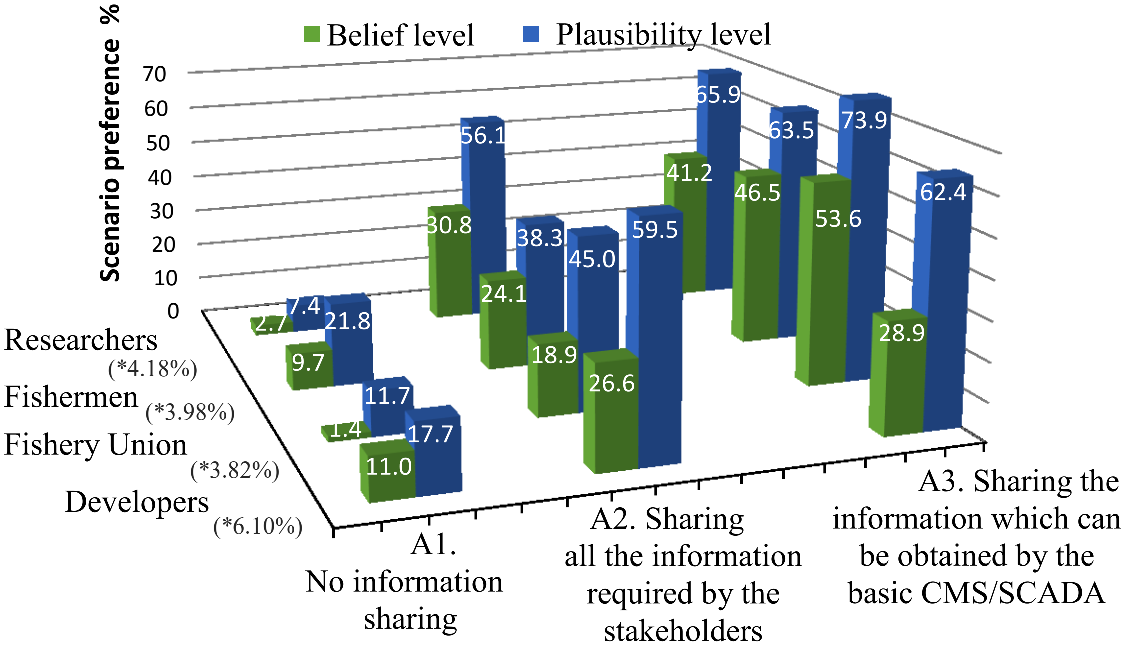


Figure 5.11 Stakeholder preference of information sharing levels based on DS-AHP method

Source: Kularathna (2016)

5.7 Summary

Ocean information sharing was considered as the optimum co-existence strategy due to preference of the most prominent local stakeholder group, the fisheries. This chapter analyzed the feasibility of the proposed ocean information sharing option both in stakeholder requirements, technical and financial feasibility aspects.

According to the stakeholders' information demand analysis, it was identified that at least ten main oceanographic and meteorological parameters are in demand. The most important parameter has been identified as the water temperature. Analysis of the existing information supply indicated that there is a significant gap between the stakeholders' ideal information requirement and the information availability (Table 5.3). From analyzing the potential information supply from the MRE power plants (Table 5.4 and Table 5.5), it was identified that most of the information gaps can be fulfilled by the proposed information sharing scheme (Table 5.6). Thus, the technical feasibility of the proposed co-existence option was proven.

There was a significant uncertainty involved in this technical feasibility study due to the unavailability of technical specification of CSM/SCADA system of the proposed MRE power projects. However the impact of this data unavailability and uncertainty was minimized by validating the primary data with secondary data from literature, and other similar ocean observation systems. Technical feasibility study suggested that there can be multiple information sharing levels with significantly different adjustments to the basic setup of the CMS/SCADA of the power plant. Hence, an economic feasibility study was conducted in order to select the optimum information sharing level. Similar to the technical feasibility study, the existing data limitations and uncertainties were minimized by referring to the relevant literature and cost benefit analysis technologies used in previous projects.

Since there were not enough data to estimate the benefits in monetary terms, an indirect indicator of benefits; WTP was used to estimate the cumulative benefits. Incremental costs were estimated based on the information sharing level and data from secondary sources such as market data and similar cost benefit analysis data in the literature.

Comparison of perceived benefits (which were estimated by WTP amounts of fishers), and incremental costs show that even the worst cost scenario is economically viable if all the local fishers actually pay the highest WTP amount (0.5 million yen annually), under the assumption that monitoring equipment does not have to be replaced at least for five years (Figure 5.10). Further, it was apparent that incremental costs of improving the basic

CMS/SCADA system grow exponentially with each attempt to supply more parameters or improve its basic data quality levels. Conversely incremental benefit levels do not improve significantly after the basic requirements (such as the parameter of temperature etc.) were satisfied. Thus it is suggested that sharing the information captured by basic CMS/SCADA (with an improvement to the monitoring capability of water temperature), is the optimum level.

6 CONCLUSIONS

This chapter summarizes the main results obtained in the previous three chapters and analyzes the overall implications of this study. The policy implications and recommendations derived from this study will be discussed with the qualitative inputs received from the key interviewers regarding the practical implementations, limitations and additional work to be done etc. Finally, conceptual ideas on generalization of the research findings, limitation and future research possibilities to improve the quality of these findings will be discussed.

6.1 Summary of results

Chapters 3, 4 and 5 of this thesis were dedicated to answer three main research questions focused in the research.

Third chapter answered the first research question on the public acceptance and underlying factors of acceptance decision. According to the analysis of the current acceptance decision, it was revealed that even though a majority of local community had formed a decision to accept and support the MRE projects, less than a third of all respondents had a firmed decision to support. However, Nagasaki case showed a higher tendency to have public support than the Kitakyushu case study. In-depth sensitivity analysis of local acceptance decision revealed that the supporters were more sensitive to the external information and had a higher tendency towards reducing their support if negative information was noticeable. On the contrary opponents' decision was more firmed and had little tendency to change towards support even with additional positive information about the projects. The between group experiment conducted to check the impacts of benefit information on the acceptance decision showed that dissemination of the full knowledge of the project impacts creates more support than sharing only the positive information in contrast to the normal expected behavior. However, even though decision behavior was different to the expected trend, there were few literature which suggested the same and gave reasons such as perception of bribery etc. Acceptance trend analysis showed a reduction of local acceptance level with the development of the MRE sector towards commercial level projects which is done independent of public funding. Further, visual impacts of MRE projects was not a critical decision criteria even in the Japanese remote islands context. Logistic regression showed that acceptance decision was more dependent on project characteristics and perceived impacts rather than the demographic factors.

Having long term policies, sharing project information with locals, involvement of the public authorities to safeguard the local inclusivity, local benefit creation etc. could be identified as the factors behind supporting decision.

After the identification of acceptance decision factors, potential co-existence strategies which could satisfy the local acceptance requirements were focused in the fourth chapter. Multi-criteria decision making model was used for the co-existence option evaluation and the considered options were (O1) sharing real time in-situ ocean information, (O2) using MRE structures as artificial reefs and support structures for commercial fishing, (O3) co-location with other industries such as leisure and tourism, aquaculture, etc., (O4) sharing generated electricity for local users at a subsidized rate, and (O5) use of local resources to construct and operate the power plant, creating business involvement opportunities. Two main preference trends were identified; fisheries preference was for the first option (O1) and all others' general preference was for the fifth option (O5). Co-existence option preference was mainly based on the individual benefits and knowledge or experience on marine activities. However, this preference decision was based on very limited knowledge on the practical impacts and effectiveness of the proposed co-existence strategies. The nature of MRE projects done in the locality and the experience on project impacts based on pilot projects were extrapolated with lot of uncertainties to estimate the impacts of future co-existence strategies in commercial level MRE project context.

Due to this high uncertainty level, the most reliable decision came from the fisheries, because they had the most practical experience and knowledge on marine activities, making them a better decision maker on evaluating the potential net impacts and limitations of the proposed co-existence options.

The most reliable selection from the most prominent stakeholder group: ocean information sharing option was focused on the fifth chapter where its feasibility was checked in technical and economic aspects. Ten oceanographic and meteorological parameters have been identified as the most important ocean information. A significant gap was also identified in terms of demand and supply of information. Technical feasibility study showed that the MRE power plants can fulfil the existing ocean information gap according to the proposed co-existence option (O1). Further it was identified that there are several information sharing levels with significantly different net impacts and required adjustments to the MRE project. Economic feasibility study and sensitivity analysis were done to compare these alternatives. Cost of proposed strategy was estimated using limited available project data and relevant secondary data. Benefit levels were estimated using indirect indicators such as current expenditure on information and WTP for future information supply. Final feasibility study showed that it is viable to supply all the required information provided all the fishers pay their highest mentioned WTP amount. However, considering the exponential costs and limited additional benefits, it is suggested that sharing information captured by the basic CMS/SCADA of the MRE power plant with an improvement to the monitoring capability of water temperature, which is the most important oceanographic parameter, is the optimum information sharing level.

Thus the conclusion of this study is that the proposed co-existence strategy of sharing ocean information is a viable option to create local benefits and a win-win situation among local stakeholders that can lead to a higher public acceptance.

6.2 Recommendations from the research outcomes

From the co-existence option preference identifications, it was identified that the fishers prefer the ocean information sharing scheme where non-fishers prefer using local resources to construct or operate the power plant and creating business collaborative opportunities. Hence, it can be recommended to follow this results according to the composition of stakeholders in the MRE projects. Further, it was identified that there is a possibility to get synergies from the other identified options to enhance the benefits of ocean information sharing and using local resources options. As an extension to the above general recommendation, a specific recommendation can be identified from the results of chapters 4 and 5, which is, institutionalizing the requirement of having a locally preferred co-existence option, instead of portraying the developers' co-existence attempts as voluntary acts.

Specific recommendations of implementing the proposed information sharing option would be as follows.

1. Confirm the power plant's information generation capacity once the CMS/SCADA system is finalized.
2. Confirm other specific data requirements depending on the exact project location and other marine uses of the nearby areas.
3. Generate a policy on data sharing and resource management by the relevant public authorities.
4. Facilitate the information sharing by providing data management services by a trustworthy third party and providing a medium to share the data.
5. Implement the information sharing scheme in the proposed commercial MRE projects as a pilot to evaluate the actual local benefits of new information.

In-depth analysis of the proposed option of using local resources to construct and operate the power plant creating local business collaboration options was not focused in this research. However it can be recommended to do a feasibility analysis and a potential impact analysis in terms of local employment level and other local economic perspectives since most of the non-fishers preferred that option.

From the acceptance decision factor analysis, the importance of preserving local interests and maintaining the inclusivity of local stakeholders could be identified. On the other hand, existing policy guideline also suggests to complete the consensus building process locally case by case. This approach is generally different to the other existing MRE markets such as UK, Netherlands, Germany, Denmark etc. where there is a well-established, centralized licensing system. Local stakeholders have shown a higher trust on public authorities than the private project developers specifically from outside the region. Hence it is important for public authorities to get involved with the MRE project development even though the projects are done from private funding. Thus the first general recommendation would be to get the involvement of the trustworthy public authorities for local stakeholder engagement process.

