FY2020 Project for Ministry of the Environment Japan

FY2020 City-to-City Collaboration Programme for Zero-Carbon society

（Support Project for Developing a Sustainable Eco-friendly Smart City: An Intercity Collaboration between Toyama City and Male' City）

Report

March 2021

Japan NUS Co., Ltd

Toyama City

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List of Abbreviations

Abbreviation	English
ADB	Asian Development Bank
Avgas	Aviation Gasoline
BOG	Boil off gas
BRT	Bus Rapid Transit
CDM	Clean Development Mechnisum
CHEC	China Harbour Engineering Company Ltd
CNG	Complessed natural gas
EPC	Engineering, Procurement and Constluction
EV	Electric Vehicle
FCF	Free cash flow
FIT	Feed in Tariff
FSRU	Floating Storage and Regasification Unit
GHG	Green house gas
IRR	Internal Rate of Return
JCM	Joint Crediting Mechanism
JFJCM	The Japan Fund for the Joint Crediting Mechanism
LNG	Liquefied Natural Gas
LPG	Liquefied petroleum gas
LRT	Light Rail Transit
MATI	Maldives Association of Tourism Industry
MMA	Maldives Monetary Authority
MMBtu	Million British thermal unit
MoED	Ministry of Economic Development
MoEn	Ministry of Environment of the Maldives
MoF	Ministry of Finance
MRT	Mass Rapid Transit
MRV	Measurement, Reporting and Verification
NDC	Nationally Determined Contributions
ODA	Official development assistance
PMS	People mover system
PV	Photovoltaics
SAP	Strategic Action Plan
STELCO	State Electric Company Limited
TA	Technical Assistans
UNFCCC	United Nations Framework Convention on Climate Change

1. Objective and Background of Program

1.1. Objective

The 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) was held in Paris, France in 2015. The Paris Agreement was adopted at COP21 as a new international framework for reducing greenhouse gas emissions. Upon entering the current fiscal (2020) the Paris Agreement has entered the stage of full-scale operation. For steady implementation of the Paris Agreement, reference has been made to the importance of roles fulfilled by various stakeholders (non-state stakeholders) including private companies, local governments, NGOs, and civil society. Cities and local governments are key players in considering and implementing specific regional climate change countermeasures and projects.

In order to transform the entire world into a carbon-free society, we must accelerate the movement toward the construction of a sustainable decarbonized society and the transit point of a low-carbon society. The need for acceleration is especially urgent in Asia, a region experiencing remarkable economic growth. On a global scale, the movement to support urban initiatives is being strengthened with the aim of achieving decarbonization and low carbonization of cities, which are the site of activities for supporting socioeconomic development.

Under the Paris Agreement, in addition to funding provided by developed countries, developing countries are also expected to voluntarily provide funding and to utilize market mechanisms such as the Joint Crediting Mechanism (JCM). Therefore, together with Japanese cities that possess experience and know-how regarding the formation of a decarbonized or low-carbon society, it is important to promote the Paris Agreement by cooperating in the JCM to overseas local governments; specifically, by supporting the formation of a decarbonized or low-carbon society and installing facilities that contribute to the formation of a decarbonized or low-carbon society.

When considering the circumstance discussed above, the objective of this survey program is to study the construction of a sustainable environment-friendly city in Malé through cooperation with Toyama City. Malé is the capital of the Maldives and is significantly affected by climate change.

1.2. Background

The Maldives is an island nation consisting of approximately 1,200 large and small atoll islands. This makes the Maldives vulnerable to rising sea levels and natural disasters caused by climate change. Global warming has a direct impact on the living environment, and a severe impact on the main industries of tourism and fisheries. In an effort to mitigate this impact, the Maldivian government has declared its vision to become a carbon-neutral country; that is, to achieve zero net emissions by reducing the use of fossil fuels and decreasing greenhouse gas emissions. The government has set the ambitious future goal of using renewable energy for 60% of electricity on all islands in the Maldives. However, the country still has a long way to go to reach this goal[1].

In the Maldives, 145,000 people (one-third of the total population) live in the Malé metropolitan

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[1] Ministry of Housing & Environment Male', Republic of Maldives TOWARDS CARBON NEUTRALITY URL:https://www.climateinvestmentfunds.org/sites/cif_enc/files/meeting-documents/3._maldives_salle_south_africa_-_srep_meeting_final_2_0.pdf

area called Greater Malé. Malé Island, which fulfills all capital functions such as housing government offices and hosting foreign diplomats, is known as one of the most densely populated areas in the world. In order to disperse such overcrowding and to prepare for the acceptance of refugees from islands that will be submerged due to rising sea levels in the future, the Maldives began the construction of a 4 km^2 artificial island name Hulhumalé Island in 1997. Currently, construction has been completed for a 1.95 km^2 area that is inhabited by approximately 50,000 people. Eventually, the Maldivian government expects a total of 240,000 people to move to Hulhumalé Island.

The Malé City government plans to develop the Hulhumalé area as a smart and compact environmentally-friendly city. As such, the Malé City government has requested support from Toyama City, which is known as an "environmental future city." The support will include the essential environmental aspects of renewable energy, waste treatment, transportation infrastructure, energy saving, and system construction.

Malé City came into contact with Toyama City through the "Training on the City-to-City Collaboration for a Low-Carbon Society," which was sponsored by the Japanese Ministry of the Environment and held in Toyama City in November 2019. One participant in this training was the Malé City Hulhumalé Housing Development Cooperation (HDC; hereinafter referred to as the "Hulhumalé Development Cooperation"). The Hulhumalé Development Cooperation expressed strong interest in Toyama City's compact city policy, which is centered around light rail transit (a next-generation streetcar system), as well as in the environmental technology possessed by companies in Toyama City. The Hulhumalé Development Cooperation requested support from the Embassy of Japan in Maldives. In response, the Embassy of Japan in Maldives and the Embassy of Maldives in Tokyo paid a courtesy call on the Mayor of Toyama in January 2020 and were able to confirm collaboration between the two countries.

2. Overview of the Maldives and Malé City

2.1. Basic Information[2]

The Maldives is an island nation located in the Indian Ocean to the southwest of India. It has an area of 298 km^2, which is about half the area of Tokyo's 23 special wards, and consists of 1,192 islands.

The Maldives has a population of 534,000 people, with a breakdown of 373,000 native Maldivians and 161,000 foreigners. The main industries are fisheries and tourism, with a GDP of approximately USD $5.760 billion and GDP growth of 5.9%.

The fishing industry accounts for 5.1% of GDP, 6.9% of employment, and 96% exports (2018). The main fish species are bonito (53% of the landed amount) and tuna (38% of the landed amount). Bonito flakes are produced as a special product.

Tourism is the main source of foreign currency, accounting for about 20% of GDP. Based on the one-island one-resort policy, 145 of the 1,192 islands nationwide are resort islands. The number of

[2] Website of the Ministry of Foreign Affairs: Basic Data on the Republic of Maldives
URL: https://www.mofa.go.jp/mofaj/area/maldives/data.html

tourists in 2018 was 1.48 million, with China (283,000), Germany (117,000) and the United Kingdom (114,000) leading the way. Japan was ranked 9th with 42,000 tourists.

The Maldives has traditionally been a pro-Japanese country. Japan maintains friendly and cooperative relations with the Maldives through cooperation in areas such as the international section. Furthermore, the Maldives is located at a key point on Japan's sea lane and therefore has geopolitical importance. Accordingly, through effective and efficient ODA activities, it is Japanese policy to support the Maldives in achieving sustainable economic growth and further socioeconomic expansion, while also overcoming the development issues faced by a small island nation. Japan’s ODA policy toward the Maldives is based on “response to vulnerabilities and support for sustainable economic growth.” It also positions “cultivation of local industries” and “measures for environmental issues, climate change, and disaster prevention” as priority fields.

2.2. Maldivian Government

The Maldivian political system based on republicanism. As of 2021, the head of state is the President His Excellency Ibrahim Mohamed Solih. A Vice President and Attorney General are appointed under the President, and there are 19 ministries responsible for administration.

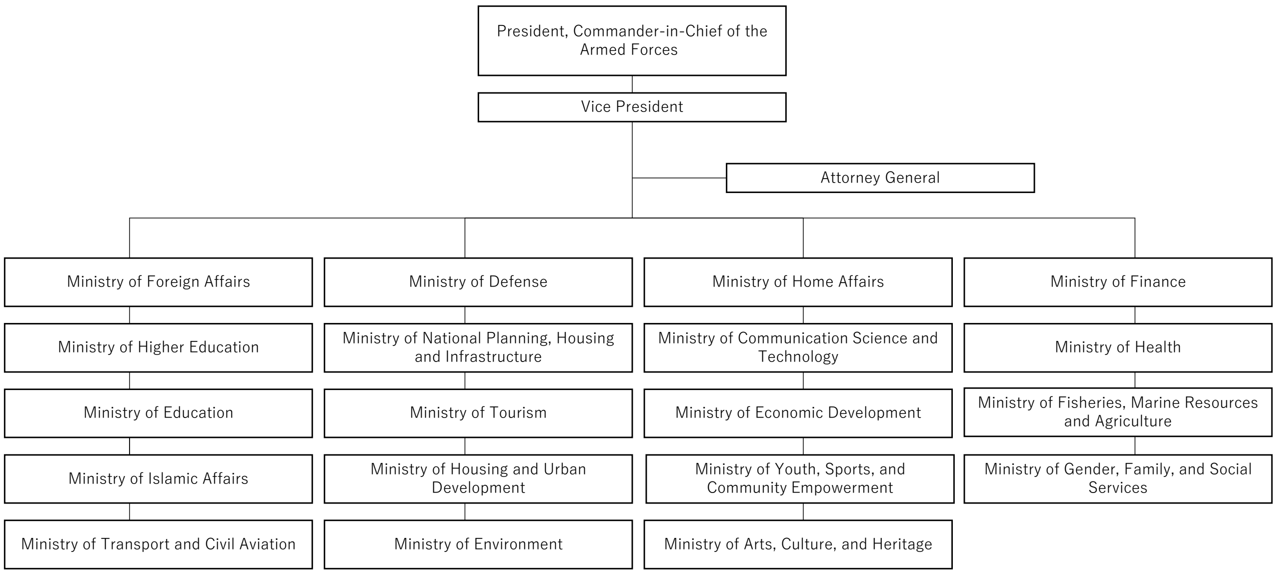

Figure 2-1 The Government Structure of Maldives[3]

In terms of the municipal system, during the Maumoon Abdul Gayoom administration (1978-2008), the administrative department consisted of 20 administrative atolls. All of the atolls which were centralized and administrative authority was held by the central government of Malé.

Then, the Mohamed Nasheed administration assumed power in 2008 and attempted

[3] Created by Japan NUS Co., Ltd. based on “The cabinet” page from Maldives’ President’s Office Website
https://web.archive.org/web/20150920062619/http://www.presidencymaldives.gov.mv/Index.aspx?lid=16

decentralization. Constituencies were established in 7 states, 17 atolls, 4 cities, and 189 islands.

A city is defined as an area with a population of at least 10,000 people. Each city forms a city council, exercises administrative authority over the region, communicates with the central government, and manages uninhabited islands and resorts within the designated region. The currently established cities are Malé, Addu, Fuvahmulah, and Kulhudhuffushi.

An atoll is a group of island councils that are responsible for the administration of the islands within the atoll as a geographical division. Atoll councils are established to manage uninhabited islands and resort islands in the region, and to communicate with the central government. Island councils are set up on each of the 189 inhabited islands and are responsible for administration on each island.

2.2.1. Main Government Policies and Other Policies

The main axis of government policies and other policies in the Maldives is a five-year plan called the Strategic Action Plan (SAP). The implementation period for the current SAP runs from 2019 to 2023. SAP is positioned as a central policy framework and planning document that will guide the direction of development in the Maldives over a five-year period.

SAP also integrates government manifests with priority items in existing sectors. SAP possesses oversight capabilities for tracking the progress of government policies and the order of development priorities. From October 1, 2019, SAP has been officially expanded to include work conducted by related ministries and agencies.

SAP is divided into five main sectors. “Policy,” “Target,” “Strategy,” and “Action” are organized for each of the sectors. There are also 33 sub-sectors.

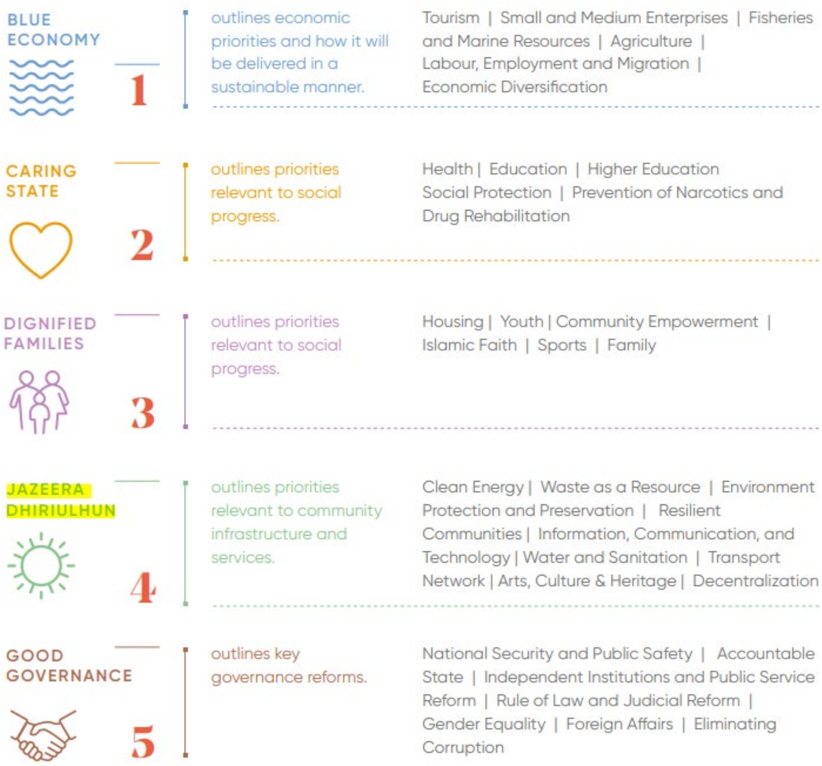

Figure 2-2　Five Main Policy Sectors and Sub-Sectors in SAP

2.2.2. Environmental Problems and Countermeasures in the Maldives and Malé City

In 1987, an abnormally high wave occurred in the Indian Ocean. This wave flooded a quarter of the urban area of the capital city Malé in the Maldives. The wave also flooded farms and washed over a landfill. At the UN General Assembly that year, Maldivian President Maumoon Abdul Gayoom first advocated the need to address climate change[4]. “Human activities release greenhouse gases that cause global warming,” stated President Gayoom while referring to scientific evidence during his appeal. “In turn, this causes glaciers to melt and seawater to expand, which eventually raises the world's sea level.” 80% of land in the Maldives is less than one meter above sea level. Subsequent surveys and research have revealed that Maldives is at risk of being submerged if global warming advances to the worst-case scenario. Since ascertaining this risk, the Maldives has positioned global warming as a national security issue and has begun to take countermeasures.

The construction of an artificial island has been advanced since 1997 as a countermeasure against rising sea levels which could threaten the existence of the Maldives. Originally, the main objective of the project was to create a site for residents to relocate from the overcrowded Malé. At the same time, the artificial island is now being positioned as a destination if rising sea levels in the future create an urgent need for relocation[5]. The Maldives also declared a policy of aiming for carbon

[4] Janet Larsen, Earth Policy Institute, Plan B Updates,「Rising Seas and Powerful Storms Threaten Global Security」, OCTOBER 09. 2008.
URL:https://www.earthpolicy.org/plan_b_updates/2008/update76.html

[5] Asahi Shimbun newspaper: Maldives moves to double the area of artificial islands for migration (March 21,

neutrality by 2020. The country has promoted initiatives to support this policy; for example, promoting a program to expand renewable energy[6]. The track record of the construction of Hulhumalé Island is shown below.

Figure 2-3 Hulhumalé Island in 1997, Before the Start of Land Reclamation

Figure 2-4 Hulhumalé Island in 2015 (the reclaimed land in the center of the island is Hulhumalé Phase I)

Figure 2-5 Hulhumalé Island in 2018 (the reclaimed land on the left side of the island is Hulhumalé Phase II)

In addition to global warming countermeasures, the Maldives is also promoting environmental measures such as coral reef conservation and marine plastic waste countermeasures. These countermeasures are being taken in order to conserve the marine ecosystem that is a resource for

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2018)
URL: https://www.asahi.com/articles/ASL3P41DTL3PULBJ002.html

[6] Materials from a lecture given by Mariyam Shakeela, Minister of Environment and Energy of the Republic of the Maldives: Climate Change and Coral Reef Conservation, International Conference on Climate Change and Coral Reef Conservation, Panel Discussion on the Form of Islands that Coexist with Nature and Island Countries—A Consideration of Global Warming Countermeasures and Coral Reef Conservation, 2013.
https://www.env.go.jp/nature/biodic/coralreefs/iccccrc2013/pdf/year2013629/panel/mariyam.pdf

tourism and fisheries, the industries which accounts for 90% of national GDP.[6]

Our survey focuses on the city of Malé, which has a population of about 145,000 people. Approximately one-third to one-fourth of the Maldives population is concentrated in Malé. Moreover, the city is also home to many foreign workers. Malé serves as the political and economic center of the Maldives, and as a trading port that accepts imports to each island. From the viewpoints of energy consumption and waste management issues, Malé contributes significantly to the entire nation. Consequently, there is an urgent need for countermeasures in Malé.

As part of this survey, a kick-off meeting was held between Toyama City, the Maldivian Ministry of the Environment, Malé City and Hulhumalé Development Cooperation[7]. Upon discussing the environmental issues of the Maldives and Malé, we identified the following major issues.