If the public authority is in charge of stakeholder management, it is expected to have better information sharing among local stakeholders, a higher trust among local communities regarding the preservation of local interests, and to bridge the existing gap between decentralized approval process in Japan and expectations of having a centralized licensing system like in the European countries. Another benefit of the involvement of public authority in the stakeholder management process is maintaining the power balance among stakeholders during the consensus building process. Because, less powerful stakeholders' voices tend to be unheard if there are few significantly powerful decision makers in the consensus building process. Even though there was no enough evidence to confirm, it was observed that there was lack of information sharing and engagement with other stakeholders in the case of Kitakyushu MRE development where the "Developers" and "Local Harbor" have the sole authority over the proposed MRE projects. Conversely, stakeholder engagement activities were apparent to be more active and inclusive of many other stakeholders in the case of Nagasaki MRE development.

Generally developers are eager to gain the legal acceptance to use marine areas exclusively for MRE projects. Less emphasis is given to co-existence or co-location of different compatible sea uses. Even though the developers identified the value of local support and maintaining the local interests, both Nagasaki and Kitakyushu MRE project proposals do not include the concepts of co-location to improve the local inclusivity. Lack of policy guidance and a MSP may be the main reasons for this apparent segregation of sea uses. Hence the second general recommendation is the development of an integrated marine spatial plan at least for the local regions, with the consideration of co-locating the compatible sea uses. However, it is important to honor the industry specific requirements and traditions in the attempt to co-locate the compatible sea uses. Because in certain cases, existing industries (fisheries) do not want to disclose their preferred marine areas (fishing grounds) while requiring MRE projects to be sited out of their preferred areas (Alexander et al., 2012).

Currently there is no generally accepted guideline or policy requirement on local benefit creation to maintain the balance of costs and benefits of MRE projects in rural local regions. Hence, even though the project developers are willing to employ local benefit creation strategies, there are significant level of barriers than drivers for that. Hence the third general recommendation is to create the policy requirement and guideline for developers to create local benefits with the mediation of the local public authorities. This type of guidelines are there in other matured renewable energy markets. For example, in England and Wales, developers must contribute to costs related to community infrastructure and/or mitigation of impacts of new developments upon existing facilities or infrastructure in order to get the initial project permission (Town and Country Planning Act, 1990: s106 quoted in Aitken, (2010)). Further, the institutionalizing of community benefit schemes has the potential to reduce bribery perceptions (Aitken, 2010), and developers can be benefitted by having a clear guideline and an better understanding about the local requirements. Further, inclusivity of public authorities can help the developers on weighting and assessing the local priorities.

6.3 Local relevance to global consistence

It was identified that there is no common trend of MRE acceptance decision and factors behind acceptance decision significantly vary from one case to another. The acceptance decision behavior identified in Nagasaki and Kitakyushu case studies has some similarities to the acceptance behaviors of other European cases. However, significant differences and unique reasoning were also identified in this study. For example, the visual impacts of the projects have been perceived positively by Nagasaki respondents because of believed synergies on local tourism industry conversely to the majority of literature which suggest visual impacts have been considered as negative impacts. However, there are exceptions in few cases such as the case of Sea-Gen tidal energy project in Ireland where local residence perceived the MRE structures as 'visually fitting' (Devine-Wright, 2011). Project location is another factors which determines the perceived impacts such as visual impacts. Projects located in offshore areas had a lower acceptance probability according to the logistic regression results. General assumption in the literature on wind energy is that those living most proximate to developments are likely to have the most negative attitudes (Devine-Wright, 2005). However this assumption has been challenged by several studies where Danish communities who reside near the wind farm tend to have more positive perceptions in comparison with individuals residing further away (Krohn & Damborg, 1999), (Anderson et al.,1997 cited in (Devine-Wright, 2005)).

Thus, the generalization of underlying factors of acceptance is hard due to the significant influence of the local contexts. However, certain decision behavioral trends identified in this research show a similarity to other cases. For example, current supporters' decision being much sensitive to the potential negative impacts while opponents decision is firmed and insensitive to the potential positive impacts is similar to the decision behavior Cape Cod offshore wind project in the US (Firestone & Kempton, 2007). Another common trend is that project characteristics have a significant impact on the acceptance decision than the other local factors such as demographics as indicated in the cases from Denmark (Ladenburg, 2010). Acceptance trend with respect to the project phase also has a significant similarity as identified in the case of tidal energy development in Washington, USA (Dreyer et al., 2017) but a clear difference is visible once the project is developed to a full scale commercial project without public funding. The size of the energy farm increases with the maturity of the MRE sector. It has been identified that there is a negative relationship between wind farm size and public support in many onshore wind projects in European context such as in Netherlands (Wolsink, 1989) and Ireland (Sustainable Energy Ireland, 2003).

The findings of this study from Japanese case studies, (which is the first attempt in this regards) can be different to the existing studies based on European MRE projects due to the significant differences in socio-cultural context, regulations, policies and perceived preferences. For example, most of the European countries have a centralized, one-stop licensing system and a well-established marine spatial plan which is inclusive of variety of marine uses. Generally, European MRE projects are under a centralized decision maker with respect to conflict management etc. These characteristics are significantly different in Japanese context where the licensing process is centralized in the very top policy creation level and decentralized in the MRE project application level. Further, there is no well-established MSP in Japan thus the ocean space is basically dominated only by the fisheries. The socio-cultural prominence of fisheries is also significant in Japan than any other cases.

Thus, despite the perception and factors behind local MRE acceptance seem to be different from one case to another (specifically different from Japan to Europe), it is apparent that decision behaviors have some commonalities across regions and different MRE technologies. Preference of different co-existence strategies is difficult to compare with other cases since this type of co-existence options have not been implemented even in matured MRE markets. Only co-existence option which is commonly discussed in previous literature is the co-location of aquaculture with offshore wind farms.

6.4 Importance of this research

This study is the first in-depth analysis of public acceptance and co-existence strategies of MRE projects in Japanese context. This study has found new trends and patterns of public decision making related to MRE acceptance in Japanese context. Those unique findings were explainable by the unique characteristic of Japanese MRE development situation. The recommended co-existence strategy; the ocean information sharing scheme is a novel approach which has a potential to create a win-win situation among local stakeholders which is the underlying success factor of any consensus building strategy. The findings of this study contributes to the seventh SDG related to the renewable energy supply as well as certain aspects of fourteenth SDG related to sustainable ocean use.

This research contributes to the academia by proposing a comprehensive package of methodologies to continue future studies on public acceptance and co-existence strategy evaluations. This is one of few studies which has the selected package of analysis methods such as descriptive statistics, logistic regression, multi-criteria decision making with DS-AHP model, WTP and sensitivity analysis combined for the cost benefit analysis etc. This package of methodologies is robust enough to be used not only in other public acceptance related studies, but also in other disciplines since it gives a holistic assessment on the focused problem. The DS-AHP software is also an important byproduct of this study which is useable for similar studies that need decision making under significant uncertainty and data unavailability.

6.5 Limitations of the research and possible future improvements

Since this is the very first attempt to evaluate the public acceptance and co-existence strategies of MRE projects in Japan, there are several limitations which can be inherent to any initial study. Lack of real commercial project data is the main limitation of the study. However, that is a practical situation in the local context where MRE project developers are also faced with. In addition to being the very first study amidst severe data limitations, indirect relationship between the potential impacts and the proposed co-existence strategies is also an inherent limitation of this study. The best example of this limitation is the difficulty to estimate monetary benefits of the proposed ocean information sharing system without a pilot deployment due to the indirect relationship between the ocean information and its potential industrial or academic benefits. Even though it was possible to estimate the benefit levels by indirect indicators such as current expenditure levels and WTP levels, there was a significant variability even among the key stakeholders on those parameters.

Even though several precautionary actions were taken to minimize the impact of data unavailability and uncertainties, there still exists a significant opportunity to improve the outcomes. Economic feasibility analysis was done without real project data and based on secondary data with lot of assumptions. This limitation could be avoided in the future studies with the availability of real project data. Only limited number of stakeholder interactions and two MRE technologies (offshore wind and tidal) were able to focus in this study. Further the two selected case studies are from the same region (Kyushu region) which might have some bias towards certain socio-economic factors. To overcome the identified limitations following suggestions can be considered in future studies.

Expanding the number as well as the variety of the interview and survey respondents by including other marine sectors, and other regions such as Northern Japan (Aomori, Iwate, Niigata etc.) will improve the reliability and the holistic nature of the research outcomes.

The real impacts of decision behaviors and information availability can be estimated by simulation methods such as agent based modeling (ABM) etc. which is another proposal for future studies. For example, the impact of ocean information availability, on the reduction of travel requirements and productivity improvement of fisheries could be simulated by ABM methods if there is reliable data to initiate a workable model.

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APPENDIXES

Appendix I: Summary of interviews

Stakeholder (group)	Description	Date & place
Consultancy group NaMICPA (n=1)	Future energy consultant co., ltd	26th January, 2017 at Toranomon, Tokyo
NaMICPA (n= 3)	Director, Chief coordinator & Project coordinator	15th March, 2017 in Dejima-chō, Nagasaki
Supplier/Pvt Company (n=1)	Shibuya Diving Co.	
Prefectural government (n=2)	Ocean and environment industry promoting section	15th March, 2017 at Nagasaki prefecture government office
Supplier/Pvt Company (n=2)	Kyowa Kiden Co.	15th March, 2017 in Togitsu cho, Nagasaki
Goto City Office (n=1)	Renewable energy promotion Section	16th March, 2017 in Goto City office
Local fishery unions, (n=1)	Fukue Fishery Union representatives	16th March, 2017 in Fukue
Local fishery unions, (n=2)	Naru Fishery Union representatives	17th March, 2017 in Naru Island
Goto City Office (n=1)	Renewable energy promotion Section	12th March, 2018 in Goto City office
Local fishery unions, (n=1)	Fukue Fishery Union representatives	12th March, 2018 in Fukue
Developer / Private Company (n=1)	Toda Constructions Co.	12th March, 2018 in Fukue
NPO / Researcher / Environmental Monitoring group (n=2)	Marine Fisheries Co-existence Center	12th March, 2018 in Fukue
Local fishery unions, (n=1)	Naru Fishery Union representatives	13th March, 2018 in Naru
NaMICPA (n= 2)	Director, Chief coordinator & Project coordinator	15th March, 2018 in Dejima-chō, Nagasaki
Local fishery unions, (n=3)	Kitakyushu Wakamatsu Fishery Union representatives	17th March, 2018 in Kitakyushu
Opponent groups (n=2)	Shimonoseki opponent group representatives	18th March, 2018 in Shimonoseki
Developer / Utility Company (n=2)	Kyuden Mirai Co.	19th March, 2018 in Fukuoka