1. Climate change mitigation: Policies for climate change mitigation are needed in the Maldives. Although CO_2 emissions in the Maldives are not high when viewed on a global scale, diesel fuel accounts for 99% of the nation's energy. Accordingly, it is necessary to replace diesel fuel with energy that emits less CO_2. In addition to considering plans for utilizing LNG in the future, the Maldives has already introduced solar power generation. Furthermore, an energy plan (roadmap) is scheduled to be completed soon. The Maldives also plans to promote decarbonization with an eye on utilizing waste power generation and ocean energy.
2. Climate change adaptation: The Maldives is highly susceptible to climate change such as coastal erosion and tsunami.
3. Public transportation issues: Public transportation is inadequate. In particular, Malé has heavy traffic, which creates issues such as insufficient parking and air pollution due to exhaust gas.
4. Waste issues: In the Maldives, waste is currently collected in each of the five districts. However, there are issues regarding collection and treatment. In the future, waste will be incinerated at the waste power plant scheduled for construction on Thilafushi Island.

The Maldives is actively accepting the support of international organizations and foreign countries in implementing measures to address these major environmental issues. In Japan, the Japan Fund for the Joint Crediting Mechanism (JCMJF), which is responsible for applying the JCM system to Asian Development Bank (ADB) loan projects, plans to contribute funds to the waste power generation project on Thilafushi Island in the Greater Malé Region. Furthermore, the Maldives is positioned as a target country of the JCM Model Project, and the "Low Carbon Growth Partnership between the Japanese side and the Maldivian side" was signed in 2013. This was followed by the establishment of a JCM Joint Committee, thus facilitating the spread of outstanding low-carbon technology. In July 2019, the Maldives received its first JCM credit issuance for a 15-month monitoring period from 2017 to 2018 as part of the "Solar Power on Rooftop of School Building Project."

In this project, Toyama City is expected to cooperate in efforts for further low-carbon measures

[7] Held on October 8, 2020 using Microsoft Teams.

and decarbonization. We have committed to providing ongoing cooperation in conjunction with commercialization that focuses on the JCM Model Project.

2.3. Background of Collaboration with Toyama City

This section describes the background leading to implementation of this survey as part of city-to-city collaboration with the Maldives.

In November 2019, the Malé City Hulhumalé Development Cooperation participated in training held in Toyama City on city-to-city collaboration projects (Training on the City-to-City Collaboration for Creating Low-Carbon Society). In addition to excellent transportation systems such as light rail transit, the Hulhumalé Development Cooperation learned about Toyama City's efforts toward a carbon-free society, renewable energy, and energy-saving technologies. The Hulhumalé Development Cooperation expressed strong interest in these areas to Toyama City. Afterwards, expectations for the city-to-city collaboration project increased in Malé. In January 2020, the Japanese Ambassador to the Maldives and the Maldives Ambassador in Tokyo paid a courtesy visit to Toyama City in order to exchange opinions with Mayor Mori. During the discussion, the officials identified the needs to improve public transportation, reduce carbon by using natural gas, optimize energy consumption by disseminating energy-saving technology, and introduce technology such as energy utilization associated with waste treatment. These needs are particularly strong as pertains to the development of Hulhumalé Island. In response, we took action to disseminate information to companies in Toyama City that have low-carbon technology; for example, companies involved in the design and construction of light rail transit. After confirming interest from such companies, Toyama City and companies in the city cooperated to construction a support system.

Discussions with Malé had been planned for March 2020 with the goal of signing a cooperation agreement and defining further details for each project. However, the meeting could not be held due to the spread of COVID-19. However, through the cooperation of the Embassy of Japan in the Maldives, we have been holding remote discussions aimed at acquiring statements of interests and defining the details of each project. We have currently reached the stage of proposal and adoption.

	
Scene from the 2019 City-to-City Collaboration Seminar[8]	Ambassadors pay a courtesy call to the Mayor of Toyama City (January 2020)

Figure 2-6 Activities Leading Up to City-to-City Collaboration in Toyama and Malé

3. Background of Consideration of JCM Project Formation

Hulhumalé Island, we performed the following activities with the objective of reducing greenhouse gas emissions through the following fields: reduction of CO_2 emissions originating from transportation by developing public transportation, low-carbon power generation by converting diesel power generators to natural gas, low-carbon fields through the spread of renewable energy and energy-saving, and low-carbon fields with biogas power generation using organic waste. Another objective is to form JCM projects which contribute to the abovementioned fields. In this survey, as countermeasures against climate change in Malé City with a focus on:

(1) Reduction of CO_2 emissions originating from transportation by developing public transportation
(2) Low-carbon power generation by converting diesel power generators to natural gas
(3) Low-carbon fields through the spread of renewable energy and energy-saving
(4) Low-carbon fields with biogas power generation using organic waste

The points of consideration and results for each field are listed below in 3.1 to 3.4.

[8] Taken from the IGES website
URL: https://www.iges.or.jp/jp/events/20191127

3.1.Reduction of CO_2 Emissions Originating from Transportation by Developing Public Transportation

In the Maldives (including the Malé metropolitan area) public transportation is insufficient and many residents own cars. Conversely, automobiles parked on the roadside result in inadequate road width and traffic congestion, both of which are serious issues. Additionally, the proportion of CO_2 emissions from automobiles is increasing in line with the increase in the number of automobiles owned. Therefore, it is necessary to develop more efficient and low-carbon methods of public transportation.

Under these circumstances, Hulhumalé Development Cooperation, which is responsible for the development policy of Hulhumalé Island, is highly interested in the introduction of the light rail transit that is a pillar of Toyama City's compact city policy.

The current population of Hulhumalé Island is about 45,000 people. Hulhumalé Development Cooperation is interested in light rail transit because it expects 160,000 people to relocate to Hulhumalé Island from Malé Island in the future. The majority of these residents are expected to commute to Malé Island or other location for work. These conditions may impact traffic congestion and increase CO_2 emissions in the transportation sector. Therefore, the Hulhumalé Development Cooperation has explained the urgent need for development of low-carbon public infrastructure.

Furthermore, the Hulhumalé Development Cooperation has a strategy to obtain tourism demand centered on the Hulhumalé region by developing new tourist spots on Hulhumalé Island. This would mark a change in the previous flow of tourists from the airport directly to resorts. There are also plans for facilities that meet business demand; for example, business centers and research centers. In conjunction, it is essential to develop public transportation systems in order to facilitate the movement of travelers and businesspeople, and to improve access to lodgings, etc.

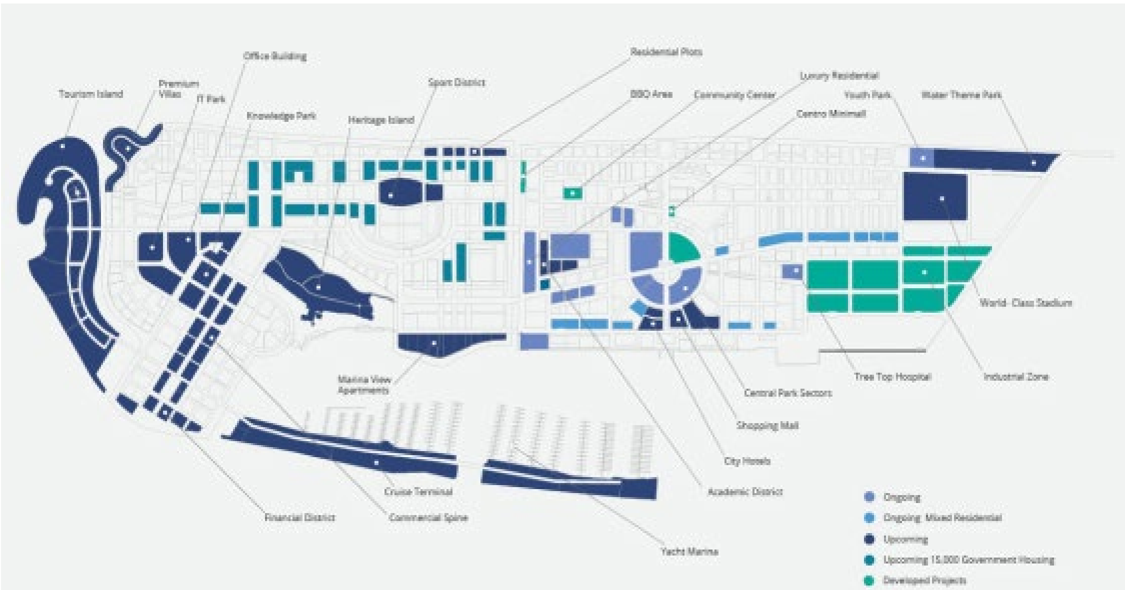


Figure 3-1　Development Plan for Tourist Facilities and Business Facilities on Hulhumalé Island

Therefore, as part of these efforts, we surveyed the following items, and surveyed the possibility of introducing light rail transit and the resulting low-carbon effect.

3.1.1. Analysis of Transportation Policies in the Maldives National Development Plan and Malé City Plan

We started by collecting and organizing information and policy documents such as development plans related to transportation in the Maldives. We obtained the information from the internet, Malé, and institutions such as local cooperating organizations. Next, we worked to understand systems and policies related to transportation, plans for public transportation, policy goals, etc. We then examined the policy and institutional promotion measures related to the introduction of light rail transit.

As described above, the Maldives has positioned its Strategic Action Plan 2019-2023 (hereinafter, “SAP”) as a document showing the development goals and priorities of the government. In SAP, the following points are described as policies (Policy 3) and targets (Target 3.1, 3.2) regarding transportation policies.

・Vehicle congestion in the Greater Malé Region is reduced by 30% compared to 2018 level.
・At least 60% of the population in the Greater Male’ Region utilize public transport services on a regular basis.

When implementing these policies and target, the strategy (Strategy 3.2) is to spread efficient public transportation systems in the broader Malé district.

For the basis of these items listed in SAP, there are two reports which served as the basis for consideration. We received these reports from Hulhumalé Development Cooperation and used them for detailed analysis of the situation and consideration for the possibility of introducing light rail transit.

The reports are the “Maldives Transport Master Plan Study” and the “Traffic Characteristics Analysis of the China-Maldives Friendship Bridge.” The latter report analyzes the impact on traffic conditions due to the construction of a bridge connecting Malé Island, Hulhule Island, and Hulhumalé Island. The official name of the bridge is The Sinamalé Bridge. However, as is evident from how it was initially called the China-Maldives Friendship Bridge, it was constructed using funds supplied by China. The bridge was opened in 2018. The cost of the bridge is estimated to be 210 million USD, of which 126 million USD was subsidized by China[9].

Overviews and details of both reports are listed below.

(1) Analysis of the “Maldives Transport Master Plan Study”

This Master Plan begins by discussing the results of analysis on the current state of traffic and transportation in the Maldives.

The Master Plan emphasizes that motorcycles are the main means of land transportation. According to the report, as of 2012, motorcycles accounted for more than 80% of the total of 556,497

[9] Ministry of foreign affearis "President of China concludes State Visit to the Maldives". 16 September 2014. URL:https://www.foreign.gov.mv/index.php/en/mediacentre/news/2707-president-of-china-concludes-state-visit-to-the-maldives

vehicles with internal combustion engines. The report also states that the rate of increase for motorcycles has been 10% or higher per year since 2000. Conversely, the number of four-wheeled vehicles as of 2012 was 3,700. Although the number of four-wheeled vehicles is increasing, it is a relatively gradual trend.

As for public transportation, two buses circulate Hulhumalé Island. The Fithuroanu Magu Ferry Terminal serves at the origin of routes connecting various areas of the island. There are also two buses operating between Hulhule Island, where the airport is located, and Hulhumalé Island. At the time this Master Plan was formulated, there were no bridges on Hulhumalé Island, Hulhule Island, or Malé Island. Consequently, all movement between Hulhumalé Island and Malé Island was by ferry. The volume of ferry riders was about 20,000 people per day and the volume of motorcycles was approximately 1,500 per day. Since Hulhumalé is a residential area, the dynamics of most residents commuting to Malé can be ascertained. Following construction of the bridge, it seems that land has become the main mode of transportation for residents who own motorcycles and automobiles. However, the ferries still remain in order to serve some commuters who wish to avoid the traffic on Malé Island, as well as a certain number of people who commute on foot.

There are many problems with traffic in Malé. The turning radius of intersections is short. Roads are narrow and crowded. In particular, there is a large number of motorcycles, and there is a chronic shortage of parking lots at facilities such as buildings, schools, and mosques. Consequently, street parking on the sidewalk has become normalized, thus creating an inconvenient and dangerous environment for pedestrians. In addition to parking on the street, the road width is narrowed due to loading and unloading of vehicles. Large vehicles also pass through the roads and cause frequent congestion. However, there are almost no intersections with traffic lights to regulate traffic. Another problem is the frequent flooding and inundation of roads. On the other hand, the report also refers to the good traffic culture in Malé. Road conditions make it difficult to drive fast, so driving conditions are relatively calm. It is also customary for drivers to yield the road to pedestrians. When parking, drivers try as much as possible to avoid causing trouble for other vehicles or pedestrians.

Based on this situation, the Maldivian Government and Malé City have been considering the People Mover System (PMS), which seeks to solve transportation problems by introducing public transportation. The background to PMS is not just the worsening traffic conditions due to an increase in motorcycles and automobiles; it is also related to targets for low carbon and decarbonization in the transportation sector. Monorails and light rail transit are being considered as specific public transportation systems. A related plan is the "Hulhumalé Phase 1 and Phase 2 Master Plan & Urban Design Review 2015", which proposes the operation of PMS on a one-way circular route. However, there is no description of the grounds for proposing the route or the reason for selecting a circular route. Therefore, we must consider whether this route plan is truly in line with demand from residents. Moreover, the proposal has not yet reached the stage of economic evaluation or financial evaluation.

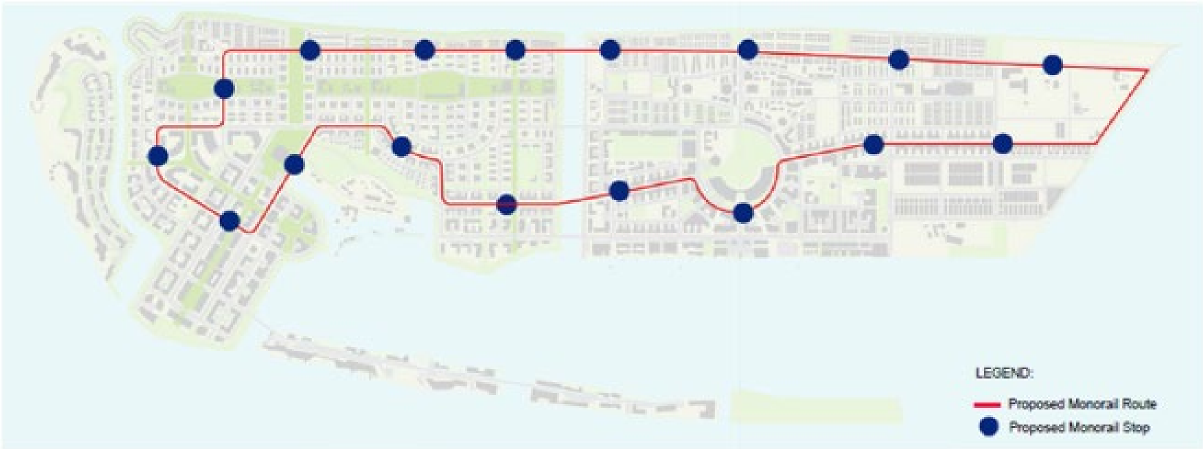


Figure 3-2 Routes Proposed in the Maldives Transport Master Plan Study

As discussed above, at the time of implementing this Master Plan, the bridge connecting Malé Island and Hulhumalé Island had not yet been constructed. Nevertheless, the bridge was in the planning and design stage, so consideration was also given to rules regarding the use of the bridge. Due to the distinct aspects of Malé Island as an office district and Hulhumalé Island as a residential district, the traffic dynamics are characterized by one-way movement to Malé Island during the morning commuting hours and then back to Hulhumalé Island when returning home. In order to avoid traffic jams, the Master Plan engaged in consideration of measures such as collecting tolls. Currently, roads are operated without any tolls being collected. However, the current system is viewed as contributing to increased incentives for residents of Hulhumalé Island to own vehicles. Consequently, there is even greater urgency for considering mass transportation measures through enhancement of public transportation.

Table 3-1 Examination of Rules Regarding the Use of Bridges

No.	Option	Explanation / Expected Merits	Expected Demerits
1	Do not charge tolls (bicycles cannot be used)	1. Bridge will contribute to improved accessibility 2. Possibility of Malé residents relocating to Hulhumalé 3. Buses can move freely between the islands and many people will ride the bus instead of driving a private vehicle	4. Hulhumalé will have the same problems as Malé (traffic jams, insufficient parking, safety issues)
2	Issue license plates in different colors for three categories: 1) for Malé, 2) for Hulhumalé, 3) for both islands	1. Buses, cargo vehicles, and taxis are exempt from license plate rules 2. Makes it possible to maintain traffic conditions in Hulhumalé at a manageable level 3. Traffic conditions in Malé will not worsen any further 4. A greater number of people will be forced to use buses or taxis when moving between the islands	5. It will be difficult to obtain support from residents for the restrictions 6. Residents who were not able to acquire a license plate for use on both islands will not be able to use the bridge even in an emergency

3	For private vehicles (cars/motorcycles), movement among the three islands will be restricted depending on whether the last digit of the licenses plate is an even number or an odd number	1. Depending on the license plate number, private vehicles will be able to travel between islands on specified days 2. Traffic conditions in Malé will only worsen very slightly 3. Use of buses will increase	4. It will be difficult to obtain support from residents for the restrictions 5. The bridge will not be used sufficiently 6. Depending on the day, it may not be possible to use the bridge even in an emergency 7. There is the possibility that some people will own two cars so that they possess both license plates, which would increase the total number of vehicles
4	1. Only permit passage by private vehicles which use the bridge at a high rate 2. Only permit the use of the bridge when carpooling (4 people in a car or 2 people on a motorcycle)	3. Makes it possible to maintain traffic conditions in Hulhumalé at a manageable level 4. Traffic conditions in Malé will only worsen very slightly 5. More people will use buses or taxis when moving between the islands	6. It will be difficult to obtain support from residents for the restrictions 7. The bridge will be not used sufficiently 8. When not carpooling, the bridge cannot be used even in an emergency
5	1. Collect tolls 2. Collect roundtrip tolls (either collect a roundtrip toll in one place, or collect separate tolls for going and coming back)	1. The bridge can be used by anyone who pays the toll 2. The revenue from tolls can be used to operate the bridge and pay for maintenance/management	3. It will be difficult to obtain support from residents for the restrictions; however, it will be easy to explain that tools will be used for bridge maintenance/management or other transportation projects

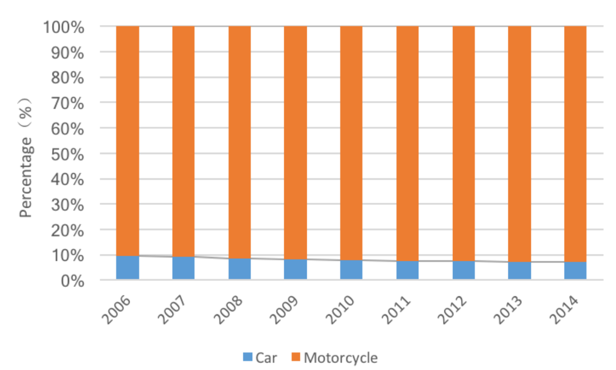
(2) Analysis of"Traffic Characteristics Analysis of the China-Maldives Friendship Bridge"

This document is a traffic analysis report on the construction of a bridge connecting Hulhumalé Island, Hulhule Island, and Malé Island. In 2014, a meeting was held between President Xi Jinping Jintao of China and President Abdullah Yameen of the Maldives. During the meeting, the two sides agreed to conduct surveys and research for a project to construct a bridge between Malé and Hulhule (the China-Maldives Friendship Bridge). The agreement was subsequently executed. It was the first bridge project in the Maldives and the bridge was considered to be the most important construction between islands. The length of the bridge was 760 meters. The project included phases such as bridge construction, reclamation, road construction, etc. The bridge is expected to have a useful life of 100 years, and the China Harbor Engineering Company (CHEC) served as the main contractor.