Appendix II: Guide questions used in semi structured Interviews

<table>
<tr><th>Interviews / Surveys</th><th>Relation with ongoing MRE projects</th><th>Guide questions for semi-structured interviews</th></tr>
<tr><td>NPO - ‘NaMICPA’ (n=4)</td><td>Engaging local stakeholders with MRE sector</td><td>1. What is the Current level of acceptability and factors underlying the decision, Consensus building process?
2. What are the Existing problems of obtaining/ improving the local acceptance?
3. What is the NaMICPA’s suggestion to achieve social acceptance?
4. What are the success factors which results a better social acceptability in the case of Nagasaki MRE development relative to the other areas in Japan?
5. How are the local stakeholders’ (e.g. Fishermen) acceptance before and after the Offshore wind project testing?
6. What is your idea about the proposed co-existence strategies mentioned in the RIOE report?
7. What will be the future impacts (local level, Nagasaki regional level, National level) of the proposed AMEC (Nagasaki Asia Marine Energy Centre)?
8. Industry specific perceived (-) / (+) impacts of MRE projects and establishment of the AMEC in the Nagasaki area?
9. What can be the learnings from the EMEC (Europe) and what is unique in Nagasaki (Japan) when considering promoting MRE sector in Japan?
10. What is the most effective incentive for the existing industries, (e.g. supply chain of ship building industry) to diversify into MRE sector?</td></tr>
<tr><td>Local city office (n=1)</td><td>Promoting MRE sector & information sharing</td><td rowspan="2">1. What is the Current level of acceptability and factors underlying the decision, Consensus building process and legal situation regarding MRE development?
2. What are the Existing problems of obtaining/ improving the local acceptance?
3. How are the local stakeholders’ (e.g. Fishermen) acceptance before and after the Offshore wind project testing?
4. What are the prefecture government’s policy on improving the local acceptability on MRE in the Nagasaki prefecture?
5. What are the expected positive and negative local impacts of the Nagasaki AMEC?
6. What can be the learnings from the EMEC (Europe) and what is unique in Nagasaki (Japan) when considering promoting MRE sector in Japan?
7. What is the most effective incentive for the existing industries, (e.g. supply chain of ship building industry) to diversify into MRE sector?
8. What is your idea about the proposed co-existence strategies mentioned in the RIOE report?</td></tr>
<tr><td>Prefectural government (n=2)</td><td>Policy guidance</td></tr>
</table>

Local fishery unions, (n=8)	Key stakeholder in consensus building process	1. What is your current opinion about the ongoing MRE developments? 2. What are the reasons for your decision? 3. What is the situation in the marine environments before and after the demonstration pilot projects? 4. From where did you get the background information? How often have you interact with the project developers? 5. What is the situation of local fishing industry? Fishing methods? Areas? Economics? 6. What are the success factors which results a better social acceptability in the case of Nagasaki MRE development relative to the other areas in Japan? 7. What can be the co-existence options suitable according the local conditions? 8. What is your idea about the proposed co-existence strategies mentioned in the RIOE report? 9. Do you think MRE industry and Fishing industry can create a sustainable co-existence in Japan? 10. What are the existing information relevant to evaluate the potential of proposed co-existence options?
Researchers, Environmental monitoring groups, (n=2)	Environmental impact monitoring of demonstration MRE projects / EIA for proposed MRE projects	1. What is the situation in the marine environments before and after the demonstration pilot projects? 2. What can be the co-existence options suitable according the local conditions? 3. What is your idea about the proposed co-existence strategies mentioned in the RIOE report? 4. What are the existing information relevant to evaluate the potential of proposed co-existence options?
Opponent groups (n=2)	Demonstrators against the proposed projects	1. What is your current opinion about the ongoing MRE developments? 2. What are the reasons for your decision? 3. From where did you get the background information? How often have you interact with the project developers?
Developers, Utility Co., & Supplier/Pvt. Companies (n=6)	Potential key supplier in future MRE projects	1. What are the possible positive and negative implications of the development of the MRE sector in your region, for your company and other regional Industries? 2. What are the main problems of achieving stakeholder acceptance for MRE sector? 3. What are the options that MRE sector can be integrated with the existing regional industries? 4. What is your idea about the proposed co-existence strategies mentioned in the RIOE report? 5. What are the positive and negative factors MRE industry face in Nagasaki area in contrast to the other regions in Japan?

Appendix III: Preliminary Survey

長崎における
海洋再生可能エネルギープロジェクトの
社会経済的側面および実証地発展に関するアンケート

回答は任意であり、また回答内容の個人情報等の秘密は保持致します。
頂いた回答は環境問題およびその他の問題解決に役立てられます。

また回答は無作為標本として扱われ、頂いた回答内容と回答者様の個人を結びつけて扱われることは有りません。 ご理解とご協力をありがとうございます。

東京大学
サスティナビリティ学
グローバルリーダー養成大学院プログラム

Full survey is available upon request.

Appendix IV: Administered Fishery Survey

洋上風力発電事業に関するアンケート

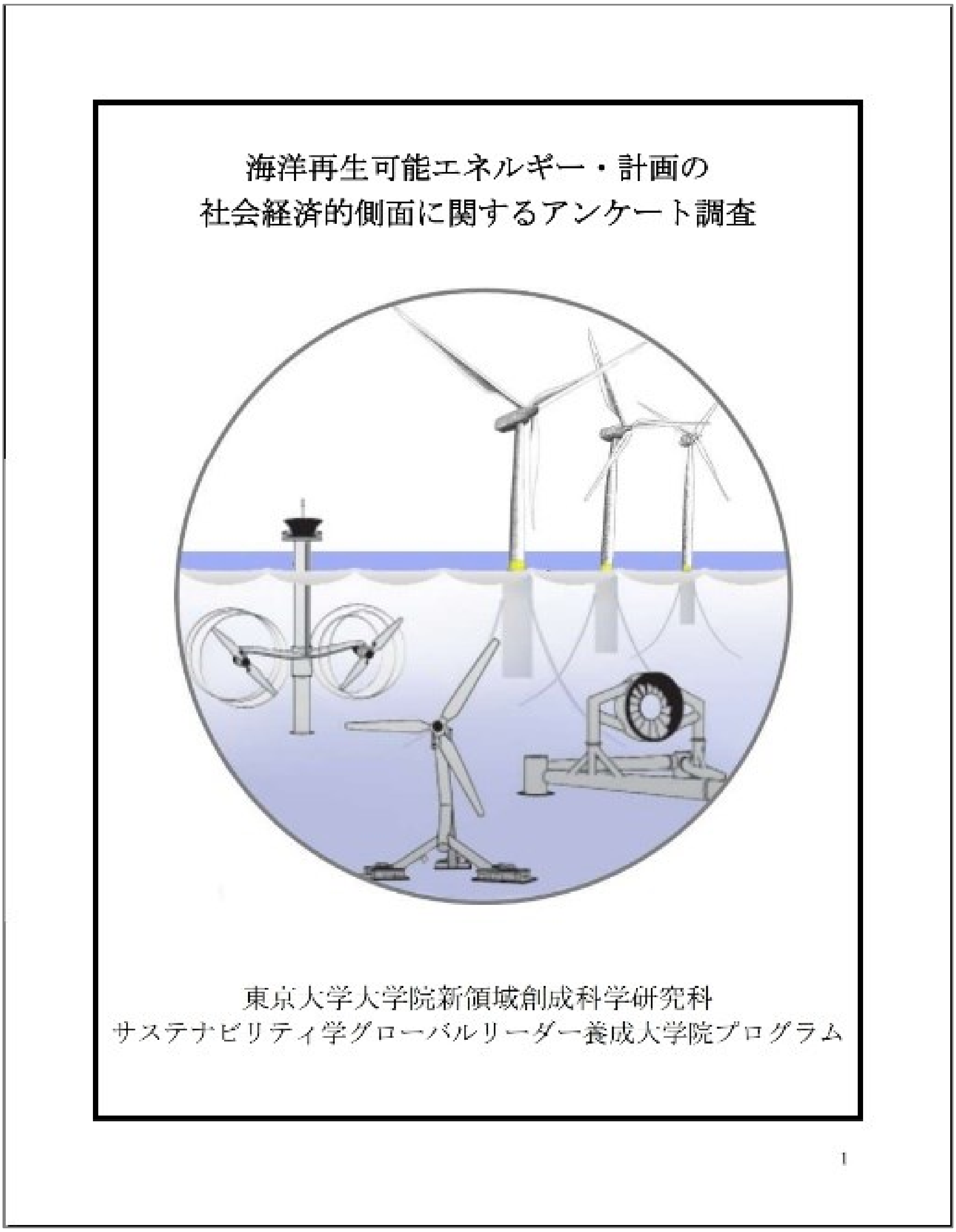
回答は任意であり、また回答内容の個人情報等の秘密は保持致します。
頂いた回答は環境問題およびその他の問題解決に役立てられます。

***また回答は無作為標本として扱われ、頂いた回答内容と回答者様の個人を結びつけて扱われることは有りません。
ご理解とご協力をありがとうございます。***

東京大学大学院新領域創成科学研究科

Full survey is available upon request.

Appendix V: Postal Survey



海洋再生可能エネルギー・計画の
社会経済的側面に関するアンケート調査

東京大学大学院新領域創成科学研究科
サステナビリティ学グローバルリーダー養成大学院プログラム

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Full survey is available upon request.

Appendix VI: Data provided to conduct the 'Between group experiment'

G1- Project information for Kitakyushu respondents

福岡県における海洋再生可能エネルギー・プロジェクトについて

福岡県は、日本の海洋再生可能エネルギー・プロジェクトの先端を担っています。2012 年より、北九州市と新エネルギー・産業技術総合開発機構（NEDO）は海上風力発電の環境影響評価や実現性の試験を行ってきました。同年 6 月には、国内初の洋上風力観測塔が市内に建設され、10 月より観測が始まりました。そして 2013 年 3 月には風車が完成し、同年 6 月より運行が開始されました。


環境影響評価


土台の建設


観測塔の建設


海底ケーブルの設置


風車の建設


配送電施設の建設


運転の様子

試験的運用の結果、北九州は風力発電の初の商業的利用に向けて準備が進んでいます。2017 年 2 月には、九電みらいエナジー、九州電力、北拓、J-Power、西部ガスの協力により、響灘港の沖合で風力発電が行われることが北九州市により発表されました。その直後、44 基の風車からなる響灘洋上風力発電施設を運営すべく、ひびきウインドエナジー社が設立されました。

G1- Project information for Nagasaki respondents

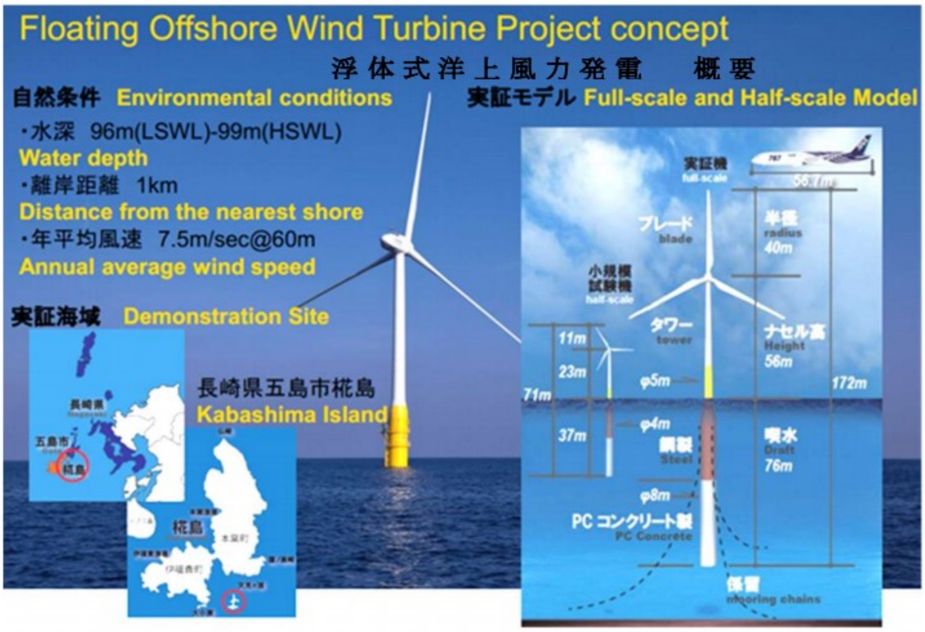
長崎県における海洋再生可能エネルギー・プロジェクトについて

長崎県は、日本の海洋再生可能エネルギー開発をリードしている県の１つです。福江島では、国内で初めての配電網付き海上風力タービンの運用実験が環境省によって行われました。波力発電の実験も同様に行われる予定です。海洋エネルギーの試験所も同地域に設置される予定であり、地域の発展に寄与する可能性があります。