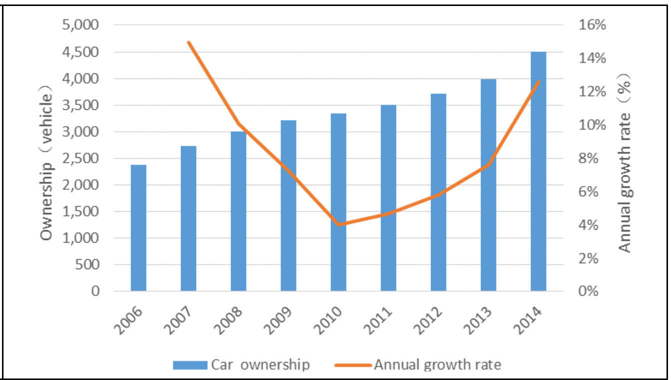
This report also analyzed traffic conditions prior to construction of the bridge. An analysis was held based on a questionnaire regarding changes in traffic dynamics and related expectations associated with construction of the bridge. According to the report, about 60% of the questionnaire respondents said they would like to buy a car after the bridge is completed. The report cites the possibility that the ownership rate of cars will increase in conjunction with an increase in income. Additionally, in a survey of Malé residents, about 45% of respondents said that they would like to move to Hulhumalé after the bridge was completed. Accordingly, the report stated the possibility of promoting relocation to Hulhumalé Island.

A more detailed analysis of the ratio of motorcycles to cars was conducted, and this report also shows that the ratio of motorcycles is overwhelmingly large. However, as of 2014, the number of car owners is said to be 4,493, which is an 89.4% rate of increase from 2006.

- 2006 Cars 10% (2,372), motorcycles 90% (22,113)
- 2014 Cars 7% (4,493), motorcycles 93% (56,503)



Percentage of cars and motorcycles



Number of car owners and rate of increase

Figure 3-3 Percentage and Rate of Increase of Vehicles in Malé Metropolitan Area

As a plan running until 2050, this report describes a comprehensive development plan for the Greater Malé Region centered on Malé Island. Specifically, this plan is called the 9 + 6 Greater Malé Program. In addition to the construction of bridges to connect four islands (Villingili and Gulhifalhu in the west; Hulhulé and Hulhumalé in the east), the plans also calls for the construction of a bridge between Thilafushi Island and Gulhifalhu Island in the west. Specifically, the plan assigns clear functions to each of the islands; for example, Gulhifalhu Island will function as a hub for freight transportation to other islands, while Hulhumalé Island will be positioned as a residential island.

Figure 3-4 Bridge Connection Plan in the Greater Malé Region

This clear assignment of functions is called the “7+1 Island Center Program.” Generally speaking, the following policies of land usage for each island are shown as a development plan running until 2050.

Malé

- Keep population within 120,000
- Move the cargo port to the west of the island and relocate some

residents to the east

Vilingilli

- Plan to become a cargo storage area
- Forecasted population of 15,000

Hulhulé

- Plan to become a business and airport area (transportation hub)
- Expected to create jobs

Hulhumalé I

- Plan to become a residential area
- Forecasted population of 60,000

Hulhumalé II

- Construction started in 2014. Plan to become a residential area
- Forecasted population of 100,000 people

Gulhifalhu

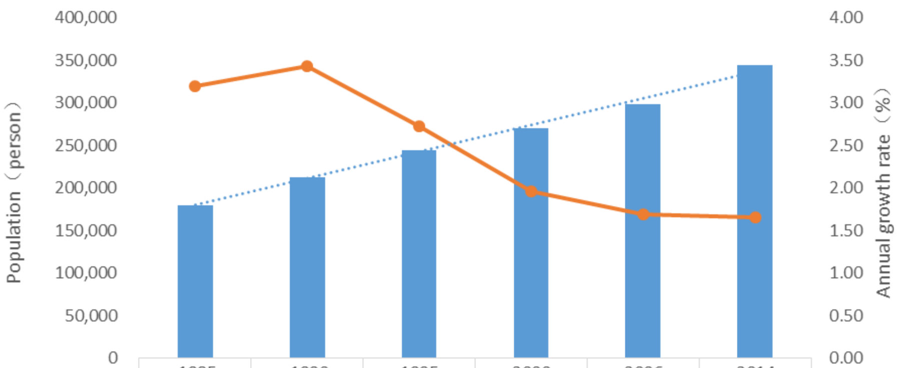
- Plan to compose of areas for a port, warehouses, and light industry

Funadhoo

- Plan to compose of areas for tourist industry and recreation facilities

This report also refers to population forecasting as a premise for traffic forecasting.

According to the population forecast data for all of the Maldives, for Malé, and for Hulhumalé throughout the Maldives, the population of Malé is increasing, but at a gradual rate. Also, the rate of population growth on Hulhumalé is expected to increase.



	1985	1990	1995	2000	2006	2014
Population	180,088	213,215	244,814	270,101	298,968	344,023
Annual growth rate	3.20	3.43	2.73	1.96	1.69	1.65

Figure 3-5　Forecast of Maldives Population

Table 3-2　Forecast of Population on Malé and Hulhumalé

Year	Malé	Malé annual growth rate	Hulhumalé	Hulhumalé annual growth rate
2018	112,000	0.52%	40,000	15.48%
2023	115,000	0.36%	65,000	8.56%
2028	116,000	0.28%	85,000	5.29%
2033	117,500	0.22%	100,000	4.31%
2038	119,000	0.19%	110,000	3.75%

In terms of traffic forecasts based on population dynamics, the report provides forecasts for the rate of increase in the amount of generated traffic volume and the amount of concentrated traffic volume, as well as for the traffic volume of each category. The generated traffic volume is the total volume of trips starting from a certain zone, and the concentrated traffic volume is the total amount of trips ending at a certain zone. That is, the generated traffic volume is a method of forecasting where and how much movement is occurring, while the concentrated traffic volume is a method of forecasting where and how much movement is concentrated. Generally speaking, the forecast results are used to estimate transportation demand and public transportation needs, and then used in the formulation of transportation service plans.

The forecast results for Malé Island, Hulhumalé Island, and Hulhule Island, where the airport is located, are shown below.

Table 3-3 Forecast for Rate of Increase of Generated Traffic Volume and Concentrated Traffic Volume in Malé, Hulhule, and Hulhumalé

Year		Malé	Hulhulé	Hulhumalé
2018	Generation	10.3%	6.2%	13.2%
	Attraction	10.0%	6.4%	13.6%
2023	Generation	5.9%	3.8%	7.3%
	Attraction	5.8%	3.8%	7.3%
2028	Generation	3.8%	2.3%	4.8%
	Attraction	3.8%	2.3%	4.8%
2033	Generation	2.5%	1.2%	3.4%
	Attraction	2.6%	1.2%	3.4%
2038	Generation	1.7%	0.3%	2.5%
	Attraction	1.7%	0.3%	2.4%

Table 3-4 Forecast of Generated Traffic Volume and Concentrated Traffic Volume in Malé, Hulhule, and Hulhumalé (number of times per day)

Year		Malé	Hulhulé	Hulhumalé	Total
2016	generation	17,250	6,932	13,505	37,687
	attraction	17,797	6,818	13,072	37,687
2018	generation	21,700	8,041	17,161	46,902
	attraction	21,876	7,984	17,042	46,902
2023	generation	30,539	10,129	26,526	67,194
	attraction	30,810	10,062	26,323	67,194
2028	generation	38,056	11,420	35,341	84,816
	attraction	38,422	11,337	35,057	84,816
2033	generation	44,371	12,356	43,091	99,817
	attraction	44,831	12,257	42,729	99,817
2038	generation	48,847	12,931	48,902	110,680
	attraction	49,403	12,816	48,461	110,680

3.1.2. Extraction of Technical Issues/Institutional Issues and Review of Financial Schemes Related to the Introduction of Light Rail

Based on the two reports listed above and on interviews with related organizations, we summarized technical issues associated with the introduction of light rail transit in the Hulhumalé, and then examined applicable countermeasures. Additionally, after summarizing institutional issues, we summarized improvement measures.

(1) Examination of public transportation methods

As described above, the Hulhumalé Development Cooperation is responsible for the development of Hulhumalé. The Hulhumalé Development Cooperation visited Toyama City for the 2019 JCM City-to-City Collaboration Seminar and expressed interest in convenient public transportation using light rail transit. This led to a request for examining introduction of light rail transit on Hulhumalé.

The development and introduction of public transportation must be done in accordance with objectives in conjunction with the development plan and policies of the region. Consequently, it is essential to engage in detailed forecasting and planning.

In this section of our report, we will reflect on the history of maintenance for light rail transit in Toyama City. In Toyama City, the development of light rail transit has been positioned as a solution to problems such as population decline and aging, automobile dependence, and depopulation of the central city area. Toyama City aims to achieve development of a compact city. A core project of these efforts was to increase the convenience of public transportation in the city by introducing light rail transit. In addition to alleviating traffic congestion, etc., light rail transit has produced results such as increasing the value of downtown areas and improving land prices. These projects were led by Mayor Masashi Mori, who has served as the mayor of Toyama since 2002. In addition to establishing the publicly-owned company Toyama Light Rail Co., Ltd., Mayor Mori has promoted approximately 30 related revitalization projects such as the Grand Plaza Maintenance Project, the Circulating City Tram Project (Centram), and the Machinaka Residence Promotion Project.

As a step toward shifting from city development that is dependent on automobiles to compact city development centered on public transportation, the decision was made to introduce light rail transit for the Toyama-ko Line. The Toyama City urban development plan seeks to create a structure in which public transportation connects urban areas scattered in each region, thus creating clusters and avoiding singular circularization. (In Japanese, this structure is referred to as *dango to kushi*, which refers to multiple rice balls being connected by a bamboo skewer.) The utilization of trams and other forms of public transportation was an essential element of this plan. In addition to reusing abandoned railway lines, Toyama City purchased the railway cars and leased them to the management company. Through such mechanisms, Toyota City has assumed responsibility for providing support such as avoiding the burden of cost, thus achieving the desired plan.

As illustrated by this example, when planning and introducing public transportation, it is important to obtain strong policy backing and to select the optimal transportation method in consideration of regional issues.

In order to ensure that light rail transit is also effectively introduced in the Hulhumalé region, it is important to clarify the current Master Plan in even greater detail and to implement a process for examining the optimal form while considering policy goals. Based on this understanding, we cooperated with the Hulhumalé Development Cooperation to review the following examination steps in our survey.

1. Select the optimal method of movement in Hulhumalé
2. Survey current conditions and analyze the results of introduction
3. Formulation of a Master Plan for introduction
4. Hold a detailed survey and engage in design
5. Introduce facilities (utilize the JCM system)

The general process for formulating a public transportation master plan is as follows.

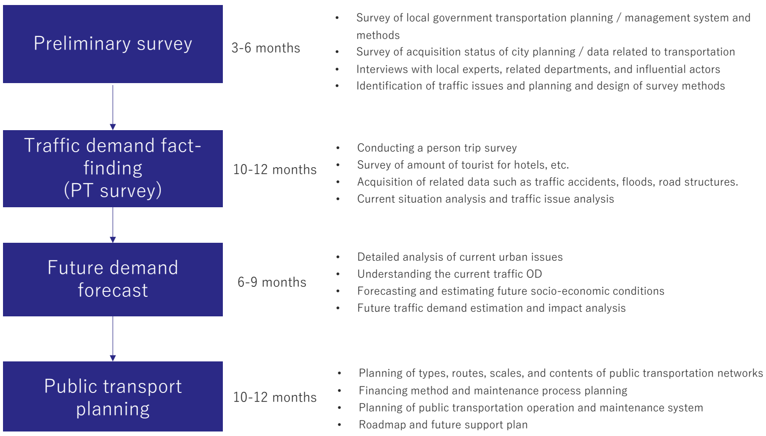


Figure 3-6 Formulation Process for Public Transportation Master Plan

Source) Created by Dainippon Consultant Co., Ltd.

Table 3-5 shows the main options for public transportation methods.

Table 3-5 Public Transportation Options

format	subway	monorail	LRT (elevated)	LRT (ground)	Bus (guideway)
Feature	Dedicated track by tunnel or viaduct Massive high-speed railway that runs	Orbital transportation that guided by a single rail	Light rail transit which runs on a dedicated track on the viaduct	Light rail transit which runs in orbit on the ground (road or open space)	A new transportation system that realizes semi-automatic driving that does not require steering operation by tracing this on a dedicated track equipped with a guide rail with a guide wheel. It can also be used as an ordinary bus on general roads
Example		Haneda	Yurikamome	Toyama	Nagoya
					
Advantages	Mass and high-speed transportation is possible	It is easy to elevate and only little space required. Little noise and vibration, and no gas emission.	Because it runs on a dedicated elevated track, there is no traffic congestion and accidents. The construction cost of the track structure can be saved by reducing the size and weight of the vehicle,	The ratio of dedicated tracks is high, and the operation is not easily affected by traffic. Larger transportation capacity than trams by forming several cargos	It will not be caught in traffic by separating it from other road. Barrier-free can be achieved by eliminating steps.
Disadvantages	High construction cost and long time required for construction work	Vehicles are more expensive and have less capacity compare with ordinary railways	Transportation volume is small and speed is slow for the construction cost	More expensive than trams	If will not reduce carbon emission unless switch it to electric or hydrogen buses.
Maximum transport capacity (person / hour / one way)	64,000	21,000	16,000	11,000	4,000
Profitability					
Construction cost	25-30 billion yen / km	6.5-14.5 billion yen / km	6.5 to 16.5 billion yen / km	Approximately 3.5 billion yen / km	Approximately 5 billion yen / km
Vehicle cost	Included	Included	Included	Approximately 300 million yen / both	Approximately 80 million yen / both
Operation cost				Approximately 610-840 million yen / 10km	Approximately 300-530 million yen / 10km

format	Bus (ground-only lane)	Bus Rapid Transit(BRT)	Share bike	SKYWAY
Feature	A transportation system that secures a dedicated driving lane and performs high-speed transportation	A system that can flexibly respond to road conditions by combining improvements such as driving routes, vehicles, stops, and fare collection based on fixed-route buses, and driving in general lanes.	Environmentally friendly, safe, active and efficient sustainable transportation. Actively used overseas as a complement to public transportation	The system of SkyWay, a Belarusian start-up company. High-speed driving (150km / h) is possible with a mechanism similar to a cable car.
Example	Jakarta	Tokyo BRT		Dubai
				
Advantages	It does not get caught in traffic by separating it from other road. Barrier-free can be achieved by eliminating steps.	By introducing IC card systems and road improvements, it achieves transportation capacity, functions and flexibility, same as trams.	It is environmentally friendly and the introduction cost is low.	Construction cost is low. about 1/10 of monorail
Disadvantages	Wide road space is required because it requires a dedicated lane on the general road.	Since it runs on general roads, it may cause traffic congestion.	It is just a complement. The maintenance of bicycle parking lots and the separation from pedestrians can be an issue.	Transportation capacity is small. The capacity is 7 to 168 people (when connected).
Maximum transport capacity (person / hour / one way)		3,120		
Profitability				
Construction cost		50-700 million yen / km		
Vehicle cost				
Operation cost				

Source) Created by Sato Kogyo Co., Ltd., from various materials

When considering the transportation volume required in Hulhumalé, it seems that light rail transit, monorail, EV bus, SKYWAY, etc., are highly-appropriate methods as low-carbon transportation alternatives to motorcycles and automobiles.

In the current fiscal year, we have comprehensively covered the contents of the preliminary survey in the general master plan formulation as shown in Figure 3-6. However, we will entrust the Maldivian Government and other donors with conducting more detailed surveys in the future. In this city-to-city collaboration project, we are examining an arrangement which focuses on studying the commercialization of the JCM Model Project for public transportation methods derived from the results of these surveys. These will be discussed further below in “(5) Examination results, future surveys, and project development policies” in this chapter.

(2) Transportation policies in Malé City

After holding discussions with Hulhumalé Development Cooperation and exchanging opinions on the examination policy discussed in (1) above, it was found that Malé City has the following policy.

First of all, the priority of public transportation is to implement transportation means which can be used instead of motorcycles and automobiles. Therefore, the policy of Malé City is to prioritize the convenience for residents. Although attention will also be given to the cost of construction and operation, convenience will be positioned as the highest priority. Accordingly, the Hulhumalé Development Cooperation seeks to design a route on which the distance to the nearest stop will be approximately 4 minutes on foot regardless of where on Hulhumalé Island the resident lives. The number “4 minutes” was originally derived because the distance between stops on public transportation is about 200 to 300 meters (a distance roughly equivalent to a 5-minute walk). However, a distance of 200 to 300 meters between stops does not satisfy the area required for acceleration or deceleration when operating a light rail transit or tram. This could make it difficult to operate such means of public transportation. Therefore, when considering the distance between stops, the operation of buses is a more appropriate means of transportation.