長崎県、企業、長崎海洋産業クラスター形成推進協議会(NaMICPA)と複数の大学の協力による洋上風力発電と潮力発電の開発計画も進められています。

過去の実験と今後の計画の概要

浮体式洋上風力発電



環境省は日本初のフルスケール(2MW)浮体式洋上風力タービンを実証中です。ハーフスケールのものは 2012 年度において実験的導入がなされ、2013 年度にフルスケールモデルが椛島において導入されました。

試験的運用が成功を収めて以降、複数の企業が同地での商業的発送電に興味を示しており、長崎県は日本で初の海洋再生可能エネルギーを商業的に利用する県となることが見込まれています。

潮流発電

潮流発電は、潮流の運動エネルギーを利用して発電する方式です。潮流は、潮の干満（潮汐）によって規則的に流れるため発電量が予測可能であり、信頼性の高いエネルギー源として注目されています。

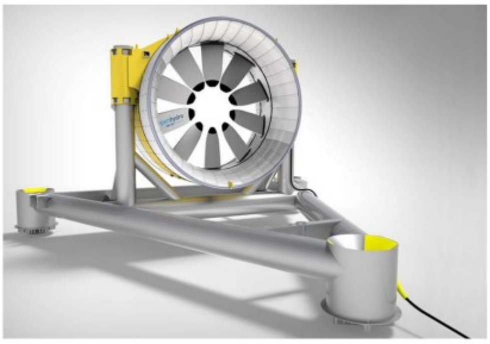
特徴

潮の干満は規則性を持っており予測が可能、発電機は海中にあるため視覚的・聴覚的な影響が小さい（環境負荷が少ない）、海水の流れを使うため燃料費が不要（持続可能なエネルギー）、水は空気に比べ約８３０倍の密度を有し風力発電に比べてローター径が小さく設備がコンパクト、稼働率が比較的高い（１日４回の干満による流れがあること、一度設置すると数年間稼動可能、台風などの影響を受けない）等の特徴があります。

発電システム

- 国内初となる大規模な MW 級（ 単機あたりでは世界最大級） の実証にあたり、 潮流発電の分野で先行している欧州の Openhydro 社の発電機を採用。

- フランスから OpenHydro 社製の発電機を輸送し、 日本にて新日鉄住金エンジニアリングが製作した支持構造物に取り付ける。 発電機は単純化された構造が特徴。



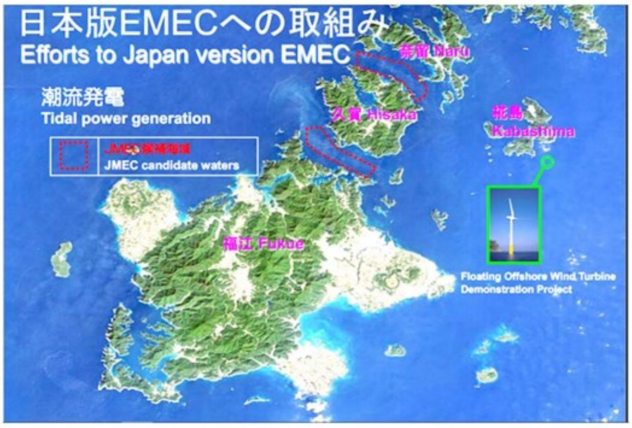
基本仕様

型式　：センターオープン方式
形式　：海底設置型
出力　：2MW
直径　：約 16m
高さ　：約 27m
重量　：約 1200 トン
回転数：10 ～ 16/ 分

Source: http://www.q-mirai.co.jp/news/archives/60
http://www.q-mirai.co.jp/renewables/explanation/tidal_power/

調査開発の状況

長崎県は海洋再生可能エネルギー実証地の開発を計画し、以下の五島列島の区域において調査開発を実施しています。実証地開発においては 2020 年までに 50 の雇用創出と一定数の訪問客を確保することが期待されています。



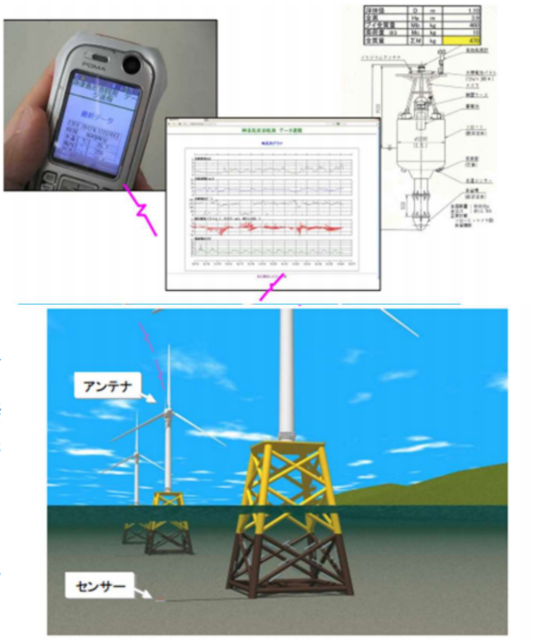
海洋再生可能エネルギー・プロジェクトの付加価値

海洋再生可能エネルギー・プロジェクト（以下、MRE）が持つ本来の目的は、海の力を利用して持続可能な発電を行うことです。しかし、MRE はこれと同時に、地域コミュニティにとって有益な効果をいくつかもたらす可能性、いわゆるプロジェクトの「付加価値」を持っています。ヨーロッパの事例研究では、以下のような付加価値の存在が認められました。

1. リアルタイムでの海況情報の提供

現在、海況情報のほとんどは人口衛星による観測から得られています。また、局地的な情報は浮のセンサーから取得されています。しかし、前者は広範囲を確認できる代わりに情報の密度が粗く、後者からの情報は濃い反面、狭い領域しか扱えません。

MRE の設備が設置されれば、設備維持のために取り付けられるセンサーを利用して、追加的な海況情報を取得することが可能になります。しかも、タービンと陸を接続する海底ケーブルを通して、それらの情報を送信することができます。つまり MRE の発電設備は、リアルタイムの海況情報を取得するための設備としても利用することも可能になります。

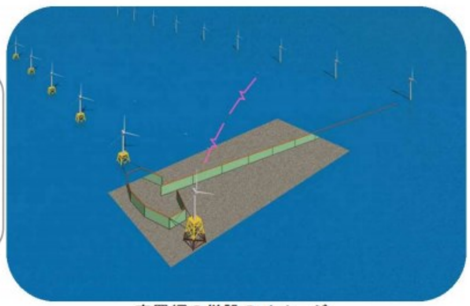


リアルタイム海況データ提供システムのイメージ

2. 漁業への海洋再生可能エネルギー設備・施設の活用

タービンを支えるための海面下の構造物は、人口の礁として役立てることができま、漁用の網や養殖用の囲いの設置に活用することができます。通常では高くつくこうした構造物ですが、MRE を利用することで、追加コストを極限まで抑えつつ、漁業活動を拡大することが可能になります。

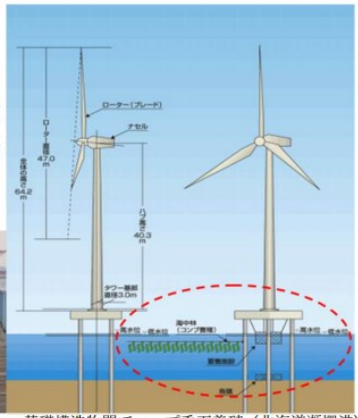

（例）風車基礎部の人工魚礁化と漁業操業（刺網）のイメージ


定置網の併設のイメージ

3. 養殖、観光・レジャーと連携した空間土地利用

現段階において MRE は非常に珍しいものです。計画次第では、観光資源として活用することもできます。発電設備を上手く設計することで、海洋レジャー施設や養殖施設として併用することが可能になります。

【海釣り公園の整備例】



基礎構造物間でロープ垂下養殖（北海道瀬棚港）
（出典 NEDO ホームページより）

4. 発電した電力の沿岸部における共有

周辺の島々は独自に発電を行っていないので、MRE によって得られた電気を共有することは、電気代の削減に繋がる可能性があります。特に、沿岸地帯の加工場や電動の船舶などを稼働するために、電力を安く供給できる可能性があります。

漁港のエコ化実証実験（長崎県対馬市豆酘漁港）、東京海洋大学、平成 23 年 7〜10 月
（ここでは太陽光発電との組み合わせも示されている。）
（出典 http://www2.kaiyodai.ac.jp/~takamasa/kaiyodai-ees-project/kaiyodai-ees-project23-3.html）

5. 海洋再生可能エネルギープロジェクトの建設と操業における地域資源（インフラや人材など）の活用

MRE 建設や運用には、漁業関係者が利用している船舶、造船施設、船着き場などを活用できる可能性があり、新たに雇用を生む機会となり、沖合での施設建築に関連する業者を呼び込むことも、地域経済にとって利点となり得ます。海洋資源利用者にとっては雇用機会を多様化することにつながり、漁船やフェリーを用いて調査、建設、修繕などの仕事を得ることができるようになります。

（出典: http://www.rioe.or.jp/0510teigen.pdf）

G3- Adjustments needed and potential negative information

海洋再生可能エネルギー産業の開発を地域コミュニティの便益を両立させるために必要な施策について

海洋再生可能エネルギー（以下、MRE）産業を日本の沿岸地域に根付かせるためには、開発者による運営に適した環境を整える必要があります。いかなるテクノロジーも、初期の段階では高額になりますが、MRE の開発者もプロジェクトの当初においては相当の支援を必要とします。一方、ヨーロッパで既に見られるとおり、この産業が定着するにつれ、必要なコストも徐々に下がっていくことが見込まれます。

日本における MRE 産業は最も初期の段階にあるため、金銭面における十分な公的支援や、海洋に関する政策の変更、沿岸地域の社会経済的変化を必要としています。

最も重要な施策は MRE プロジェクトに必要な空間の提供ですが、これは船舶の往来や漁業など、従来における海洋利用のあり方への変化を伴います。よって、地域コミュニティ全体にとっての利益を確保するために、海洋や沿岸に関わる各産業間の協調や協力が必要になってきます。また、MRE 産業の開発に伴う設備の建設や、これに付随する新しいビジネスの発展は沿岸地域の景観を変容させるため、沿岸地域の活動に関する一般社会の認識も変化する可能性があります。

Appendix VII: MCA sheet

1. ５つの選択肢を評価する上で、重要だと思われる指標を挙げて下さい。また、各選択肢の有無に応じた指標の値を予想し、現在値と並べて記入して下さい。

選択肢 1 : リアルタイムでの海況情報の提供		単位	現在値	計画導入後の各指標の予想値	
				選択肢 1 あり	選択肢 1 なし
指標	漁業を行える年間の日数	日			
	支払っている保険料	円			

選択肢 2 : 漁業への海洋再生可能エネルギー設備・施設の活用		単位	現在値	計画導入後の各指標の予想値	
				選択肢 2 あり	選択肢 2 なし
指標	漁業設備・施設のコスト	円			
	漁業の生産高	円			

選択肢 3 : 養殖、観光・レジャーと連携した空間土地利用		単位	現在値	計画導入後の各指標の予想値	
				選択肢 3 あり	選択肢 3 なし
指標	年間所得	円			

選択肢 4 : 発電した電力の沿岸部における共有		単位	現在値	計画導入後の各指標の予想値	
				選択肢 4 あり	選択肢 4 なし
指標	電気代	円			

選択肢 5 : 海洋再生可能エネルギー計画の建設と操業における地域資源(インフラや人材など)の活用		単位	現在値	計画導入後の各指標の予想値	
				選択肢 5 あり	選択肢 5 なし
指標	雇用	人			

Appendix VIII: DS-AHP Evaluation sheet

計画を評価するにあたり、「経済的な費用と利益」、「環境への影響」、「関係者の協力と損益の公平分配」という３つの価値は、それぞれお互いと比べて比べてどの程度重要だと思われますか？次の２つの記入例を参考にご回答ください。

記入例 1

「経済的な費用と利益」が「環境への影響」と比べて極めて重要である場合

より重要 ← 同程度 → より重要

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

経済的な費用と利益 | 環境への影響

「環境への影響」が「経済的な費用と利益」と比べて多少重要である場合

より重要 ← 同程度 → より重要

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

経済的な費用と利益 | 環境への影響

記入例 2

「環境への影響」が「関係者の協力と損益の公平分配」と比べて極めて重要である場合

より重要 ← 同程度 → より重要

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

環境への影響 | 関係者の協力と損益の公平分配

「関係者の協力と損益の公平分配」が「環境への影響」と同程度重要である場合

より重要 ← 同程度 → より重要

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

環境への影響 | 関係者の協力と損益の公平分配

ご回答

より重要 ← 同程度 → より重要

9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9

経済的な費用と利益 | 環境への影響

経済的な費用と利益 | 関係者の協力と損益の公平分配

環境への影響 | 関係者の協力と損益の公平分配

前の質問で取り上げた３つの価値に対して、以下の５つの選択肢がどれほど好ましいと思われるか、下記の２つの記入例を参考にご回答ください。

*ある項目の判断にあたり十分な情報を得られていないと考える場合、空欄のままで構いません。

それぞれの視点から各項目を７段階で評価してください。

1 好ましくない	2 ⇔	3 どちらかといえば好ましくない	4 ⇔	5 好ましい	6 ⇔	7 とても好ましい

記入例

項目	A リアルタイムでの海況情報の提供	B 漁業への海洋再生可能エネルギー設備・施設の活用	C 養殖、観光・レジャーと連携した空間土地利用	D 発電した電力の沿岸部における共有	E 海洋再生可能エネルギー計画の建設と操業における地域資源(インフラや人材など)の活用
評価 (1~7)	4	2	5		7

＊個別の評価が難しい場合は、複数の項目をまとめて評価してください
（例：B, D. E が A, C より好ましいと思われる場合）

グループ	A-C	B-D-E			
評価	2	5			

「経済的な費用と利益」の視点から各項目を評価してください。

項目	A リアルタイムでの海況情報の提供	B 漁業への海洋再生可能エネルギー設備・施設の活用	C 養殖、観光・レジャーと連携した空間土地利用	D 発電した電力の沿岸部における共有	E 海洋再生可能エネルギー計画の建設と操業における地域資源(インフラや人材など)の活用
評価 (1~7)					

グループ					
評価 (1~7)					

「環境への影響」の視点から各項目を評価してください。

項目	A リアルタイムでの海況情報の提供	B 漁業への海洋再生可能エネルギー設備・施設の活用	C 養殖、観光・レジャーと連携した空間土地利用	D 発電した電力の沿岸部における共有	E 海洋再生可能エネルギー計画の建設と操業における地域資源(インフラや人材など)の活用
評価 (1~7)					

グループ					
評価 (1~7)					

「関係者の協力と損益の公平分配」の視点から各項目を評価してください。

項目	A リアルタイムでの海況情報の提供	B 漁業への海洋再生可能エネルギー設備・施設の活用	C 養殖、観光・レジャーと連携した空間土地利用	D 発電した電力の沿岸部における共有	E 海洋再生可能エネルギー計画の建設と操業における地域資源(インフラや人材など)の活用
評価 (1~7)					

グループ					
評価 (1~7)					

Appendix IX: Stakeholders' ocean information requirement survey

Q1. What ocean information is required for your operational and planning activities? Please fill the following table in the order of parameter preference. (Index for the parameters and its qualities are in the second sheet table 1&2) (あなたの操業や計画には、海の状態に関するどのような情報が必要ですか。下記の項目のそれぞれについて、その重要性を選択して下さい。)

Q2. What kind of information sources or sensors do you use currently for your operational activities? At what cost?　E.g. GPS systems (もし自分たちで情報を収集している場合、そうするために全体でいくら投資しましたか。例)GPS、航路ナビなど)

Q3. What is the cost of getting the above data if you can get it from the market? (現在､企業や研究機関から毎日の活動に情報を得ていますか？もしそうである場合､いくら支払っていますか。)

Q4. What is the most that you would be prepared to pay for getting the specified ocean information as a data set / downloadable package?　(将来、もしすべての項目の情報が手に入るとしたら最大いくらなら支払ってもよいと思いますか。)

Stakeholders Ocean information requirement survey

	1	2	3		4		5		6		7		8		9		10		11		12
	Parameter Category (Table 2) 情報群（表 2）	Parameter (Table 2) （情報）（表 2）	Coverage （モニターされる範囲）	Grade（順位）	Product Type 情報の種類	Grade（順位）	Accuracy（正確性　）	Grade（順位）	Temporal resolution （モニターされる頻度）（毎）	Grade（順位）	Spatial resolution （モニターされる地点の間隔）	Grade（順位）	Vertical resolution （モニターされる水深の間隔（毎））	Grade（順位）	Forecast period （観測期間） （対象とする期間）	Grade（順位）	Latency　（待機時間） （情報が得られるまでの期間）	Grade（順位）	Delivery medium （配信媒体）	Grade（順位）	Other Comments （その他注釈）
1																					
2																					
3																					
4																					
5																					
6																					
7																					

<u>Grading Instructions</u>

Blank（空白）- Not Useful　（まったく役に立たない）

1- Might have some occasional use.　（時々使用するかもしれない）

2- Might be useful, but it falls short of what we need
（役に立つかもしれないが、本当とする必要な情報ではない）

3 - Useful product.　（役に立つ情報である）

4 - Good product which would be very useful.（とても役に立ちそうである）

5 - Ideal product which would meet the highest requirements
（必要な情報であり、得られたら理想的である）

Source: Made by the author based on Fischer & Flemming (1999)

Table 1 – List of Parameters (表 1 - 情報)

(1) Surface level information ("海面に関する情報)	(2) Surface Topography information (海面の形状)	(3) Upper Ocean Information (海中)	(4) Sea Ice Information (海氷)
1.1 Sea Surface Temperature (海面の温度)	2.1 Hourly Mean Sea Level (海面の高さ（毎時間))	3.1 XBT_ Depth wiseTemp Distr (海中温度の分布)	4.1 Extent, Boundary, Leads % (海氷が占める面積%)
1.2 Sea Surface wind (海面の風力)	2.2 Marine geoid (海域ジオイド)	3.2 XCTD sections (XCTD_ Depth wise CTD Distr)	4.2 Concentration/Density (密度)
1.3 Wind velocity (風速)	2.3 Monthly mean sea level (海面の高さ（毎月))	3.3 Upper ocean heat content (上層海洋熱容量)	4.3 Surface Ice state (表面海氷の状態)
1.4 Wind Direction (風向き)	2.4 Sea level anomaly (海面高度アノマリ)	3.4 Upper ocean salinity (塩度)	4.4 Surface Ice Roughness (氷の硬さ)
1.5 Heat Flux (熱流速 熱流束)	2.5 Oceanic Tides (海面の潮流)	3.5 Upper ocean fresh water % (淡水が占める割合)	4.5 Ice Thickness (氷の厚さ)
1.6 Moisture Flux (湿流)	2.6 Geostrophic currents (地衝流)	3.6 Upper ocean heat transport (熱輸送)	4.6 Ice surface temperature (氷の表面の温度)
1.7 Precipitation (降水量)	2.7 Meteorological forcing (気象関連の力)	3.7 Fresh water transport (淡水輸送)	4.7 Air, Sea & Ice temp (気温、海中の氷の温度)
1.8 Sea surface Salinity (海面の塩度)		3.8 Salt transport (塩分輸送)	4.8 Ice motion (氷の動き)
1.9 Wave spectrum (波浪スペクトル)		3.9 Salt flux (塩分フラックス)	4.9 Albedo, Reflection coefficient (反射能)
1.10 Wave direction spectrum (波浪方向スペクトル)		3.10 Buoyancy Flux (浮力フラックス)	4.10 Snow on ice (氷上の降雪量)
1.11 Wave Heights (波の高さ)		3.11 Upper Ocean Current Speed (海流流速)	4.11 Water on ice (氷上の水量)
1.12 Wave Period (波周期)		3.12 Ocean Currents (海流)	
1.13 波のうねり (Wave Swell)		3.13 Upwelling velocity (上昇流の流速)	
1.14 Sea surface CO_2 (海面の二酸化炭素量)		3.14 Downwelling Velocity (下降流の流速)	
1.15 Sea surface GHGs (海面の温室効果ガス量)		3.15 Eddies, Jets & Fronts (渦流，ジェット，フロント)	

Table 1 – List of Parameters (Continued)

(5) Ice shelves Information (棚氷)	(6) Icebergs Information (氷山)	(7) Deep Ocean Information (深海)	(8) Seabed information (海底の状態)
5.1 Surface area (表面積)	6.1 Numbers (数)	7.1 CTD sections (電気伝導度、温度、水深)	8.1 Bathymetry (海底地形)
5.2 Topography (地形)	6.2 Distribution (分布)	7.2 Ocean Salinity (深海塩度)	8.2 Surface outcrops (地面の露出の割合)
5.3 Hardness (硬さ)	6.3 Trajectories (軌道)	7.3 Carbon Storage (炭素量)	8.3 Surface sediments (表層体積物)
5.4 Surface condition (表面の状態)	6.4 Area, Volume (面積・体積)	7.4 Ocean tracers (海洋トレーサー)	8.4 Gridded bathymetry (グリッド化的な海底地形)
5.5 Bottom Topography (底面の形状)		7.5 Deep Ocean Currents (深海海流)	8.5 Gravity (重力)
5.6 Snow line (凍結線)			8.6 Magnetics (磁気)
5.7 Albedo, Reflection coefficient (反射能)			8.7 Heat flow (熱流)
5.8 Surface Temperature (表面温度)			
5.9 surface Ice velocity (移動する速度)			
5.10 Sub-shelf ocean circulation (サブ大陸棚海洋循環)			

Table 1 – List of Parameters (Continued)

(9) Coastal & Shelf information (海岸/大陸棚)	(10) Bio-Chemical Information (生物化学的情報)	(11) Optics (光学)	(12) Acoustics (音響学)
9.1 Coastline map (海岸線地図)	10.1 Chlorophyll (葉緑素)	11.1 Incident light spectrum (入射光スペクトル)	12.1 Sound velocity profiles (音速プロファイル)
9.2 Hinterland topography (ヒンターランド地形)	10.2 Nitrate (硝酸塩)	11.2 Depth of photic zone (透光層の水深)	12.2 Sound ray paths (音線経路)
9.3 Coastal bathymetry (海岸線地形)	10.3 Phosphate (リン酸塩)	11.3 Transmissivity (透過率)	12.3 Acoustic scattering (音波の散乱)
9.4 Shelf bathymetry	10.4 Oxygen	11.4 Phosphorescence	12.4 Reverberation characteristics