One advantage of operation via bus is that buses can be used for inter-island movement. Malé has a plan to connect all the islands in the Greater Malé Region with bridges, as described in the “9+6 Greater Malé Program” introduced above. Malé is considering a transportation network that spans these bridges. The concept is to use vehicles as the main form of inter-island movement. There is also a policy to reduce the volume of movement by marine ship.

However, we intend to continue to examine the implementation of light rail transit and trams. Consequently, it is necessary to consider plans that consider the optimal distance between stations based on the required area for acceleration and deceleration.

When examining the possibility of light rail transit, we must consider the issues of road width and securing temporary land for construction. For Hulhumalé, Phase II land on the east side of the island is available for use; however, Phase I land on the west side has already been developed and is home to residents. This makes it difficult to secure temporary land. Furthermore, in order to minimize obstructions to existing traffic, it is necessary to secure a number of road lanes during the construction period. Then, when actually operating the light rail transit system, there is the need for a marshalling yard (garage). Although land for a terminal has secured for the current public bus system, it is necessary to secure additional land when examining a new means of transportation.

Examination is organized as preliminary survey results in the TRANSPORT MASTERPLAN REPORT 2019. The report includes sections on long-term plans, long-term road network development plans, bus and other transit networks, performance evaluation of existing networks, economic and financial assessments, staging decisions and implementation, and preliminary engineering examination for transportation system security. The report lists information on four types of PMS: BRT, MRT, LRT, and AGT.

(3) Examination of funding scheme

In the track maintenance related to the introduction of light rail transit and the construction of station buildings, etc., the possibility of utilizing ODA, assistance from international organizations, financing schemes, etc., was examined through methods such as conducting surveys of literature and holding interview surveys with related organizations.

In November 2020, the Asian Development Bank published a report entitled “A BRIGHTER FUTURE FOR MALDIVES POWERED BY RENEWABLES, ROAD MAP FOR THE ENERGY SECTOR 2020–2030.”[10] According to the report, the Maldives faces issues with fund procurement in numerous development projects, including climate change mitigation projects.

The main limiting factor is said to be the low ability of the public sector to raise fund. It has been pointed out that the current state of development assistance is dependent on grants and soft loans.

It is has also been mentioned that in order to achieve NDC and the CO_2 emissions reduction target defined in SAP, the Maldives needs to consider technology transfer and financing by the following methods in the future.

・Sustainable support of plans and goals by multilateral development banks.

・There is the need to include bilateral cooperation with donor countries, and mechanisms for the transfer of knowledge and technology.

・Partnerships with foreign investors interested in introducing innovative renewable energy technologies.

・Enhanced sharing of knowledge with other island nations.

Additionally, it is necessary to promote access to domestic lending, not just public sector investment programs. Examples include the Maldives Fund, which uses taxes collected from tourists as funding, and the Green Loan scheme managed by the Maldives Bank.

On the other hand, in the case of developing public transportation infrastructure, the scale of funds is large and the investment is recovered over the long-term. This means that financing by a development bank is appropriate. Therefore, we conducted interviews with the Asian Development Bank, which has an extensive record of financing in the Maldives. We obtained information on the possibility of financing for public transportation development, as well as the construction of required systems and the required procedures. The main points are shown below.

First, as funding in 2019, the Asian Development Bank (ADB) achieved a commitment amount of approximately $20 billion. This amount includes loans, grants, investments and guarantees. In 2018, ADB announced Strategy 2030 as a guideline for assistance to developing member countries. While continuing efforts to eradicate extreme poverty, the ADB has committed to the following operational priorities based on an overall vision to realize a sustainable Asia-Pacific region that is affluent, inclusive, and resistance to shocks such as climate change and disasters.

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[10] ADB” A BRIGHTER FUTURE FOR MALDIVES POWERED BY RENEWABLES, ROAD MAP FOR THE ENERGY SECTOR 2020–2030”,November 2020.
https://www.adb.org/sites/default/files/publication/654021/renewables-roadmap-energy-sector-maldives.pdf

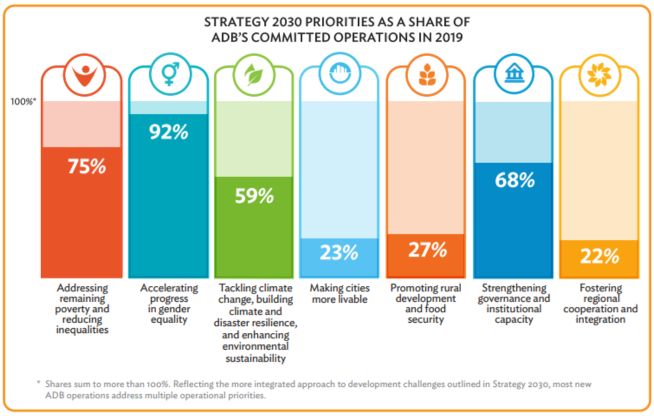


Figure3-7 Operational Priorities of the ADB Strategy 2030 and the Committed Business Ratio

Source) Asian Development Bank Annual Report 2019[11]

One of the operational priorities for Strategy 2030, is "Tackling Climate Change, Building Climate and Disaster Resilience, and Enhancing Environmental Sustainability." This theme focuses on scaling up support to address climate change, disaster risks, and environmental degradation; accelerating low GHG emission development; ensuring a comprehensive approach to build climate and disaster resilience; ensuring environmental sustainability; and increasing focus on the water–food–energy nexus. Through this focus, Strategy 2030 aims to increase the ratio of support for climate change mitigation and adaptation among work committed to by the ADB to more than 75% by 2030. Furthermore, another goal is to have the ADB apply USD 80 billion of its own funds to climate-related support during the period from 2019 to 2030.

Another operational priority is to "Making Cities More Liveable." In pursuit of this theme, the ADB works to increase the convenience, quality, and reliability of services in cities; to strengthen the sustainability of urban planning and finance; to increase the resilience of cities to environmental change and climate changes; and to improve disaster management. One example these efforts is the ADB support project in Guian, a rapidly growing new city in Guizhou Province, China.

The project will provide USD 192.8 million in funding for intelligent transportation systems that reduce pollution, alleviate traffic congestion, and improve traffic safety in the city. The funds will be used for real-time monitoring of traffic and road-related weather, a multimodal transportation operations center, traffic safety and emergency management systems, as well as sustainable transportation infrastructure such as clean energy buses and electric vehicle charging stations.

The project also includes a policy of defining small island developing countries as future priority countries.

From these plans and precedents of the ADB, we expect great lending potential for public transportation on Hulhumalé Island.

Conversely, a similar project of the ADB is a sovereign loan, which requires a government guarantee. Therefore, in this project as well, it has been pointed out that the government—for

[11] Asian Development Bank Annual Report 2019. https://www.adb.org/sites/default/files/institutional-document/650011/adb-annual-report-2019-jp.pdf

example, the Ministry of Transport—needs to formulate a national plan and then serve as a contact point for loan negotiations.

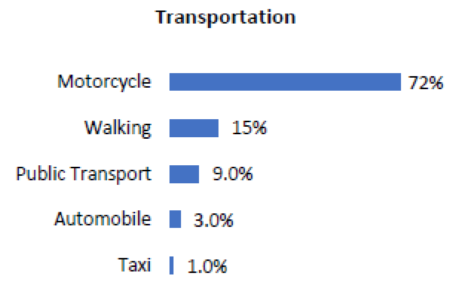
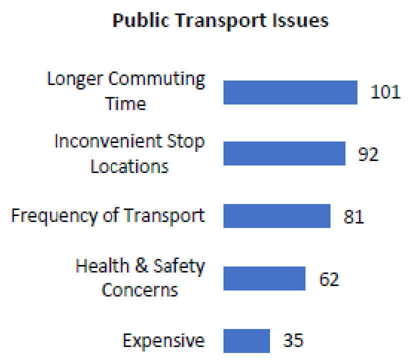
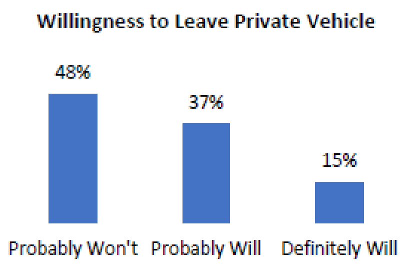
Therefore, it is necessary to encourage the involvement of the Ministry of Transport in this study and to formulate a concrete plan (Public Transport Master Plan) that will lead to financing. The plan should include elements that are in harmony with the operational priorities of ADB Strategy 2030.

(4) Considerations during the spread of COVID-19

In Hulhumalé Development Cooperation, a survey is being conducted to reflect the impact of the COVID-19 pandemic on urban planning. The survey was conducted in the form of a questionnaire and held from May 20 to 27, 2020. There were 360 respondents.

The following report was given in regards to public transportation.

Table 3-6 Results of Questionnaire Survey Following the Spread of COVID-19

<table>
<tr><td>
</td><td>Considering transportation, respondents mainly use motorcycles (72%), whereas only 9% use public transport.</td></tr>
<tr><td>
</td><td>The lack of preference for public transport is mostly due to longer commuting time and inconvenient stop locations.</td></tr>
<tr><td>
</td><td>52% of respondents who own private vehicles are willing to leave them in favour of an efficient public transport system.</td></tr>
</table>

Source) Materials provided by Hulhumalé Development Cooperation

72% of the respondents use motorcycles for their means of transportation, while 9% use public transportation (bus). The main reasons for the low ratio of public transportation was a long commute time and an inconvenient stop location. Approximately 16% of respondents raised concerns about safety, including health issues associated with the spread of COVID-19. It is estimated that a certain number of respondents worry about using public transportation.

On the other hand, 52% of the respondents (who own private vehicles) indicated their willingness to switch from private vehicles to public transportation if the convenience of public transportation improves. Based on these results, it is conceivable that a need for public transportation and a certain number of users can be secured even if the impact of COVID-19 is prolonged.

(5) Examination results, future surveys, and project development policies

As mentioned above, this survey analyzed existing plans and traffic volume data, and examined future processes and policies necessary for introducing public transportation systems. As a result, in order to properly analyze the form of optimal public transportation systems, it is necessary to first obtain traffic data which is currently lacking from the survey. We must then derive and evaluate the optimal public transportation system, and formulate a master plan which describes the introduction plan.

When formulating the master plan, there is room for considering the utilization of ADB Technical Assistance Program, including a balance with financial procurement required at the introduction stage. However, to ensure sufficient ties with this city-to-city collaboration project and sufficient room for entry by participating corporations, it is necessary to examine the utilization of Japanese technical cooperation programs, etc. One example of technological development and examination for implementation of smart transportation systems is The Project of Smart Transport Strategy for Thailand 4.0 using the JICA SATREPS Program[12]. This project seeks to curb the rapidly increasing volume of CO_2 emissions from automobiles in Bangkok, the capital of Thailand. By utilizing ICT technology to integrate and visualize big data and 3D data on Digital Earth, the project will construct a policy evaluation system based on the quality of life of citizens. Through this system, the project will contribute to the realization of policy-making which balances solutions for traffic problems, the realization of a low-carbon society, and the improvement of the total happiness of citizens.

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[12] Science and Technology Research Partnership for Sustainable Development. Jointly operated by the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA). A three-year to five-year research program for joint research with researchers in developing countries.

Figure 3-8 SATREPS Program Currently Being Implemented in Thailand

Source) Materials provided by Dainippon Consultant Co., Ltd.

Members of the SATREPS Program include Dainippon Consultant Co., Ltd., which participates in the city-to-city collaboration project. Toyama University is also listed as a proposing corporation. In parallel and conjunction with this city-to-city collaboration project, it is possible to consider other forms of collaboration. Examples include implementation of similar R&D projects and formulation of a public transportation master plans based on conditions in the Maldives.

3.1.3. Estimate of Current CO_2 Traffic Emissions and Estimate of Low-Carbon Effect from Introduction of Light Rail

There are few application cases of JCM in the transportation field. The same is true of CDM. CO_2 emitted from the transportation sector is said to account for one-fourth of the total emissions. Nevertheless, from among CDM projects registered with the UNFCCC, the reduction ratio for the transportation sector is said to account for approximately 0.09%.[13] This illustrates the difficulty of application to the transportation sector in market mechanisms.

On the other hand, when looking at the cases of methodology development, one project of reference is “Modal Shift through Development of Mass Rapid Transit (MRT).” This verification survey project was a joint venture between the Japan Weather Association and Almec conducted in 2012. This methodology targets the development of urban railways in the Bangkok metropolitan area of Thailand. The goal is to reduce GHG emissions through modal shift measures for traffic volume and improvement of traffic flow.

The outline of the methodology is as follows.

[13] Mitsubishi UFJ Morgan Stanley Securities “Contributions Toward the Resolution of Transportation CDM Issues” Energy Forum (monthly publication), December 2009 issue. https://www.sc.mufg.jp/company/sustainability/cef/article-04.html

Table 3-7 Draft of Methodology in "Modal Shift through Development of Mass Rapid Transit (MRT)"

	MRV Methodology
Eligibility Requirements	The methodology can only be applied to projects that meet all of the following requirements. ・Must include the establishment and extension of the MRT in cities. ・Applicable only to passenger transportation. ・The MRT must be an orbital transportation system. ・Under the reference scenario, a conventional transportation system must exist along the MRT route. ・There must be technology transfer and financial support from developed countries such as Japan in the construction or operation of the MRT.
Calculation options	The operator can select the option to calculate the effect of modal shift and the effect of road congestion alleviation. When calculating the effect of modal shift, the decision can be made regarding whether or not to use a passenger questionnaire.
Boundary	[Effect of modal shift] Limited to MRT zones.
	[Effect of road congestion alleviation] Roads that are affected by the development of MRT routes. Among the parallel roads on both sides of the MRT line, the roads that are closer to the line and are main road are targeted.
Reference scenario emissions	[Modal shift effect] ・(Transport volume by MRT (person-kilometer)) x (reference modal share ratio) x (CO_2 emission factor by modal) ・MRT transportation volume (person-kilometer): When the value can be obtained directly from the railway company, use that value. Otherwise, calculate the value via the following formula: Number of passengers riding MRT x average distance ridden in MRT). Calculations can be simplified by using the reference travel distance as the average distance ridden in MRT instead of the actual travel distance of individuals (from the departure point to the destination). ・Reference modal share ratio: Calculation Option 1-1: Without conducting a questionnaire, select a transportation mode (for example, a bus) that has a comparatively conservative emission factor. Calculation Option 1-2: Obtain the average percentage of all samples from the questionnaire survey. ・CO_2 emission factor by mode: In principle, use an eigenvalue for the project. If an eigenvalue cannot be obtained, use a default value.
	[Effect of road congestion alleviation] ・(Extension of route section of target road) x (Project traffic volume) x (CO_2 emissions factor by vehicle type at reference scenario vehicle speed) ・Extension of the route section of the target road: Measure on the map.

	・Project traffic volume: Use the traffic volume survey results obtained from monitoring. ・CO_2 emissions factor by vehicle type at reference scenario vehicle speed: Use the default value. Here, the reference scenario vehicle speed is set by the road QV relational expression. The road QV relational expressions are created from traffic volume surveys and travel speed surveys obtained from monitoring.
Project emissions	[Modal shift effect] ・(Power consumption amount associated with MRT operation) x (System power CO_2 emissions factor) *By setting the reference travel distance to the MRT average riding distance, emissions associated with terminal traffic are eliminated.
	[Effect of road congestion alleviation] ・(Extension of route section of target road) x (Project traffic volume) x (CO_2 emissions factor by vehicle type at reference scenario vehicle speed) ・The setting of each variable is the same as for the reference scenario emissions. ・The project vehicle speed is set from the travel speed survey obtained from monitoring.
Leakage	・Not targeted. *Road congestion alleviation effects are included in the reference scenario emissions and project emissions.

The applicability of this methodology and the setting of default values for the Maldives must to be examined according to the public transportation system to be adopted in the future.

Here, based on the concept of the above methodology, since there is some data that cannot be obtained at present, we will attempt a very simple trial calculation assuming the introduction of LRT.

Currently, the population of the Hulhumalé area is about 45,000. Public transportation is currently inadequate in the Hulhumalé area. Private vehicles or taxis are the main from of transportation. Movement within the district is expected to be dynamic; for example, traveling from home to work or going to a ferry port to travel to Malé or other areas.

In the case of the above methodology, the following values are set as project eigenvalues. These values are used for trial calculation.

Table 3-8 Business-Specific Value in the Methodology of "Modal Shift through Development of Mass Rapid Transit (MRT)"

	Transportation mode CO_2 emissions factor [gCO_2/km]	Passenger rate [people]	CO_2 emissions factor per transportation mode transit amount [gCO_2/people km]
Bus	1150.1	24.2	47.5
Motorcycle	38.2	1.3	29.4
Private vehicle	170.2	1.5	113.5
Railway			25.2

Traveling one loop around Hulhumalé Island is about 10 kilometers. It is assumed that 22,500 residents (half of the island's 45,000 residents) will travel 10 kilometers by some means.

Vehicle ownership in the above-mentioned Malé metropolitan area is 7% for cars and 93% for motorcycles. Based on these percentages, the calculation is performed as follows.

Table 3-9 Estimated CO_2 Originating from Transportation in Hulhumalé (current population)

	CO_2 emissions factor per transit amount [gCO_2/people km]	Number of users [people]	CO_2 emissions per day [tCO_2/day]	CO_2 emissions per year [tCO_2/year]
Motorcycle	29.4	20,925	6.15	2,244.7
Private vehicle	113.5	1,575	1.78	649.7
Total	-	22,500	7.93	2,894.4

The CO_2 emissions per transit amount for railways is 25.2g-CO_2 per person-kilometer.

Therefore, the CO_2 emissions (project emissions) when 22,500 people travel 10 kilometers are 5.67 tons of CO_2 per day (2,069.5 tons of CO_2 per year).