(大陸棚地形)	(酸素)	(リン光)	(残響特性)
9.5 Tidal constants (潮汐調和常数)	10.5 Silicate (ケイ酸塩)	11.5 Secchi disk depth (透明度)	12.5 Ambient noise spectrum (背景雑音スペクトル)
9.6 Tidal ellipses (潮流楕円)	10.6 Iron (鉄)	11.6 Bioluminescence (生物発光)	12.6 Anthropogenic noise (人為的ノイズ)
9.7 Stratification (層化)	10.7 Biological pigment (生物色素)		12.7 Acoustic tomography (音響トモグラフィー)
9.8 River runoff (河川流出)	10.8 Pathogens (病原体)		
9.9 Land non-river runoff (非河川流出)	10.9 Suspended Sediments (浮遊堆積物)		
9.10 Sediment transport (土砂流送)	10.10 Artificial radionuclides (人工放射性核種)		
9.11 Wetlands characteristics (湿地情報)	10.11 Petroleum hydrocarbons (石油性炭素水素)		
	10.12 Pesticides & Herbicides (害虫駆除剤/ 除草剤)		
	10.13 Trace metals (微量金属)		
	10.14 Pharmaceutical wastes (薬物廃棄物)		
	10.15 Phytoplankton (植物プランクトン)		
	10.16 Zooplankton (動物プランクトン)		
	10.17 CO_2 amount (二酸化炭素量)		
	10.18 Tritium (トリチウム)		
	10.19 Marine toxins (海中の毒素)		

Source: Made by the author based on Fischer & Flemming (1999)

Table 2 – Data Quality levels (表 2- 情報の質)

Coverage (モニターされる範囲)	Product Type (情報の種類)	Accuracy (正確性)	Temporal resolution (モニターされる頻度)(毎)
1.1 Ocean basin (海底盆地)	1.2 Raw data (そのままの情報)	1.1 0.01%	1.1 1 hr (1 時間)
1.2 Coastal seas (沿岸部)	1.3 Processed (処理済みの情報)	1.2 0.1%	1.2 6 hr (6 時間)
1.3 Estuarine (河口部)	1.4 Forecast (予報)	1.3 1%	1.3 1 day (1 日)
	1.5 Nowcast (リアルタイムの情報)	1.4 10%	1.4 10 days (10 日)
	1.6 Statistics (統計)	1.5 20%	1.5 1 month (1 ヵ月)
		1.6 30%	1.6 3 months (3 ヵ月)
			1.7 1 yr (1 年)
			1.8 3 yr (1 年)

Table 2 – Data Quality levels (Continued)

Spatial resolution 空間分解能 (モニターされる地点の間隔)	Vertical resolution モニターされる水深の間隔(毎)	Forecast period 観測期間 (対象とする期間)	Latency 待機時間 (情報が得られるまでの期間)	Delivery medium 配信媒体
1.1 Less than 0.5 km (0.5 km 以下)	1.1 1 m	1.1 10 days (10 日)	1.1 Realtime (リアルタイムの情報)	1.1 Internet (インターネット)
1.2 0.5 km	1.1 10 m	1.2 30 days (30 日)	1.2 6 hour (6 時間)	1.2 Hardcopy (紙媒体)
1.3 1 km	1.2 50 m	1.3 3 months (3 ヵ月)	1.3 12 hours (12 時間)	1.3 FAX (ファックス)
1.4 10 km	1.3 100 m	1.4 1 year (1 年)	1.4 1 day (1 日)	1.4 Email (電子メール)
1.5 100 km	1.4 500 m	1.5 10 years (10 年)	1.5 5 days (5 日)	1.5 EDE
1.6 500 km	1.5 1000 m		1.6 10 days (10 日)	1.6 *other (その他)
1.7 1000 km			1.7 1 month (1 か月)	

Source: Made by the author based on Fischer & Flemming (1999)

* Please specify the others

Appendix X: DS-AHP Software

General description

This software tool has been developed using C# programing language on .net 4.5 framework using the Microsoft visual studio 2010™ software development tool. This software has six basic modules i.e. user management, DS-AHP problem set up, criteria evaluation, scenario evaluation, decision aggregation, and results display. All the user inputs are being saved to a local database (SQL Server Compact 3.5) and calculations are performed on demand and results are passed to the subsequent calculations or the final results display module. According to the latest version, only two decision hierarchy levels can be handled (criteria level and scenario level). Currently this tool can be considered as single user PC application. However, basic design can facilitate the future development up to a web based application where multiple decision makers can participate in the group decision making scenario online.

Installation guide

Prerequisites: dot net framework 4 or above
SQL server compact edition

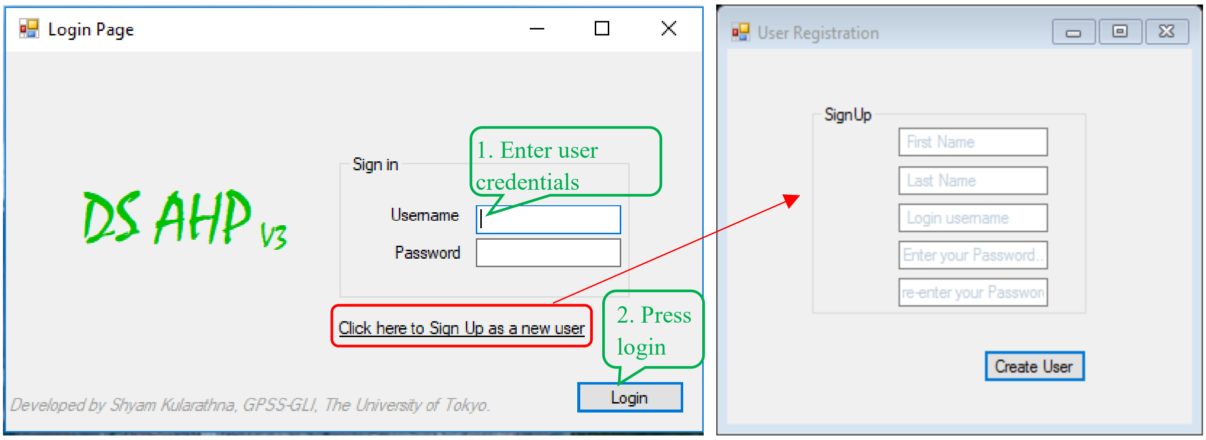
A test version is available upon request

Basic steps of using this software can be described as follows.

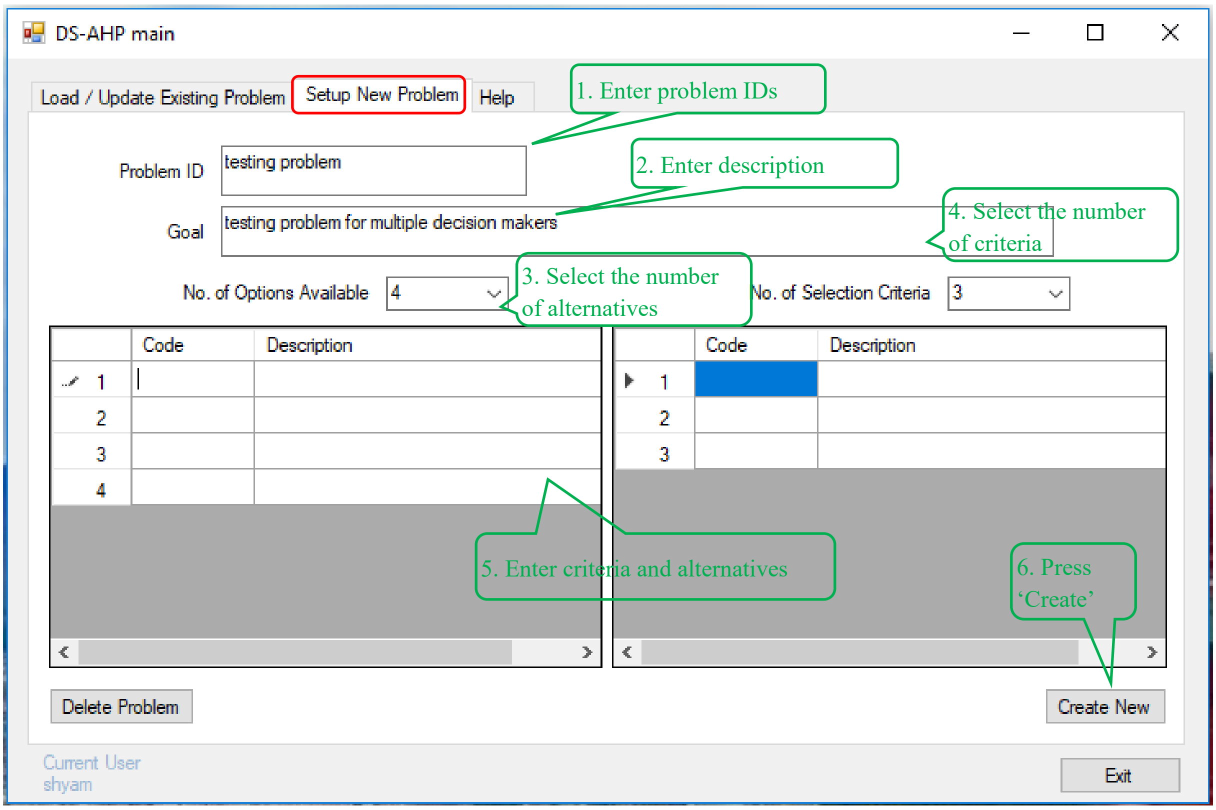
Work flow

Step 1: User registration and authentication

All the user inputs are being saved with the UserID (decision maker ID). Hence user login is required at the beginning. New users can sign up by clicking on ‘sign up as new user?’ label.