The amount of emissions reduction will be 824.9 tons of CO_2 per year.

As mentioned above, Hulhumalé envisions a population of 160,000 in the future. Since the public transportation system is planned and designed based on this future population, we will make trial calculations assuming this population size.

Similar to the current population-based calculation, we will consider a case in which a distance of 10 kilometers is traveled by half of the population of 160,000 people. It has been pointed out that there is an increasing trend for the ratio of automobiles within the vehicle ownership rate. However, in our calculation, we will make a conservation estimate using the current ratio. The result of calculations in this case is as follows.

Table 3-10 Estimated CO_2 Originating from Transportation in Hulhumalé (future population)

	CO_2 emissions factor per transit amount [gCO_2/people km]	Number of users [people]	CO_2 emissions per day [tCO_2/day]	CO_2 emissions per year [tCO_2/year]
Motorcycle	29.4	74,400	21.87	7,983.8
Private vehicle	113.5	5,600	6.35	2,319.9
Total	-	80,000	28.23	10,303.8

The CO_2 emissions per transit amount for railways is 20.16 tons of CO_2 per day (7,358.4 tons of CO_2 per year). Therefore, amount of emissions reduction is 2,945.4 tons of CO_2 per year.

In the JCM Project, railway cars are considered as a target of facilities subsidies. When including all equipment such as tracks, station buildings, etc., the construction cost of light rail transit ranges from 2 to 4 billion yen per kilometer. The cost of maintaining about 10 kilometers of railway is expected to range from 20 to 40 billion yen. As described above, the use of finance from the ADB will be reviewed for the construction cost of this infrastructure.

In the case of Toyama City Light Rail, the acquisition price of three light rail cars is about 800 million yen. The depreciation period of vehicles is 13 years, which corresponds to the “Train” item of “Railroad or track Vehicles” according to the Ministry of Finance's “Attached Table for Ministry Ordinance on the Useful Life of Depreciable Assets.” Cumulative CO_2 emission reductions over a 13-year period are 38,290 tons of CO_2. If 50% of the rail car cost of 800 million yen is subsidized, the cost-effectiveness of 400 million yen will be 10,446 yen per ton of CO_2.

The cost-effectiveness is low due to the scale of the JCM Model Project. In this estimation, the acquisition of eigenvalues for the project, the effect of alleviating road congestion, and the estimated number of users are assumed values. Moving forward, we will calculate and verify more precise values through transportation demand surveys scheduled for the future, and through evaluation of modal shift effects.

3.1.4. Implementation System and Schedule

This project starts from the planning and proposal of a future public transportation infrastructure system. Numerous preparations and decisions must be made to achieve the commercialization of JCM. On the other hand, this is also a theme for which city-to-city collaboration is most effective. For example, the formulation of public transportation policy in Toyama City can be used as a reference for good practice. We will continue our examination while keeping an eye on the utilization of other programs. Ultimately, we envision that ADB financing will be used to develop public transportation infrastructure and that the JCM Model Project will be used for rail cars. However, we are also considering the possible utilization of other programs such as The Japan Fund for the Joint Crediting Mechanism (JFJCM), which is one of the lending programs operated by the ADB.

In the case of the JCM Model Project, we are examining a system for constructing an international consortium with an urban transportation operators. The operators are headed by Sato Kogyo Co., Ltd., which is in charge of LRT maintenance in Toyama City and has extensive experience in overseas urban transportation maintenance.

The contractors for ADB loan projects are selected through international competitive bidding. It would be ideal for Sato Kogyo to bid on the project and promote commercialization together with the JCM Model Project. For this reason, it is necessary to collaborate and cooperate with organizations such as the Ministry of Transport of the Maldives from the stage of formulating a public transport master plan that determines project policy and of examining the technology to be introduced.

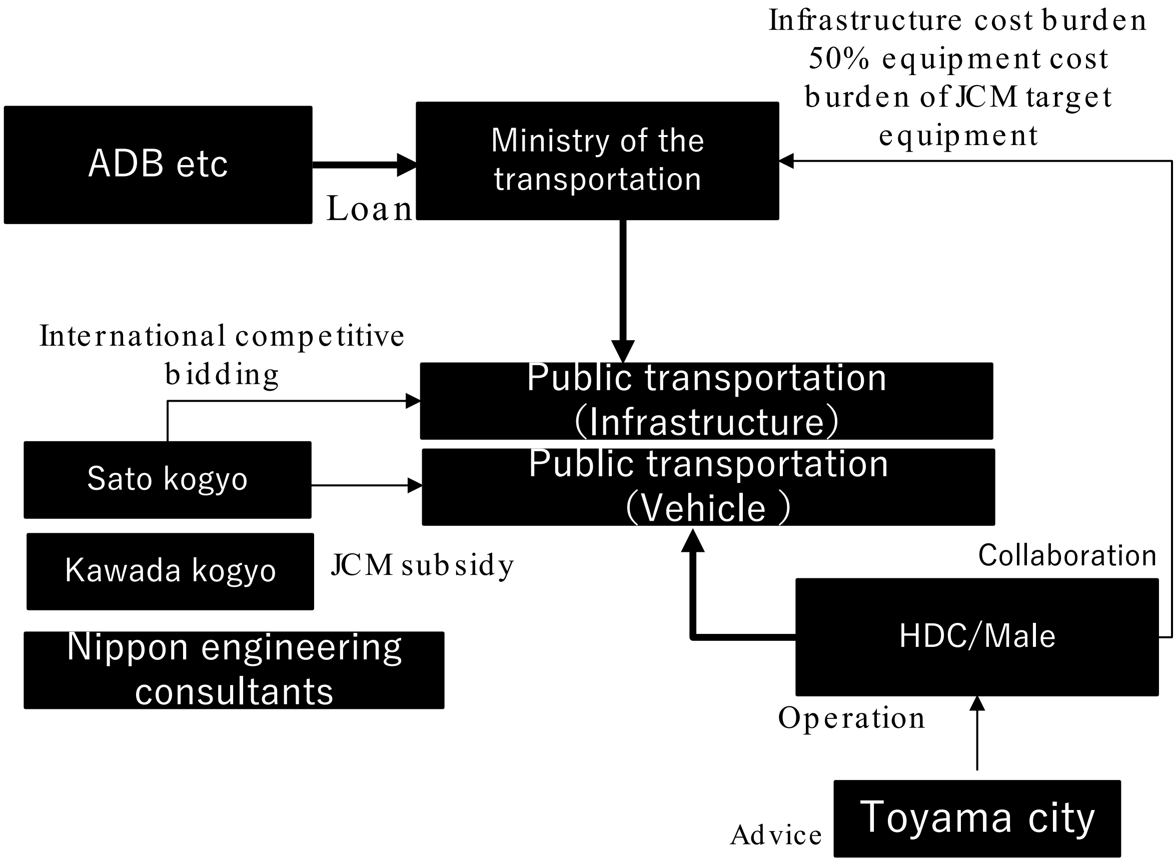

Figure 3-9 Draft of JCM Project Implementation System for LRT Public Transportation System

3.2. Low-Carbon Power Generation by Converting Diesel Power Generators to Natural Gas

Due to land and resource constraints unique to an island nation, the Maldives mainly uses diesel fuel as an energy source for power generation. Diesel power generation has the advantages of being compact and lightweight with respect to output, being suitable for any type of location, and having high startability and high thermal efficiency. Consequently, diesel fuel is still the main power source in remote island regions around the world, including Japan. Even though renewable energy such as solar power is spreading and expanding, we have no choice but to depend on diesel power generation as a base load power source that responds to load fluctuations. However, as a low- carbon technology option, is conceivable to use natural gas co-firing for existing diesel power generation equipment.

Natural gas emits less CO_2 per thermal unit than diesel. As such, it is known as a relatively clean energy source. Amidst the global trend of decarbonization, natural gas is positioned as nothing more than a technology for use during the transition to renewable energy. Still, when considering that it will take an extremely long time until we are able to obtain all required power from renewable energy, natural gas is an effective measure to reduce CO_2 emissions as much as possible in the short-term with a small investment. Additionally, the main component of natural gas is methane. There are also biotechnologies and technologies for synthesis from hydrogen, so it is possible to pursue the complete elimination of carbon. This creates the merit of being able to effectively use the existing infrastructure. In this survey, we investigated the following items, and we examined the conversion to natural gas co-firing by renovating the existing diesel power generation equipment.

3.2.1. Analysis of Maldives National Energy Plan and Malé City Energy Plan (fields such as natural gas utilization, etc.)

The "Maldives Energy Policy and Strategy"[14] is a five-year plan, with the most recent plan covering the period from 2016 to 2020. From 2021, the Maldives will transition to a new Maldives Energy Policy and Strategy which is currently being compiled.

The Maldives Energy Policy and Strategy for the period from 2016 to 2020 shows the amount of fuel imports as of 2015. In the Maldives, there is no domestic production of energy resources except for renewable energy, so the country depends on imports for all primary energy. The breakdown of fuel imports is reported as follows.

[14] MINISTRY OF ENVIRONMENT AND ENERGY REPUBLIC OF MALDIVES "MALDIVES ENERGY POLICY & STRATEGY",2016.
URL:https://www.environment.gov.mv/v2/wp-content/files/publications/20161220-pub-mv-energy-policy-strategy-2016-20dec2016.pdf

Table 3-11 Amount of Fuel Imported in the Maldives (2015)

Type of Energy	Value	Unit
Gas for cooking (LPG)	12,835	Mt/year
Diesel	389,968	Mt/year
Gasoline	38,683	Mt/year
Aviation gas (Avigas)	65,299	Mt/year
Total	506,334	Mt/year

As you can see, diesel fuel accounts for approximately 80% of fuel imports. In addition to power generation on each island, diesel is also used for large vehicles and ships. In regards to these energy conditions, the Maldives Energy Policy and Strategy defines the following nine key policies for the future.

1. Provide all citizens with access to affordable and reliable supply of electricity
2. Achieve carbon neutrality in the energy sector by year 2020
3. Promote energy conservation and energy efficiency
4. Increase national energy security
5. Promote renewable energy technologies
6. Strengthen the management capacity of the energy sector
7. Adopt an appropriate pricing policy for the energy sector
8. Ensure customer protection
9. Enhance the quality of energy services

In addition, the following seven items are listed as the guiding principles of energy policy in the Maldives.

1. Create an enabling environment for the growth of a reliable and sustainable energy sector and meet the constitutional obligation of Government in the provision of electricity to every inhabited island at reasonable standards commensurate to the island
2. Reduce overreliance of the energy sector and the national economy on fossil fuels through the diversification of energy supplies
3. Improve energy efficiency and energy conservation
4. Encourage the adoption of low-carbon technologies in production, distribution and energy consumption through promotion of a healthy lifestyle
5. Exploit local energy resources and renewable technologies
6. Engage private sector participation in the development of the energy sector, energy services and quality assurance mechanisms
7. Ensure energy equity through social protection and mechanisms and/or safety nets for vulnerable groups of the population

Examining these key policies and guiding principles leaves no doubt that the core of energy policy in the Maldives is to reconsider the bias on diesel energy usage and shift to decarbonization. Nevertheless, as of 2021, energy usage conditions focused on diesel power generation continue to exist, although there is an increase in the introduction of renewable energy such as solar power. These conditions require drastic improvement.

3.2.2. Technical and Economic Review of Natural Gas Supply Potential

(1) Technical examination for the possibility of natural gas supply

① Overview of natural gas supply and power generation technology

Natural gas is a flammable gas that is used as "city gas" in Japan. It refers to naturally stored gas containing carbon compounds such as methane and ethane.

In Japan, there are underground reserves of natural gas in Hokkaido Prefecture and Chiba Prefecture. Even today, natural gas is still mined and produced from water-soluble gas fields at the Minami Kanto gas field in Chiba Prefecture. Gas fields are widely distributed throughout the world. Main production areas include Asia, the Middle East, Africa, the United States, and Australia. In Asia, in addition to China, Vietnam and Indonesia, a large amount of production takes place in Central Asian countries such as Kazakhstan and Turkmenistan. The North Field in Qatar has the largest recoverable reserves in the world.

When using natural gas, the demand areas are located far away from the mining and production point. Consequently, efficient transportation is performed via pipeline or liquefaction. Pipelines are suitable for long-distance, large-capacity transportation. For example, the Druzhba Pipeline is the world's longest pipeline. With a total length of 4,000 kilometers, it delivers gas from Samara in Russia to Eastern European countries. On the other hand, the initial cost of pipelines is enormous, and transportation to areas across the sea poses an issue in terms of profitability.

Accordingly, Japan and other island countries mainly use the method of importing liquefied natural gas by tanker. Natural gas is liquefied by cooling it to -162°C at atmospheric pressure. The volume is compressed to about 1/600 so that a greater amount of gas can be transported with a small volume. This improves the transportation cost and portability are improved.

LNG needs to be regasified in order to be used as gas. Regasification is the process of returning natural gas to a gaseous state by raising the temperature of LNG to trigger evaporation. Therefore, when using natural gas, there is the need for regasification facilities, LNG storage facilities, and land.

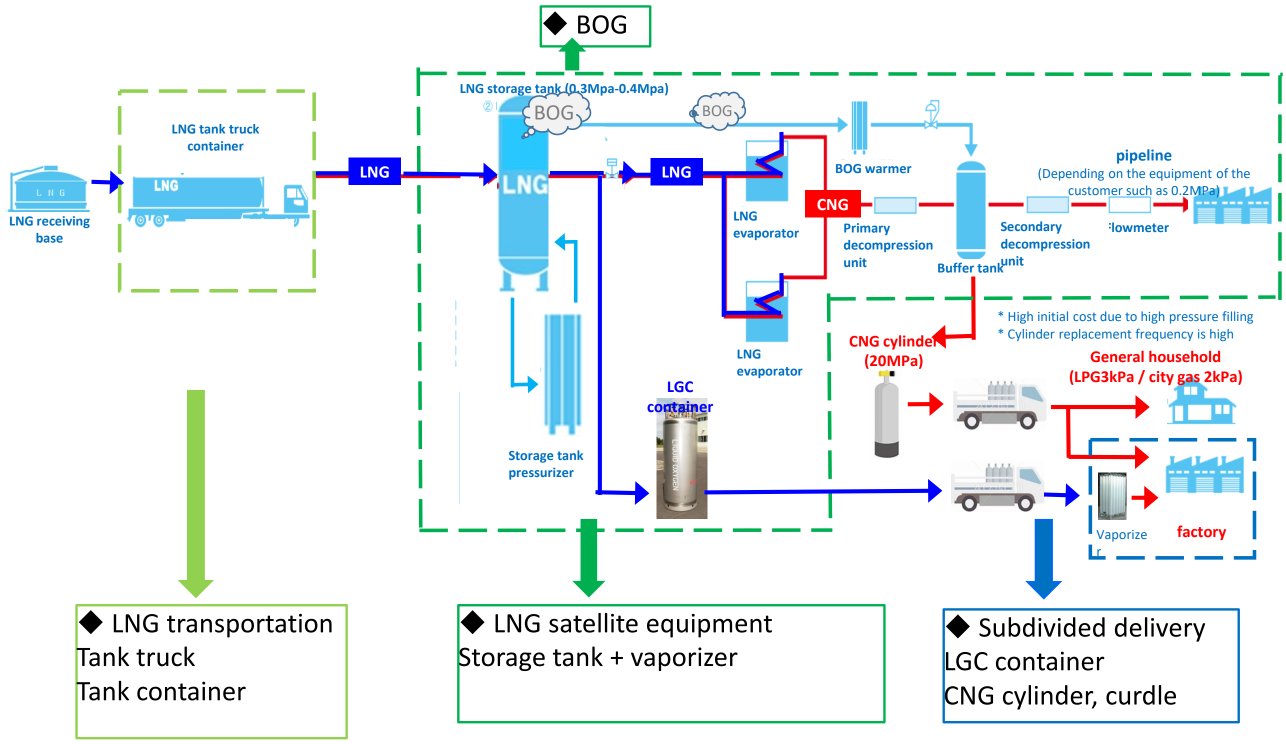

Figure3-10 Process Flow Diagram for LNG Delivery, Storage, and Gasification

Source) Created by Hokusan Co., Ltd. based on various materials

Power generation technology using LNG as fuel is generally divided into steam power generation using steam turbines and combined cycle power generation that integrates gas turbines and steam turbines. The first element of combined cycle power generation is gas turbine power generation, which burns fuel in compressed air to generate combustion gas and rotates a generator via expansion power. The second element is steam power generation, which recovers residual heat from exhaust gas and is used for steam turbines. Combined cycle power generation is highly efficient and the equipment can be contained in a relatively small facility. It also has the advantage of high responsiveness to starting and stopping.

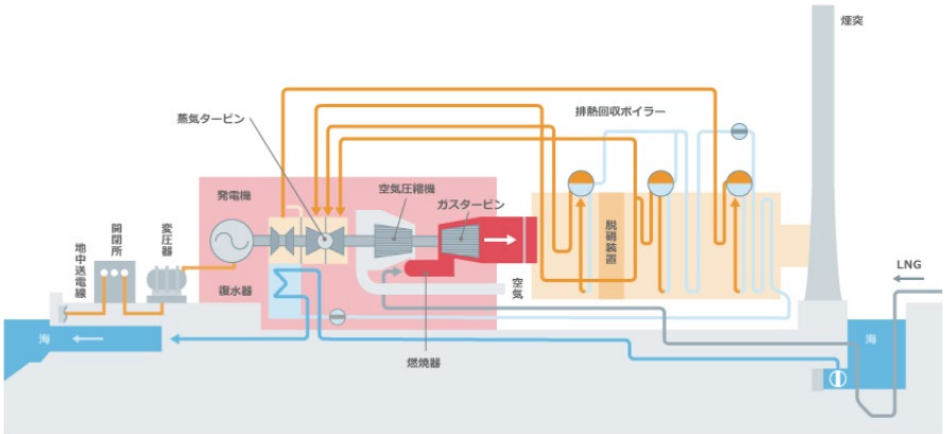

Figure 3-11 Construction Image for Combined Cycle Power Generation

Source) JERA https://www.jera.co.jp/business/thermal-power/type

② **LNG introduction plan in the Maldives and Malé region**

STELCO is an electric power company responsible for shipping electricity in the Greater Malé region. In its 2019 Annual Report, STELCO announced its investment plan for future power generation composition. The report makes reference to investment in LNG, solar power, battery technology, and hybrid systems.[15]

The capacity of the LNG power generation facility envisioned by STELCO is assumed to be 200 MW. Construction of facilities is planned for Thilafushi Island. STELCO formulated this plan because it views clean and low-priced LNG as preferable to diesel. This decision was reached because demand in the Greater Malé Region is estimated to exceed 260 MW, and because electricity generation in the Greater Malé Region is one-fourth of total generation in the Maldives. STELCO plans to continue using the existing diesel power plant for load adjustment.