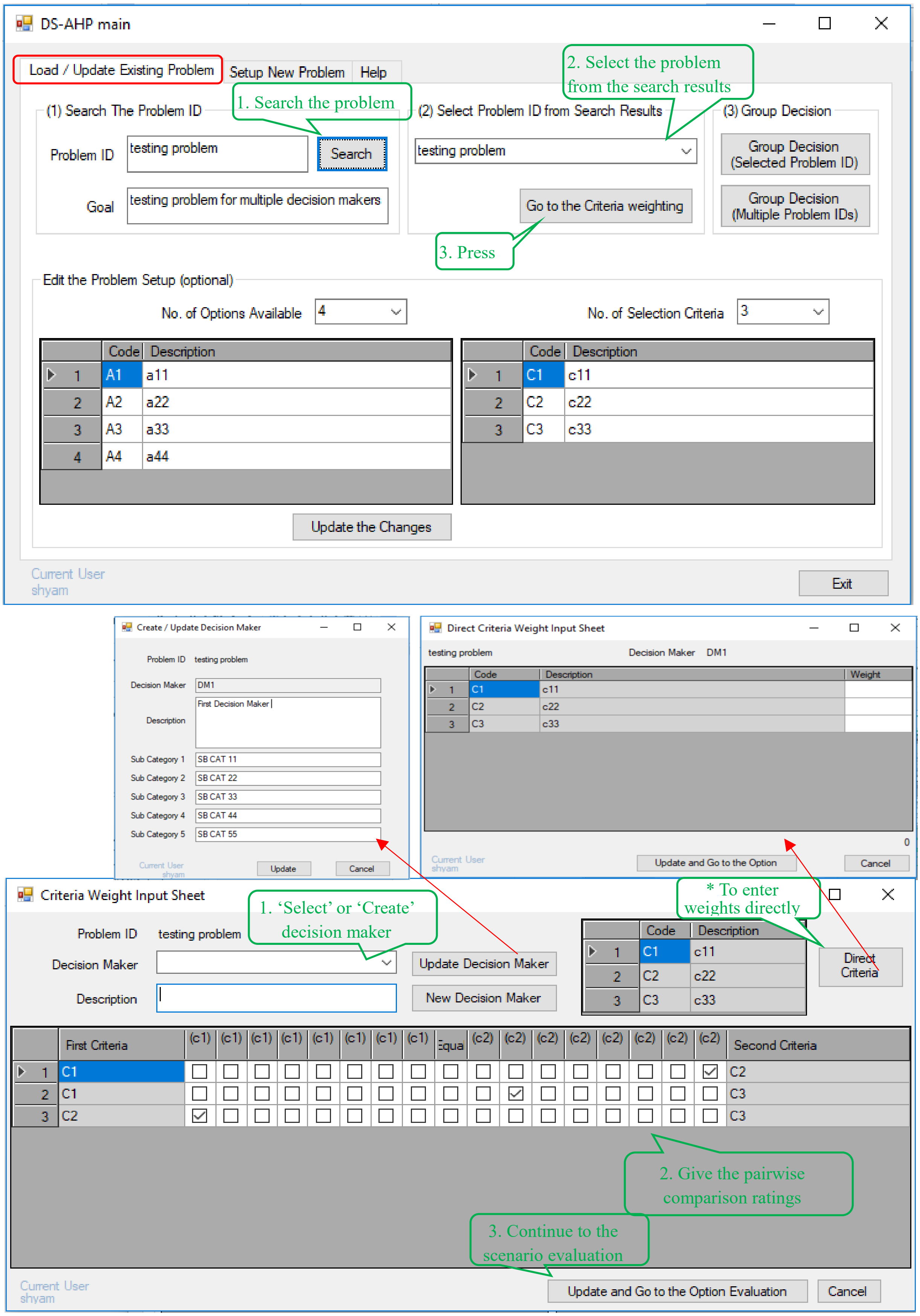


Step 2: Setting up the decision criteria and scenarios (two level decision hierarchy)

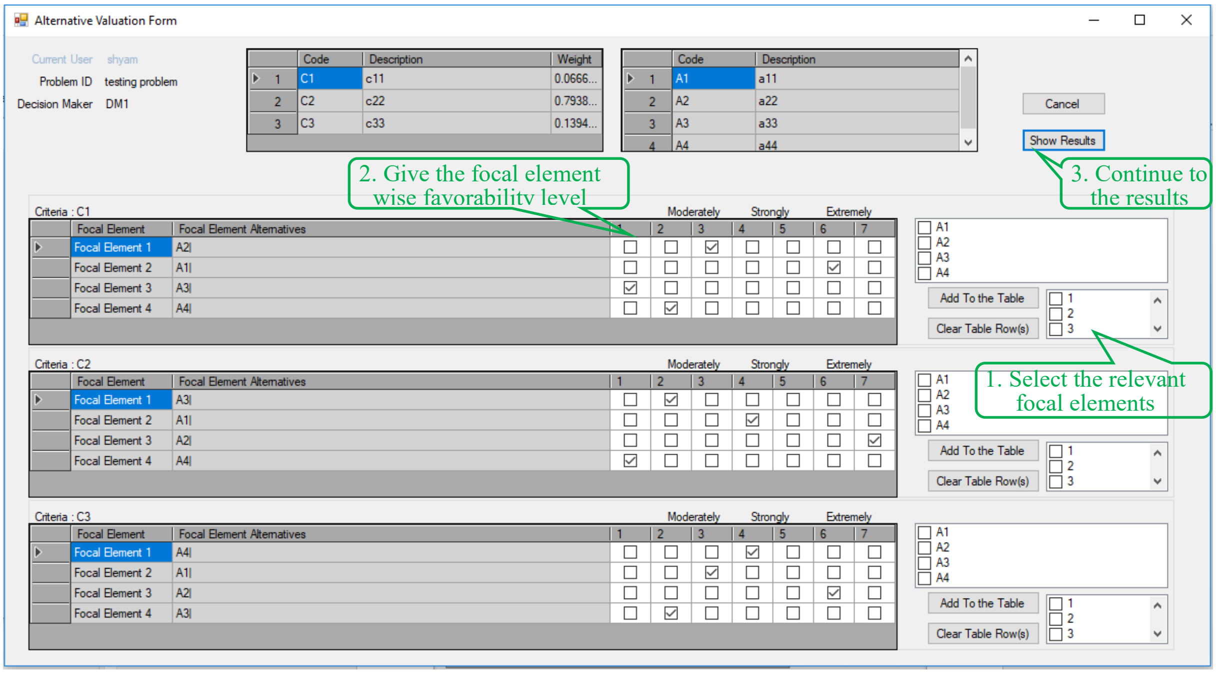


After login to the system, users can create decision hierarchy by the second tab of the subsequent window.

Step 3: Selecting the problem and giving the criteria evaluation

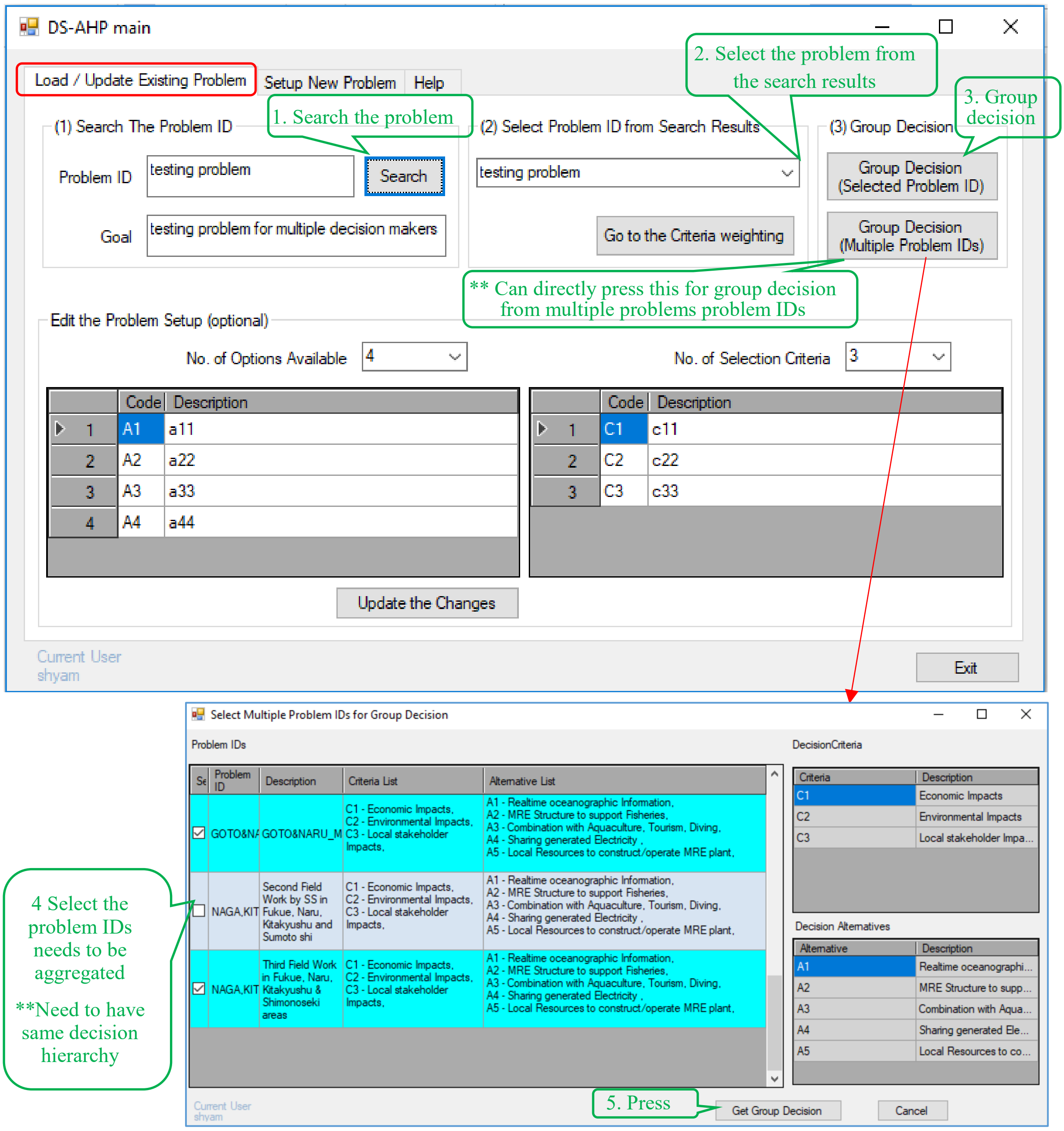


Step 4: Selecting the scenarios which can be evaluated for each criteria and giving a criteria wise preference level for the selected scenario or group of scenarios (Focal elements)

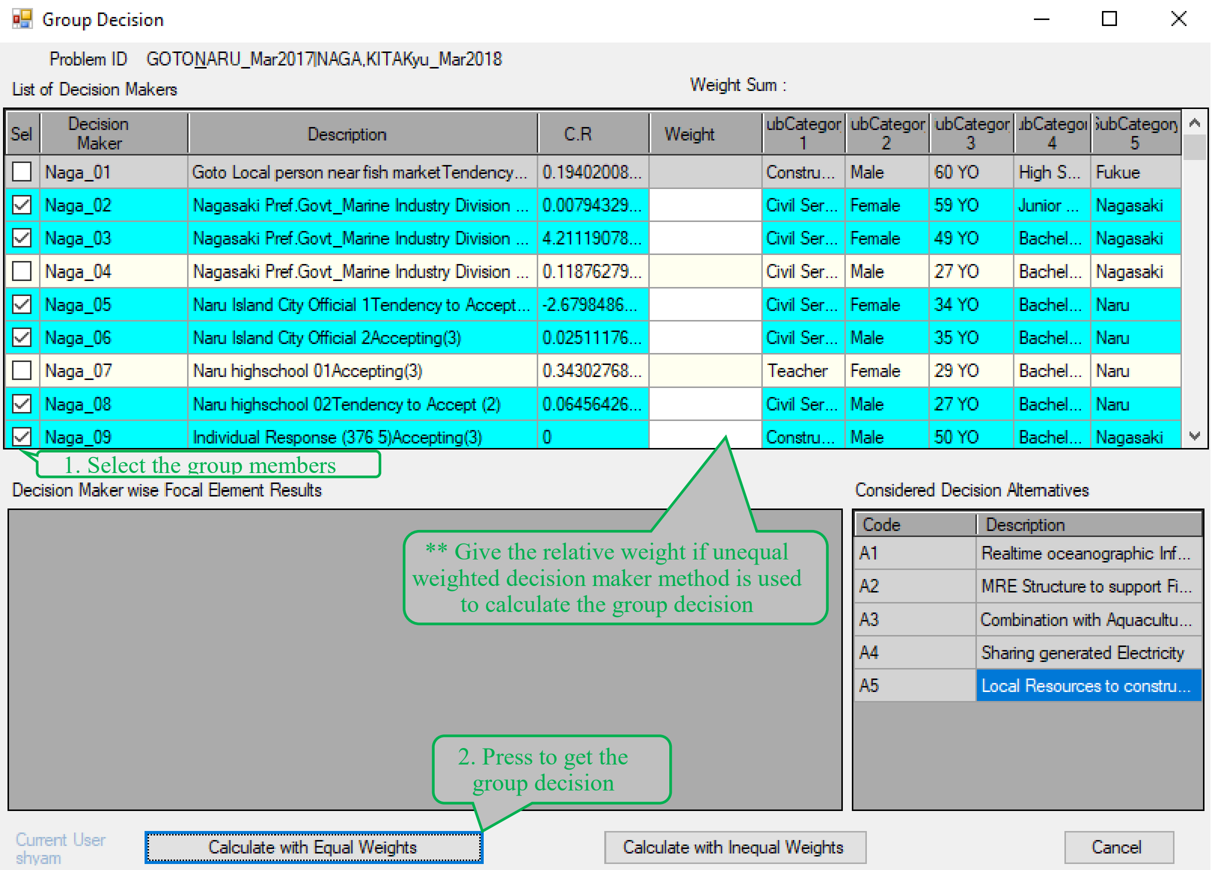


Step 5: Results display (Individual decision maker)