Figure 3-12 Power Grid Development Plan for the Greater Malé Region

This plan is reflected in the BUR (Biennial Update Report to the UNFCCC) which is submitted by the Maldivian Government to the UNFCCC. The plan to promote the use of LNG can be interpreted as one mitigation measure.[16]

LNG supply is an issue of using LNG in the Maldives. Currently, LPG (liquefied petroleum gas) is being imported as cooking gas in the Maldives, but the country has no record of importing LNG. Therefore, it is necessary to develop a new procurement route.

In response to this issue, review is being given to transporting LNG to the Maldives with Sri Lanka as a hub. In the past, Sri Lanka has developed power with a focus on coal-fired power. However, the

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15 STATE ELECTRIC COMPANY LIMITED(STELCO)"ANNUAL REPORT",2017.
URL:https://www.stelco.com.mv/download/stelco-annual-report-2017?wpdmdl=5602&refresh=600bb5ef7547f1611380207

16 MINISTRY OF ENVIRONMENT "MALDIVES FIRST BIENNIAL UPDATE REPORT TO THE UNFCCC",2019.
URL:https://unfccc.int/sites/default/files/resource/First%20BUR%20of%20Maldives.pdf

country is now considering the introduction of natural gas-fired power in response to opposition from citizens and in conjunction with policies for the selection of cleaner energy.[17] Sri Lanka is now considering the introduction of FSRU as an LNG import port and hub. In August 2020, a Sri Lankan investment commission collaborated with Pearl Energy (Pvt) Ltd. to establish the Hambantota LNG Hub,[18] a floating facility for LNG storage and trading in Hambantota Harbor. Feasibility studies for these projects in Sri Lanka are implemented with the ADB budget, and LNG exports to the Maldives are envisioned in the study.[19][20]

In this way, a supply chain for utilizing LNG in the Maldives is in the process of being built. However, power lines are an issue in regards to the plan for constructing an LNG thermal power plant on Thilafushi Island. To address this issue, plans are currently underway to build a bridge between Thilafushi Island and Malé Island. India is taking steps toward funding this project.[21] Specifically, in August 2020, the Indian Foreign Minister Subrahmanyam Jaishankar promised a USD 100 million subsidy for construction of the bridge and a further USD 400 million in new financing credit.

However, it is forecasted that the project will require somewhere from 5 to 10 years to complete when considering the upcoming bridge design, financial planning, construction preparation, and actual construction.

When considering the need to quickly reduce emissions, it is not possible to wait for the completion of power plants and transmission lines; instead, it is necessary to take some mitigation measures against the dependence on existing diesel power generation.

The position of the LNG utilization proposal in this city-to-city collaboration project is to minimize CO_2 emissions as much as possible. This will be done by examining the utilization of LNG for carbon reduction at base load diesel power generation facilities which must operate in order to achieve load adjustment, while at the same time prioritizing the introduction of renewable energy. Specifically, the plan will employ a method of converting existing diesel equipment for use in natural gas co-firing power generation. The next section shows the examination results of the introduction plan and LNG supply plan.

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[17] "Project on Electricity Sector Master Plan Study in Democratic Socialist Republic of Sri Lanka," 2018. Japan International Cooperation Agency (JICA), Tokyo Electric Power Company Holdings, Inc. (TEPCO HD), TEPCO Power Grid, Incorporated (TEPCOPG), Tokyo Electric Power Services Co., Ltd. (TEPSCO). URL:https://openjicareport.jica.go.jp/pdf/12303665_01.pdf

[18] LNG INDUSTRY"Agreement signed to launch a floating storage LNG facility in Sri Lanka",25 August 2020. URL:https://www.lngindustry.com/liquid-natural-gas/25082020/agreement-signed-to-launch-a-floating-storage-lng-facility-in-sri-lanka/

[19] Asian Development Bank "Sri Lanka: Supporting Feasibility Study and Survey to Adopt Liquefied Natural Gas (LNG) Power Generation to Diversify Energy Mix",2020. URL:https://www.adb.org/projects/53193-001/main#project-pds

[20] AVAS" Gas hub to be developed in Sri Lanka; will supply fuel to Maldives",24 Jun 2019. URL:https://avas.mv/en/65905

[21] DW.com" India seeks to counter China influence in Maldives with bridge project", 13 Aug 2020. URL:https://www.dw.com/en/india-seeks-to-counter-china-influence-in-maldives-with-bridge-project/a-54555981

③ Introduction plan

1) Facilities being introduced

As discussed above, this proposal does not assume perpetual use of LNG power generation. Instead, as a stepping stone in the process of reducing carbon, it envisions the introduction of technology for converting existing diesel power generation equipment into co-firing equipment. This is called Dual Fuel (DF) technology. DF technology has been introduced to large ships and vehicles with diesel engines, and has also been used with power generation equipment. DF technology was also utilized in the 2018 JCM Model Project entitled “Introduction of CNG-Diesel Hybrid Equipment to Public Bus in Semarang.” Hokusan Co., Ltd. (a joint implementer of the city-to-city collaboration project) is the head operator of the JCM project.

DF technology can be applied to all diesel engines, whether in vehicles, ships, or generators. By mixing the diesel fuel sprayed in the engine with the gas, the amount of diesel used can be reduced and a low-carbon effect can be obtained. At the same time, DF technology is expected to be cost-effective due to the difference in thermal units. Moreover, since only devices such as a gas tank, piping, a supercharger, and a control need to be added to the existing diesel generator, there are merits in terms of construction cost and construction period.

Gas conversion technology for diesel power generation equipment is used in regions such as Europe, China, and India. The technology is also possessed by manufacturers of heavy electric machinery and engineering companies in Japan. For example, JFE Engineering Corporation has developed a gasification conversion technology for dual fuel engines. This technology has a track record of operating for 20,000 hours and a natural gas fuel ratio of 95%, making it one of the most efficient facilities in the world. In developing countries, there is a tendency to emphasize price superiority over performance. Even so, there is a possibility that gas conversion technology will be utilized through implementing JCM Model Projects which stipulate use of the technology, and by securing price competitiveness.

JFE Engineering Corporation has already delivered nine facilities in Japan and overseas, including in countries such as India and Indonesia. This gives JFE a strong market advantage in developing countries.

Introduction record in India (NEDO demonstration)

Introduction record in Indonesia

Figure 3-13 Example of DF Technology at JFE Engineering Corporation

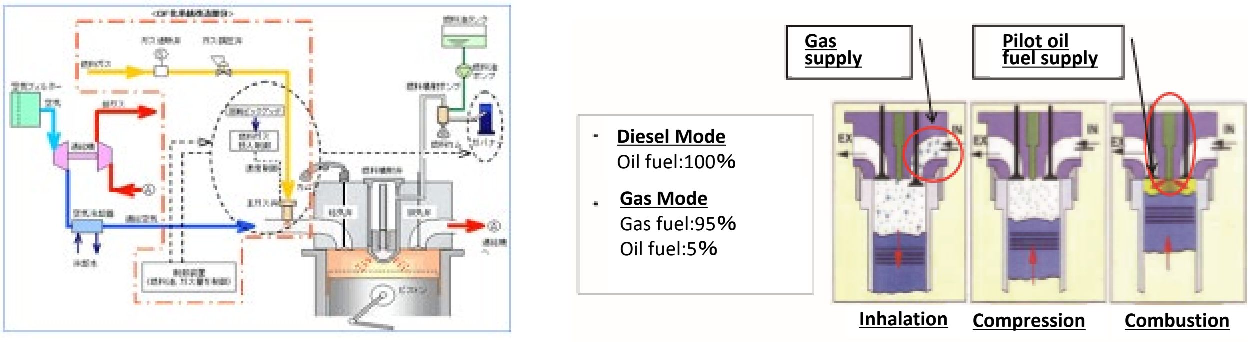

Figure 3-14 Combustion Image for Natural Gas Co-Firing

Source) JFE Engineering Corporation[22]

2) LNG supply

In regards to the procurement of LNG, it is obvious that transportation via a pipeline from producing countries is not realistic because the Maldives is an island nation. This means that the only option is importing liquefied natural gas (LNG). However, due to a lack of available land on Malé Island and Hulhumalé Island, there are challenges in developing the necessary facilities; that is, bases for receiving natural gas.

Therefore, one candidate method for supplying natural gas to the Maldives is the introduction of a floating storage and regasification unit (FSRU). An FSRU is an offshore LNG receiving terminal. It fulfills following functions: 1) receiving LNG offshore from a tanker that has transported natural gas in the form of LNG from the production area, 2) regasifying the LNG, and 3) supplying the natural gas to land. An FSRU can be conceptualized as a ship that is equipped with facilities such as LNG tanks and regasification equipment. FSRU can be introduced at low cost and in a short period of time, so they are being introduced all over the world. For example, the introduction of an FSRU is envisioned for the plan to establish an LNG base in Sri Lanka as discussed above.

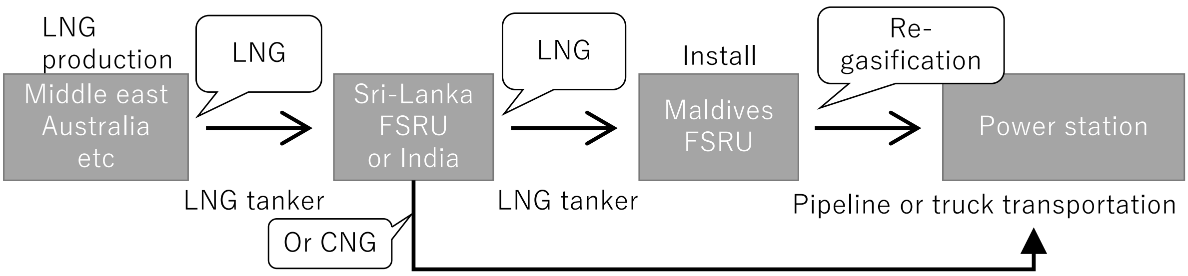

Figure 3-15 Natural Gas Supply Chain from Country of Origin to the Maldives

[22] Taken from "Dual Fuel Engine Gas Fuel Conversion Technology" by JFE Engineering Corporation, January 2013, JFE Technical Report No.31, pp. 89-90, https://www.jfe-steel.co.jp/research/giho/031/pdf/031-22.pdf

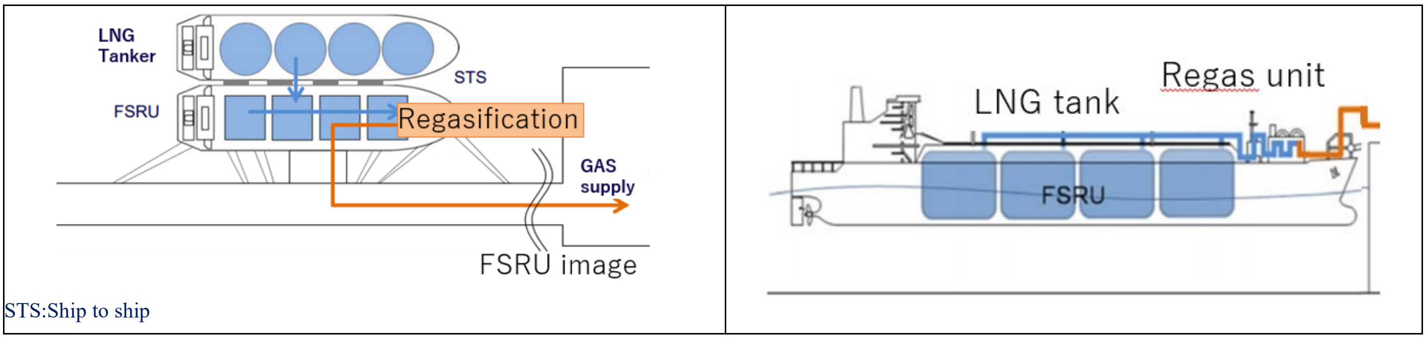

Figure 3-16 Conceptual Diagram of FSRU

Source) Japan Oil, Gas and Metals National Corporation[23]

As discussed above, under support from the ADB, the plan consists of supplying Sri Lanka with a large amount of LNG from the Middle East, Australia, etc., via tankers. In addition to supplying LNG thermal power, etc., for Sri Lanka, the country will also serve as a supply hub to the Maldives through reloading of LNG on to small LNG transport vessels.

For this supply chain, the size of the FSRU is considered based on the annual required amount. First, the amount of diesel consumed for diesel power generation in the Greater Malé Region is 239,000 liters per day (87 million liters per year) on Malé Island and 52,000 liters per day (19 million liters per year) on Hulhumalé Island. In total, this amounts to 290,000 liters per day (106 million liters per year).

When converting this value into heating value, the generated heating value per liter of kerosene is 38.2 MJ, so the total for both islands is 4,057,413 GJ per year. Of this amount, it is assumed that 95% of the heating value, that is, 3,8545,42 GJ per year, will be replaced with natural gas.[24] Since the unit generated heating value per 1 kilogram of LNG is 54.5 MJ (0.0545 GJ), 70,726 tons of LNG is required per year when replacing the same amount of heating value with natural gas.

Looking at the scale of the world's major FSRUs, the annual capacity is 400,000 to 5,000,000 tons per year.[25] When considering supply only for the existing power generation on Malé Island and Hulhumalé Island, demand is extremely small compared to the scale of the existing FSRU. Therefore, when considering the cost effectiveness, it is necessary to consider further expanding the use of LNG. For example, DF technology is also applicable to diesel engine vessels. Furthermore, remote islands outside of the Greater Malé Region also depend on diesel power generation. Consequently, it is necessary to consider the compression of regasified natural gas on Malé and use of the resulting substance as CNG (Compressed Natural Gas) for power generation on remote islands.

Table3-12 Main FSRUs in the World and Scale of FSRUs

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[23] Japan Oil, Gas and Metals National Corporation "Globally Expansion of FSU & FSRU (Floating LNG Acceptance Bases)," 2013.
URL:https://oilgas-info.jogmec.go.jp/_res/projects/default_project/_project_/pdf/5/5033/1312_b02_nagai_FSRU.pdf

[24] The value of 95% is based on the specifications of JFE Engineering Corporation.

[25] Japan Oil, Gas and Metals National Corporation "Trends in the Natural Gas/LNG Market and Expansion of Demand through FSRU," Oil & Natural Gas Review, Vol. 52, No.1, 2018.
URL:https://oilgas-info.jogmec.go.jp/_res/projects/default_project/_project_/pdf/8/8081/201801_045a.pdf

Area	Country	Project	Year	Project owner	Ship name	Capacity Mil-t /year
Asia	Pakistan	Port Qasim、Karachi/ (EETPL)	2015	Excelerate Energy	Exquisite	5.7
	Pakistan	Port Qasim、Karachi/PGPL	2017	BW Offshore	BW Integrity	6.2
	Indonesia	Nusantara Regas Satu/West Java	2012	Golar LNG	Nusantara Regas Satu	3.7
	Indonesia	PGN Lampung	2014	Höegh LNG	PGN Lampung	3
	Indonesia	Benoa、Bali	2016	Pertamina	FRU+FSU	0.4
	China	Tianjin LNG	2013	Initially accepted LNG at FSRU. After that, gas equipment was installed on land. Operates LNG as FSU according to demand.		-
	Malaysia	Melaka	2013	Petronas	Tenaga Satu	2.6
	Malaysia	Melaka	2013	Petronas	Tenaga Empat	2.6
EU	Lithuania	Klaipeda	2014	Höegh LNG	Independence	2.9
	Turkey	Etki LNG FSRU	2016	Höegh LNG	GdF Suez Neptune	5.6
	Italy	OLT Offshore LNG Toscana	2013	OLT	FSRU Toscana	4.4
	Malta	Malta LNG	2016	Bumi Armada	Armada LNG Mediterrana (FSU)	0.4
	UK	Teesside Gasport	2007	Shut down		
Middle east	UAE	Jebel Ali/Dubai	2010	Excelerate Energy	Explorer	4.1
	UAE	Ruwais/Abu Dhabi FSRU	2016	Excelerate Energy	Excelerate	4.1
	Israel	Hadera Gateway	2013	Excelerate Energy	Excellence	-
	Egypt	Ain Sokhna	2015	Höegh LNG	Höegh Gallant	4.1
	Egypt	Ain Sokhna	2015	BW Offshore	BW Singapore	5.6
	Kuwait	Mina Al-Ahmadi	2009	Golar LNG	Golar Igloo	5.5
	Jordan	Aquava/Al-Sheikh Sabah LNG	2015	Golar LNG	Golar Eskimo	5.5
North America	USA	Neptune	2010	Shut down		
	USA	Northeast Gateway	2008	Shut down		
	USA	Gulf Gateway	2005	Shut down		
South America	Argentina	Bahia Blanca	2008	Excelerate Energy	Exemplar	4.1
	Argentina	GNL Escobar	2011	Excelerate Energy	Expedient	4.1
	Columbia	Cartagena	2016	Höegh LNG	Höegh Grace	4.1
	Jamaica	Montego Bay/Bogue LNG	2016	Golar LNG	Golar Arctic (FSU)	0.5
	Brazil	Pecem	2009	Excelerate Energy	Experience	6.6
	Brazil	Bahia/TRBA Salvador	2014	Golar LNG	Golar Winter	3.8
	Brazil	Baia de Guanabara	2009	Golar LNG	当初、Golar Sprit号で受け入れ	1.9

Source) Japan Oil, Gas and Metals National Corporation "Trends in the Natural Gas/LNG Market and Expansion of Demand through FSRU,"[25]

This consideration is also important in regards to the cost strategy of energy imports. In hearings with the State Trading Organization (STO), consumption of diesel fuel will decrease due to import of LNG and the import price of diesel per unit will increase. This means that the price of supplying diesel to remote islands will increase. As pointed out, this issue must be considered in regards to the introduction of LNG.

The Greater Malé Region alone accounts for about 40% of the total power generation in the Maldives. Accordingly, converting only the Greater Malé Region to LNG co-firing will have a significant impact on the diesel imports throughout the Maldives. Specifically, there is concern regarding an increase in the price of supplying diesel to remote islands, which means an increase in the overall price of energy.

Therefore, at the same time as considering introduction in the Greater Malé Region, it is also necessary to consider DF conversion of diesel power plants on remote islands, as well as the construction of an LNG supply system, optimization of energy prices, and reduction carbon consumption in the Maldives as a whole.

Hokusan Co., Ltd., a joint operator based in the Hokuriku region of Japan, handles optimal delivery and management of natural gas stored in pressurized containers. Hokusan can provide technical support for the transportation, etc., of CNG to remote islands. The example of small cargo delivery of LNG/CNG is shown below.

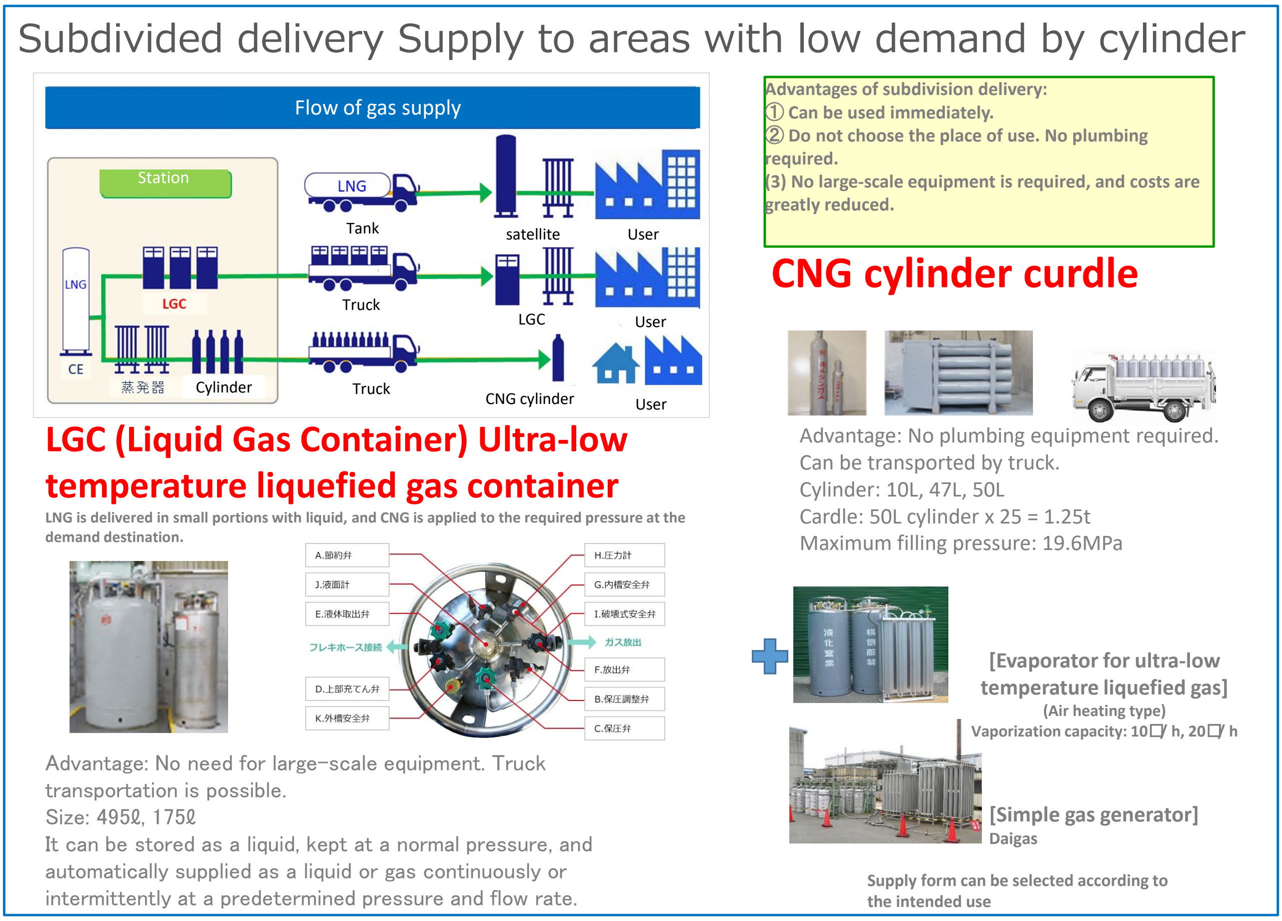


Figure 3-17　Example of LNG/CNGSmall Cargo Delivery

Source) Created by Hokusan Co., Ltd. based on various materials

In addition to supplying two power plants in the Greater Malé Region, it is possible to commence with review of FSRU introduction on an economical scale rather than changing to CNG co-firing for diesel power generation facilities on remote islands, changing to LNG/CNG co-firing for ships, switching from LPG to natural gas for cooking gas in household use and tourism industries, etc.

As mentioned earlier, this examination is intended as nothing more than the implementation of stepping-stone technology which will lead to decarbonization. However, the natural gas supply infrastructure also enables utilization of renewable energy-derived hydrogen[26] which can be used as the main fuel of a decarbonized society, as well as the utilization of methane derived from biomass. Accordingly, developing such infrastructure and attempting to reduce carbon in diesel usage as soon

[26] Through meta-nation technology, it is possible to envision developments such as using hydrogen and carbon dioxide to generate methane and then using that methane as a gas.

as possible is a steady step toward building a carbon-free society.

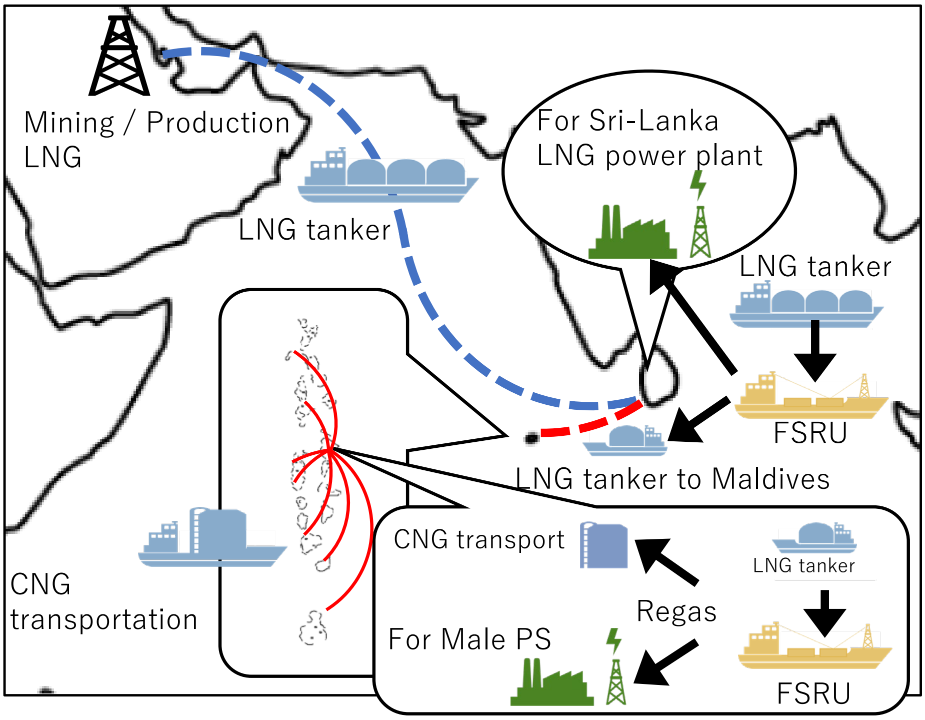


Figure 3-18 Image of Natural Gas Supply Chain in the Maldives

The demand for LNG supply to remote islands is not expected to be large. Consequently, it is assumed that the investment cost will not be worth the use of LNG carriers or the construction of an LNG reception terminal. Therefore, it is desirable to use ISO container shipping which enables transport from even a small amount of LNG and can be used for storage without modification. Even a relatively small port on a remote island can be outfitted as a reception terminal by installing a crane and container yard. Furthermore, the utilization of LNG mobile satellites can also be considered during the utilization of such small port reception facilities.

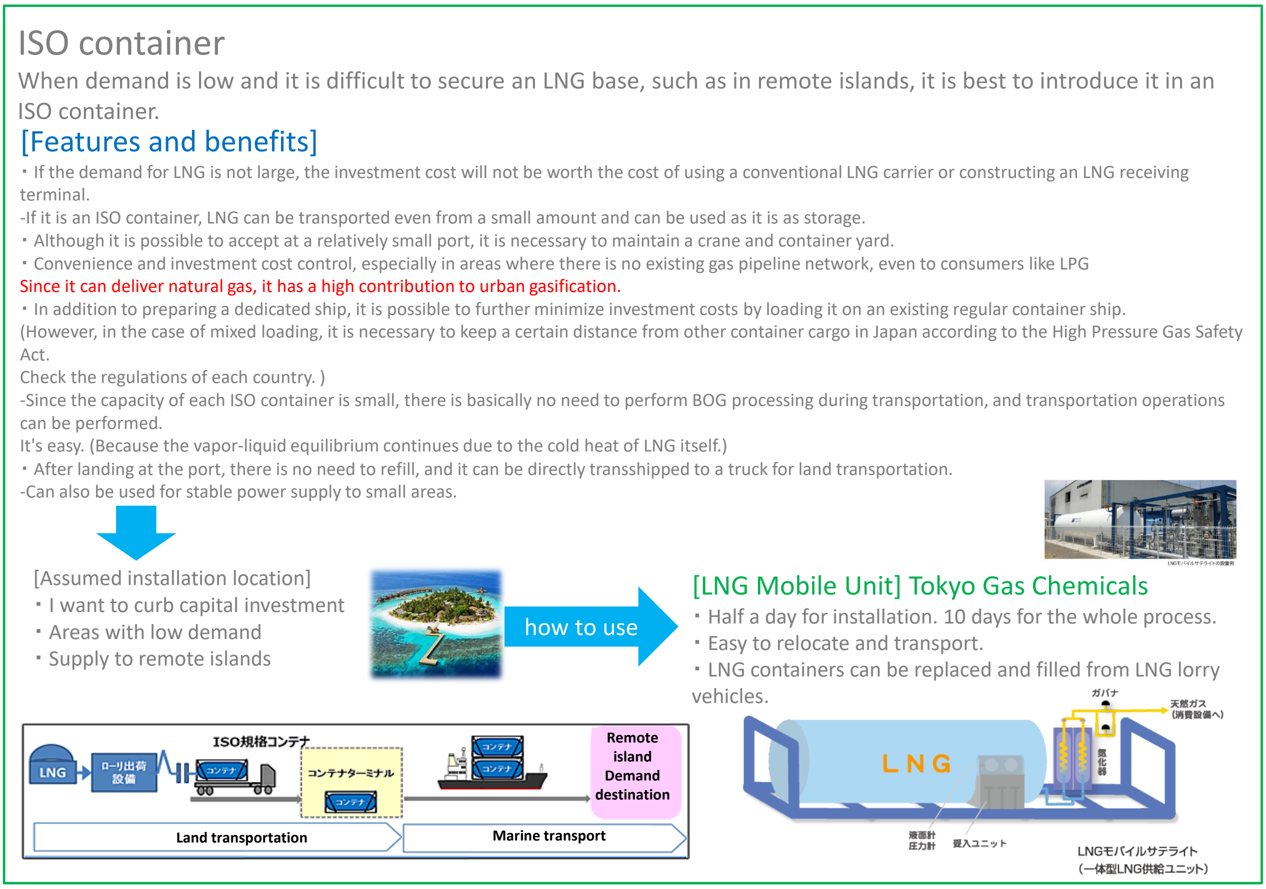


Figure 3-19 Image of Transport in ISO Containers to Remote Island and Subsequent Usage

Source) Created by Hokusan Co., Ltd. based on various materials

3) Economic study of natural gas supply potential

Based on the results of 1) above, we will estimate the infrastructure development and operating costs related to natural gas supply and gas conversion. At the same time, we also examined the financial schemes, etc., that can be used for the development of the required infrastructure.

In regards to the supply of natural gas, we will first examine the cost of infrastructure development. According to documents from the Japan Oil, Gas and Metals National Corporation, FSRU is characterized by a lower construction cost than land-based LNG terminals. Furthermore, it is possible to modify or divert existing LNG ships. According to the documents, this costs about 8 billion yen, while the construction cost for the landing pier is about 10 billion yen[23]. Therefore, an initial cost of approximately 20 billion yen is forecasted for the development of FSRU and onshore receipt infrastructure.

Next, we will consider the cost of LNG fuel procurement (fuel cost). The LNG pricing system is somewhat complicated and difficult to conceptualize because it varies greatly depending on the contract period (long-term or spot) and contract type. First, LNG trading is based on prices from Henry Hub (HH, a US gas trading hub), Title Transfer Facility (TTF, a Dutch gas trading hub), Japan Korea Marker (JKM, Platts marker for Northeast Asian spot LNG assessment price), Japan LNG Cocktail (JLC, the average LNG import price for all of Japan), etc. Although each of these prices is linked to oil prices and shows similar trends, there are still large differences in price. The maximum difference is about 8 times. Price trends for main exchanges in 2020 are summarized in a document[27] which analyzes the discrepancy between the long-term contract LNG price linked to oil prices and the spot LNG price. A graph illustrating the discrepancy between the prices is shown below for reference.

Figure 3-20 Differences and Fluctuations in LNG Prices on Each Exchange

The highest price in 2020 was approximately USD 9.5 per million BTU on the JLC (Japan LNG Cocktail, the average LNG import price for all of Japan). The supply of LNG to the Maldives is likely to come from a hub scheduled to be constructed in Sri Lanka; however, a high price per unit is expected due to the small amount of LNG imports. In our examination, we use a conservative estimation which assumes the aforementioned highest value of USD 9.5 per million BTU on the JLC.

As discussed above, the LNG required for power generation co-firing application in Malé and Hulhumalé is 3,854,542 GJ (70,726 tons). Since 1 million Btu is equal to 1,054 MJ, the value obtained through division is 3,657,061 million Btu. We then multiply this value by USD 9.5 per million Btu to arrive at an annual LNG procurement price of approximately USD 35.61 million.

In addition to this value, we must take into account the cost of shipping to the Maldives, a region with low demand. For LNG, attention must be paid to the handling of volatile gas called “Boil off Gas” (BOG), and to setting the optimum delivery frequency and storage amount. BOG is particularly likely to occur at LNG terminals. Conversely, it is unlikely to occur at ISO containers that are in a state of gas-liquid equilibrium due to the cold heat of LNG itself.

[27] Japan Oil, Gas and Metals National Corporation “Latest Trends in Natural Gas and LNG: Rising Oil Prices Create the LNG Price System Issue of Different Prices for the Same Product” 2020. URL:https://oilgas-info.jogmec.go.jp/_res/projects/default_project/_page_/001/008/857/2010_c_price_lng.pdf

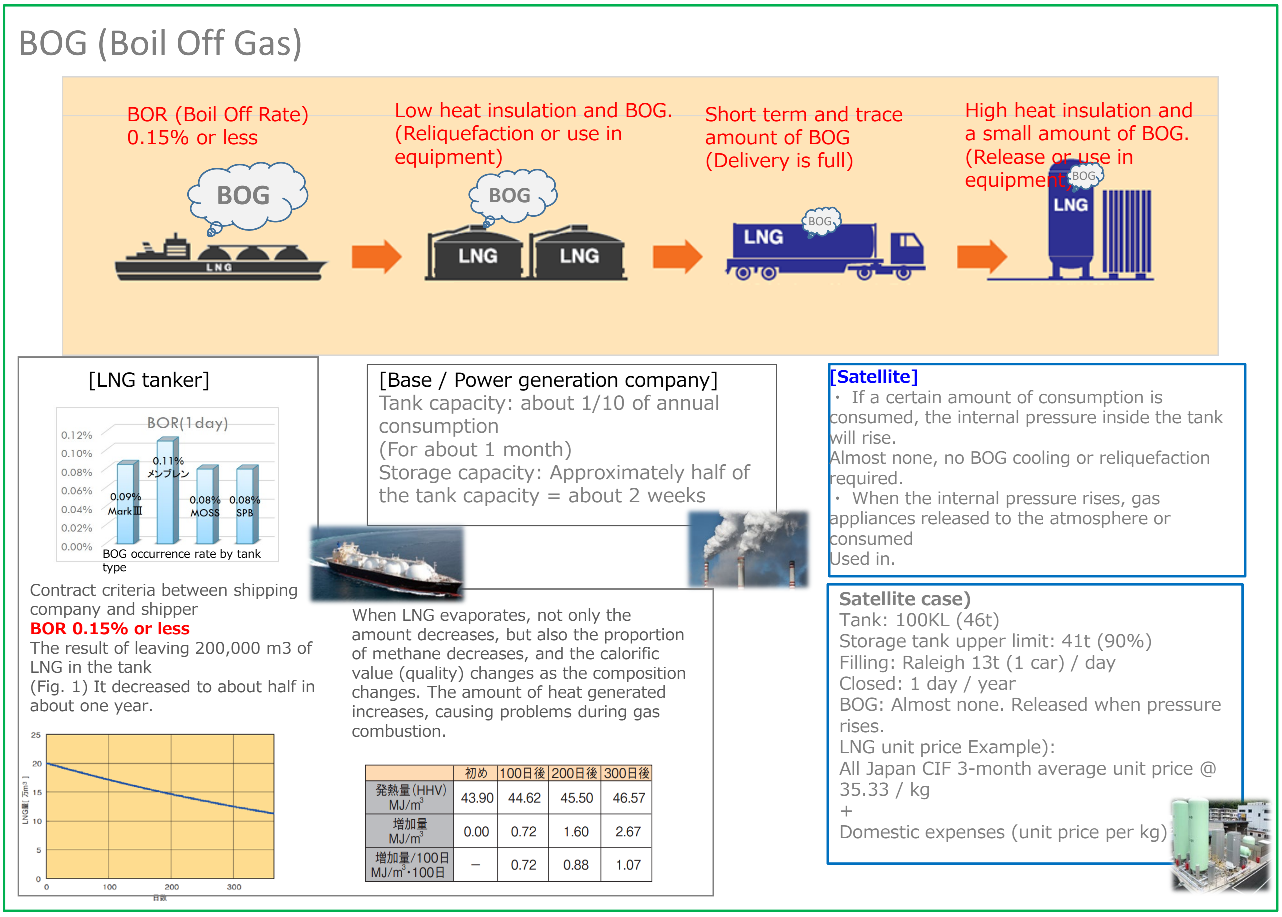


Figure 3-21　BOG Characteristics of LNG

Source) Created by Hokusan Co., Ltd. based on various materials

In our survey, we noted these characteristics of LNG and examined the cumulative freight charges for 3,500 m3 LNG carriers. For our examination, we tentatively set various specifications such as fuel consumption amount, operating cost, charter fee, LNG liquid density, and cargo handling capacity of the transport ship. Upon interviewing shipping companies, we arrived at a rough price of approximately 10 dollars per million Btu. Therefore, when including the procurement price of LNG, the procurement cost is approximately USD 20 per million BTU, or USD 74,969,081.