Step 6: Aggregation of individual decision makers' results to group decision



Step 7: Selecting individual decision makers



After pressing the 'Calculate with Equal Weights' (or 'Calculate with Inequal Weights' button) button, the final group decision will be displayed in the same results window as shown in the step 5

Appendix XI: Summary of Acceptance Sensitivity

Summary of acceptance decision

Case study	Acceptance decision	Total [formed opinion holders + Leaners]	Already formed opinion holders' sensitivity		Leaners
			Firmed	Soft	
Nagasaki [108]	Support MRE projects	90.74% [69+29]	32.41% [35]	31.48% [34]	26.85% [29]
	Oppose MRE projects	5.56% [2+4]	1.85% [2]	0% [0]	3.70% [4]
	Not answered**	3.70% [4]*			
	Total	**100% [108]**	**34.26% [37]**	**31.48% [34]**	**34.26% [33]**
Kitakyushu [45]	Support MRE projects	62.22% [18+10]	22.22% [10]	17.78% [8]	22.22% [10]
	Oppose MRE projects	37.78% [12+5]	17.78% [8]	8.89% [4]	11.11% [5]
	Total	**100% [45]**	**35.56% [18]**	**31.11% [12]**	**33.33% [15]**
Combined [153]	Support MRE projects	82.35% [87+39]	28.10% [45]	28.76% [42]	25.49% [39]
	Oppose MRE projects	15.03% [14+9]	6.54% [10]	2.61% [4]	5.88% [9]
	Not made up mind	2.61% [4]			
	Total	**100% [153]**	**34.64% [55]**	**31.37% [46]**	**33.99% [48]**

* Four Nagasaki respondents haven't indicated the acceptance decision (4/108 ~ 3.7%), ** Totals may not add up to 100% due to rounding off

Appendix XII: Acceptance prediction using Logistic regression in STATA™

Data set is available upon request.

Logit regression

```
logit Accept Informed_Adj Impct_Fishing_Adj Effect_Beachgoing_Adj
ib3.Prefrd_Device_Loc WTP Demo_Male_Adj Demo_EduYrs_Adj
Demo_IslandLiving_Adj Demo_Visibility_Adj
```

Marginal effects and Predictions

```
predict prob
margins, dydx(*) post
```

Margins plot

```
marginsplot, horizontal xline(0) yscale(reverse) recast(scatter) ylabel(1 "Project
information sharing level" 2 "Impacts to local fishery" 3 "Impact on beach going
frequency" 4 "Devices in Offshore" 5 "Devices in Nearshore" 7 "Willingness to
Pay" 8 "Gender" 9 "Years of formal Education" 10 "Living on an Island" 11
"Routine project visibility", grid glwidth(vvvthin) glcolor(eggshell) glpattern(solid)
gmin gmax) ytitle(, margin(vsmall)) yscale(lwidth(medium)) xtitle(,
margin(medium)) xlabel(-1(0.25)0.5, labels labcolor(black) angle(Zero) format(%20s)
labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax
nogextend) title("Average Marginal Effects with 95% CIs", position(1)
margin(medium)) graphregion(margin(large) fcolor(none) lcolor(none))
plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - Acceptance Vs. Project information sharing level

```
twoway (qfitci prob Informed_Adj, level(90) fitplot(connected) atobs clcolor(ltblue)
clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium)
msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid)
cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium))
yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell)
glpattern(solid) gmin gmax) xtitle("Project information sharing level") xtitle(,
margin(medium)) xlabel(0 "Not Informed" 1 "Somewhat Informed" 2 "Informed" 3 "Well
Informed" 4 "Verywell Informed", labels labcolor(black) angle(forty_five) format(%20s)
labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax
nogextend) title("Acceptance Vs. Project information sharing level") legend(on nostack
rows(2) size(medsmall) position(11) ring(0)) graphregion(margin(large) fcolor(none)
lcolor(none)) plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - Impacts to local fishery

```
twoway (qfitci prob Impct_Fishing_Adj, level(90) fitplot(connected) atobs clcolor(ltblue)
clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium)
msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid)
cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium))
yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell)
glpattern(solid) gmin gmax) xtitle("Impacts to local fishery") xtitle(, margin(medium))
xlabel(1 "Deteriorate" 2 "No Impact" 3 "Improve", labels labcolor(black) angle(zero)
format(%20s) labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin
gmax nogextend) title("Acceptance Vs. Impacts to local fishery") legend(on nostack rows(2)
size(medsmall) position(11) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none))
plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - Impacts on beach going frequency

```
twoway (qfitci prob Effect_Beachgoing_Adj, level(90) fitplot(connected) atobs clcolor(ltblue) clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium) msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid) cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium)) yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell) glpattern(solid) gmin gmax) xtitle("Impact on beach going frequency") xtitle(, margin(medium)) xlabel(1 "Decrease" 2 "No Impact" 3 "Increase", labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend) title("Acceptance Vs. Impact on beach going frequency") legend(on nostack rows(2) size(medsmall) position(11) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none)) plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - Device Location

```
twoway (qfitci prob Prefrd_Device_Loc, level(90) fitplot(connected) atobs clcolor(ltblue) clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium) msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid) cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium)) yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell) glpattern(solid) gmin gmax) xtitle("Device Location") xtitle(, margin(medium)) xscale(reverse) xlabel(1 "Offshore" 2 "Nearshore" 3 "Onshore/Onland", labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend) title("Acceptance Vs. Device Location") legend(on nostack rows(2) size(medsmall) position(1) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none)) plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - WTP

```
twoway (qfitci prob WTP, level(90) fitplot(connected) atobs clcolor(ltblue) clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium) msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid) cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium)) yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell) glpattern(solid) gmin gmax) xtitle("Willing to Pay additional amount for MRE?") xtitle(, margin(medium)) xlabel(0 "No" 1 "Yes", labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend) title("Acceptance Vs. Willingness to Pay") legend(on nostack rows(2) size(medsmal2) position(12) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none)) plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - Gender

```
twoway (qfitci prob Demo_Male_Adj, level(90) fitplot(connected) atobs clcolor(ltblue) clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium) msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid) cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium)) yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell) glpattern(solid) gmin gmax) xtitle("Gender") xtitle(, margin(medium)) xlabel(0 "Female" 1 "Male", labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend) title("Acceptance Vs. Gender") legend(on nostack rows(2) size(medsmal2) position(12) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none)) plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs - Years of formal Education

```
twoway (qfitci prob Demo_EduYrs_Adj, level(90) fitplot(connected) n(13) clcolor(ltblue)
clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy)
msize(medium) msymbol(circle) fcolor(bluishgray)    blcolor(ltblue) blwidth(vvvthin)
blpattern(solid) cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium))
yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell)
glpattern(solid) gmin gmax) xtitle("Years of formal Education") xtitle(, margin(medium))
xlabel(9(1)21, labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid
glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend)
title("Acceptance Vs. Years of formal Education") legend(on nostack rows(2) size(medsmal2)
position(12) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none))
plotregion(fcolor(none) lcolor(black))
```

Prediction Graphs – Island Living

```
twoway (qfitci prob Demo_IslandLiving_Adj, level(90) fitplot(connected) atobs clcolor(ltblue)
clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium)
msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid)
cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium))
yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell)
glpattern(solid) gmin gmax) xtitle("Residence on a nearby Island?") xtitle(, margin(medium))
xlabel(0 "No" 1 "Yes", labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid
glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend)
title("Acceptance Vs. Island Living") legend(on nostack rows(2) size(medsmal2) position(12)
ring(0)) graphregion(margin(large) fcolor(none) lcolor(none)) plotregion(fcolor(none)
lcolor(black))
```

Prediction Graphs – Routine project visibility

```
twoway (qfitci prob Demo_Visibility_Adj, level(90) fitplot(connected) atobs clcolor(ltblue)
clwidth(vvthin) clpattern(shortdash) connect(direct) cmissing(y) mcolor(navy) msize(medium)
msymbol(circle) fcolor(bluishgray) blcolor(ltblue) blwidth(vvvthin) blpattern(solid)
cmissing(y)), ytitle(Probability of Acceptance) ytitle(, margin(medium))
yscale(lwidth(medium)) ylabel(0(0.2)1, grid glwidth(vvvthin) glcolor(eggshell)
glpattern(solid) gmin gmax) xtitle("Routine project visibility") xtitle(, margin(medium))
xlabel(0 "No" 1 "Yes", labels labcolor(black) angle(zero) format(%20s) labgap(zero) grid
glwidth(vvvthin) glcolor(lavender) glpattern(vshortdash) gmin gmax nogextend)
title("Acceptance Vs. Routine Project Visibility") legend(on nostack rows(2) size(medsmal2)
position(12) ring(0)) graphregion(margin(large) fcolor(none) lcolor(none))
plotregion(fcolor(none) lcolor(black))
```

Note

Results of the preliminary survey which is part of Chapter 3 & 4 was published as;

A. H. T. Shyam Kularathna and K. Takagi, "Factors Behind Local Acceptability of Marine Renewable Energy Projects and Perceived Preferences of Possible Co-Existence Options: Case Study of Marine Renewable Energy Development in Nagasaki, Japan" 2018 OCEANS - MTS/IEEE Kobe Techno-Oceans (OTO), Kobe, 2018, pp. 1-7. doi: 10.1109/OCEANSKOBE.2018.8559073

The results of the postal survey which is part of Chapter 3 is in preparation for a journal publication as;

Kularathna, A.H.T. Shyam; Takagi, K. "Local Acceptance Decision Factors of Marine Renewable Energy Development in Japan".

A part of Chapter 4 was published as;

Kularathna, A.H.T. Shyam; Suda, Sayaka; Takagi, Ken; Tabeta, Shigeru. "Evaluation of Co-Existence Options of Marine Renewable Energy Projects in Japan" Sustainability. 2019; 11(10):2840

A part of Chapter 5 was published as;

Kularathna, A.H.T. Shyam; Takagi, K. "Analysis of Oceanographic Information as a Co-benefit of Marine Renewable Energy Projects - A Case Study of Japan's Ocean Current Power Project", Journal of Japan Society of Ocean Policy, No.7, pp.88-104, 2017