On the other hand, this procurement of LNG will reduce the use of diesel fuel. Currently, 106 million liters of diesel are consumed annually for power generation on Malé and Hulhumalé. From this amount, it is possible to achieve a reduction of approximately 100 million liters. This excludes the 5% of diesel fuel used in co-firing. Diesel fuel costs approximately USD 0.98 USD per liter in the Maldives, so the price of 100 million liters is USD 98.88 million. This difference of approximately USD 23.91 million is the reduction in fuel costs.

Table 3-13　Fuel Procurement Cost when Using LNG Co-Firing

	Annual usage		Unit conversion		Unit price		Total price	
Diesel	100,904,250	L	-	-	0.98	USD/L	98,886,165	USD
LNG	70,726	t	3,748,454	MMBtu	20	USD/MMBtu	74,969,081	USD
						Difference	23,917,084	USD

It is necessary to consider operation costs, equipment maintenance costs, etc., as well as interest rates related to financing of initial investment. We must also engage in detailed analysis based on factors such as inflation rates. Nevertheless, we estimate that the initial investment amount of approximately 20 billion yen (approximately USD 192 million) can be recovered in about 8 years due to the effect of fuel cost reduction.

Table 3-14 Economic Efficiency Realized by Conversion to LNG Fuel

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Outflow																
初期投資 （1USD=0.096JPY）	192,000,000															
燃料調達コスト		74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081	74,969,081
Inflow																
燃料費削減額		98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165	98,886,165
Free cash flow	-192,000,000	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084	23,917,084
	-192,000,000	-168,082,916	-144,165,831	-120,248,747	-96,331,662	-72,414,578	-48,497,493	-24,580,409	-663,325	23,253,760	47,170,844	71,087,929	95,005,013	118,922,098	142,839,182	166,756,266

IRR	9%
投資回収	8年

*オペレーションコスト、メンテナンスコスト、資金調達コスト、インフレ率を考慮していない。

3.2.3. Estimate of CO_2 Emissions Related to Current Diesel Power Generation and Estimate of Low-Carbon Effect of Introducing Technology for Conversion to Natural Gas

We collected and acquired fuel consumption data related to diesel power generation from Malé City and local cooperating organizations. Based on this data, we estimated the reference CO_2 emissions. Then, from the interviews with manufacturers possessing gas conversion technology as discussed above in (2)-1), we ascertained the efficiency related to gas conversion. Next, we will estimate the amount of diesel that can be replaced by fuel conversion and calculate the results for reference emissions. Based on these results, we will calculate the reduction of CO_2 emissions.

Since our study targets the reduction of CO_2 emitted as the result of generating power, the effect of our study will be clarified after analyzing CO_2 emitted as the result of power generation in all of the Maldives and analyzing contributions from the Malé region.

The Maldives Ministry of the Environment completed the GHG emissions inventory in 2015 based on a sectoral approach[16]. Here, the total CO_2 emissions as of 2015 are estimated to be 1,536.04 Gg (Gigagram = 1,000,000 kilograms = 1,000 tons; 1,536,040t-CO_2). 95.8% of these emissions comes from the energy sector and 4.2% comes from waste. In the energy sector, power generation is the main source of emissions. The next highest is the transportation sector. The contribution of emissions from economic activities is 40% from the tourism industry, 38% from household activities, and 18% from transportation.

The facilities capacity of diesel power generation facilities in the Malé region is 81.35 MW on Malé Island and 66.24 MW on Hulhumalé Island. According to information from Malé Island, annual power generation is 712,626 MWh on Malé Island and 580,262 MWh on Hulhumalé Island. Also, diesel fuel consumption is reported to be 230,000 liters per day (84 million liters per year) and 52,000 liters per day (19 million liters per year), respectively.

When converted to heating value, the values are 3.2 million GJ on Malé Island and 1 million GJ on Hulhumalé Island. Therefore, when multiplied by the CO_2 emissions factor (0.0187t-CO_2 per GJ) of diesel fuel, emissions are calculated as 60.55 million t-CO_2 per year on Malé Island and 19,476 t-CO_2 per year on Hulhumalé Island, for a total of 79,531 t-CO_2 per year.

This shows that CO_2 emissions from power generation in the Malé region account for approximately 5% of the total GHG emissions in the Maldives.

Table 3-15 Reference Emissions of Low-Carbon Power Generation Using Natural Gas

	Power generation facilities capacity (MW)	Diesel consumption (L/day)	Diesel consumption (L/day)	Heating value (GJ/year)	Emissions (t-CO2/year)
Malé	81.35	230,332	84,071,180	3,211,519	60,055
Hulhumalé	66.24	52,355	19,109,575	1,041,472	19,476
Total	147.59	282,687	103,180,755	4,252,991	79,531

For the JFE Engineering Corporation facilities introduced above, the natural gas utilization ratio can assumed to be 95%. When presupposing the introduction of these facilities, the emissions for this project are the sum of 1) CO_2 emissions from natural gas consumption equivalent to 95% of the current required heating value and 2) CO_2 emissions from diesel consumption equivalent to 5% of the heating value.

The amount of natural gas consumed is equivalent to a heating value of 3,050,943 GJ per year on Malé Island and 989,398 GJ per year on Hulhumalé Island, for a total of 4,040,341 GJ per year (equivalent to 70,726 tons of LNG). Since the emissions factor of natural gas is approximately 0.0135 t-CO_2 per GJ, we expect emissions of approximately 41,188 t-CO_2 per year on Malé Island and 13,357 t-CO_2 per year on Hulhumalé Island, for a total of 54,545 t-CO_2 per year.

In the reference scenario, diesel fuel consumes more than 5% of the heating value. This breaks down to 160,576 GJ per year on Malé Island and 989,398 GJ per year on Hulhumalé Island, for a total of 212,650 GJ per year (equivalent to 5,566,754 liters of diesel). Since the CO_2 emissions factor of diesel fuel is 0.0187 t-CO_2 per GJ, this means that CO_2 emissions are 3,977 t-CO_2 per year. The sum amounts to 58,521 t-CO_2 per year, so the difference with the reference emissions amount of 79,531 t-CO_2 is 21,010 t-CO_2 per year, which is the amount of emissions reduction due to conversion to natural gas.

Table 3-16 Project Emissions of Low-Carbon Power Generation Using Natural Gas

・Unit conversion

Type of fuel	Heating value per year (physical properties)		Annual fuel usage	Heating value
	[MJ/L]	[GJ/L]	[L, t]	[GJ/year]
Diesel [L]	38.2	0.0382	5,566,754	212,650
LNG [t]	54.5	0.0545	70,726	4,040,341

・Emissions

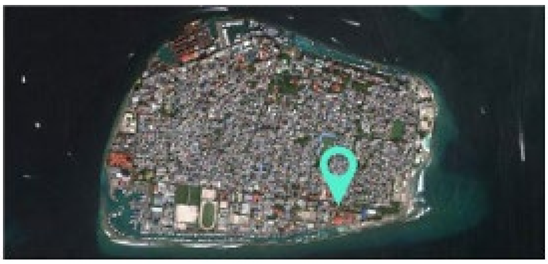
	Heating value from gas conversion (GJ/year) *95% of total heat capacity	Heating value from diesel consumption (GJ/year) *5% of total heat capacity
Malé	3,050,943	160,576
Hulhumalé	989,398	52,074
Total	4,040,341	212,650
CO_2 emissions	54,545 t-CO_2/year	3,977 t-CO_2/year
Total		58,521 t-CO_2/year

The overall scope of reduction scale is as described above. However, when verifying the reduction amount and cost-effectiveness in the JCM Model Project, it is necessary to engage in consideration based on the specifications of each generator. Additionally, JFE Engineering Corporation has agreed to a technical decree with the French company SEMT (currently the German company MAN), so it is first necessary to consider application to generators manufactured by MAN.

The following is a list of generators on Malé Islands and Hulhumalé Islands, as well as the manufacturer and facility capacity.

K. MALÉ

Population	127079
Area of Island (km^2)	1.90
Distance from Male' (km)	0
Nearest Airport	Velana International Airport
Electricity Provider	STELCO
Daily Peak Load (kW)	55,230
Peak load time	15:00
Installed Capacity (kW)	72084
Installed Generator sets (kW)	1664X1, 4320x1, 2160x3, 2000X2, 5760x1, 6500x2, 1000x5, 1600x9, 8730x2
Monthly Average Usage (kWh)	27123256.08
Yearly electricity production (kWh)	325,479,073.00
Yearly Oil Consumption (L)	83,063,916.00
Yearly Lube Oil Consumption (L)	302,556.00
Synchronizing Panel	Yes
Type of Synchronizing Panel	Auto
Electricity cable installed year	1949
Distribution Cable size (mm^2)	6,16,25,35,50,70,95,120,150,185
CO_2 emission (tCO_2)	221149.37



Power generation facilities on Malé Island

K. HULHUMALÉ

Population	15769
Area of Island (km^2)	2.00
Distance from Male' (km)	4.1
Nearest Airport	Velana International Airport
Electricity Provider	STELCO
Daily Peak Load (kW)	6,120
Peak load time	21:00
Installed Capacity (kW)	12200
Installed Generator sets (kW)	800X1, 1000X7, 1200X1, 1600X2
Monthly Average Usage (kWh)	3223895.43
Yearly electricity production (kWh)	38,686,745.12
Yearly Oil Consumption (L)	10,453,827.64
Yearly Lube Oil Consumption (L)	37,136.73
Synchronizing Panel	Yes
Type of Synchronizing Panel	Auto
Electricity cable installed year	2003
Distribution Cable size (mm^2)	70,95,120,150,185
CO_2 emission (tCO_2)	27832.27

Power generation facilities on Hulhumalé Island

Set No.	Make (ENGINE)	Make (GENERATOR)	kW (出力)	kVA (容量)	Year (設置年)	RPM (回転数)
DG-1	Wartsila Diesel Vasa Oy	ABB Industry	4, 320	5, 425	1998	750
DG-2	Wartsila Diesel Vasa Oy	Leroy-Somer	2, 160	2, 700	1990	750
DG-3	Wartsila Diesel Vasa Oy	Leroy-Somer	2, 160	2, 700	1990	750
DG-4	Wartsila Diesel Vasa Oy	Leroy-Somer	2, 160	2, 700	1993	750
DG-5	Wartsila Diesel Vasa Oy	ABB Industry	5, 760	7, 235	1995	750
DG-6	Wartsila Diesel Vasa Oy	ABB Industry	6, 500	8, 143	2001	750
DG-7	Wartsila Diesel Vasa Oy	ABB Industry	6, 500	8, 143	2001	750
CG-1	CUMMINS	STAMFORD	1, 000	1, 250	2005	1, 500
CG-2	CUMMINS	STAMFORD	1, 000	1, 250	2005	1, 500
CG-3	CUMMINS	STAMFORD	1, 000	1, 250	2005	1, 500
CG-4	CUMMINS	STAMFORD	1, 000	1, 250	2005	1, 500
CG-5	CUMMINS	STAMFORD	1, 000	1, 250	2005	1, 500
CG-6	CUMMINS	STAMFORD	1, 000	1, 250	2005	1, 500
CG-7	CUMMINS	STAMFORD	1, 600	2, 000	2007	1, 500
CG-8	CUMMINS	STAMFORD	1, 600	2, 000	2007	1, 500
GE-4	CUMMINS	STAMFORD	1, 600	2, 000	2009	1, 500
GE-5	CUMMINS	STAMFORD	1, 600	2, 000	2009	1, 500
GE-6	CUMMINS	STAMFORD	1, 600	2, 000	2009	1, 500
CE-7	CUMMINS	STAMFORD	1, 600	2, 000	2009	1, 500
N/A	MAN	N/A	8, 700	N/A	N/A	N/A
N/A	MAN	N/A	8, 700	N/A	N/A	N/A
N/A	CUMMINS	N/A	1, 000	N/A	N/A	N/A
N/A	CUMMINS	N/A	1, 000	N/A	N/A	N/A

List of power generation facilities on Malé Island

No.	Engine Model	Manufacturer	Rated Output (kW)	Start of Commercial Operation
1	KTA 50 G2	Cuimmins	800	December 2004
2	KTA 50 G2		1,000	June 2009
3	KTA 50 G2		1,000	July 2007
4	KTA 50 GS8		1,200	November 2008
Total			4,000	

List of power generation facilities on Hulhumalé Island

Figure 3-22 Information on Power Generation Facilities on Malé Island and Hulhumalé Island

From among these facilities, there are two 8,700 kW machines which are manufactured by MAN and have the largest facilities capacity on Malé Island. These two machines can be given priority for commercialization.

The amount of fuel consumed by the generators is calculated by apportioning from diesel consumption (84,071,180 liters per year) on Malé Island, which is approximately 17,982,035 liters per year. This is equivalent to 686,914 GJ per year when converted to heating value. When this value is multiplied by the CO2 emission factor (0.0187 t-CO2 per GJ) of diesel fuel, the reference emissions are 12,845 t-CO2 per year. In the project, the heating value of 652,568 GJ, which is 95% of the aforementioned 686,914 GJ per year, will be converted to derivation from natural gas. 34,346 GJ, which is 5%, will be converted to derivation from diesel. Based on the emission factors of 0.0135 t-CO2 per GJ for natural gas, the CO2 emissions derived from natural gas are 8,809 t-CO2 per year. Based on the emissions factor of 0.0187 t-CO2 per GJ for diesel, the CO2 emissions derived from diesel are 642 t-CO2 per year. The total project emissions are 9,451 t-CO2 per year.

The amount of emissions reduction is 3,394 t-CO2 per year. This value is calculated by subtracting the project emissions from the reference emissions.

Table 3-17 Project Emissions of Low-Carbon Power Generation Using Natural Gas

・Unit conversion

Type of fuel	Heating value per year (physical properties)		Annual fuel usage	Heating value
	[MJ/L]	[GJ/L]		[GJ/year]
Diesel [L]	38.2	0.0382	1,312	34,346
LNG [t]	54.5	0.0545	35,564	652,568

・Emissions

	Heating value from gas conversion (GJ/year) *95% of total heat capacity	Heating value from diesel consumption (GJ/year) *5% of total heat capacity
Total	652,568	34,346
CO2 emissions	8,809 t-CO2/year	642 t-CO2/year
Total		9,451 t-CO2/year

Cost depends on the installation status of the local power generation facilities, so it is difficult to estimate cost at this point in time. On the other hand, investigation, design, procurement, and installation of DDF conversion technology from JFE Engineering Corporation was performed through the Model Project "Converting a Diesel Generator to Dual-fuel Operation (India),"[28] which is part of the "Infrastructure Improvement Project for Rationalization of International Energy Use" operated by the New Energy and Industrial Technology Development Organization (NEDO). The cost of this model project is used as reference. In our project, a budget of 150 million yen is being introduced for natural gas conversion of 3.6 MW equipment. The target capacity of facilities manufactured by MAN on Malé Island referred to in the above calculation is 8.7 MW x 2 machines, which is approximately five times the scale of the reference project. However, in plant construction, the cost is generally not proportional to the scale of facilities and the 0.6th power rule[29] is used. Therefore, the plant cost is estimated to be about 400 million yen, which is approximately 2.6 times higher.

According to interviews with JFE Engineering Corporation, the actual cost depends on various factors such as the operating status of facilities, the necessity of overhaul, and the status of peripheral equipment. Therefore, no unconditional statements can be made regarding cost. In actuality, detailed cost estimation including on-site confirmation is indispensable; however, in our project, we engaged in trial calculations based on the approximate values listed above.

The target JCM facilities are various types of gas conversion equipment assigned to diesel engines. The legal useful life of these facilities is assumed to be 15 years because the equipment is in the category of "internal combustion power or gas turbine power generation equipment." The amount of CO2 emissions reductions for 15 years will be 141,765 t-CO2. If 50% of the estimated construction cost of 400 million yen is targeted for subsidy, the subsidized amount will be about 200 million yen, and the cost-effectiveness per ton will be approximately 1,410 yen. This is a sufficient level of cost-effectiveness and a substantial amount of reduction, so we expect JCM entrepreneurs.

In regards to this methodology, there are no precedents related to gas conversion for power generation facilities. Therefore, it is necessary to conduct studies in the future. A similar example is the 2018 JCM Model Project entitled "Introduction of CNG-Diesel Hybrid Equipment to Public Bus in Semarang." This is an example of natural gas co-firing for public buses, which use diesel fuel engines. As such, it will be a helpful example for examining our methodology.

Our methodology was approved at a JCM Joint Committee with Indonesia on December 23, 2020 as the "Joint Crediting Mechanism Approved Methodology ID_AM026: Introduction of CNG-Diesel Hybrid Equipment to Public Buses."

The contents when referring to our methodology are shown below.

1) Target project

The methodology targets projects for introducing equipment that allows the combined use of two fuels (diesel and CNG) for power generation facilities fueled by diesel.

2) Eligibility requirements

The eligibility requirement for Methodology AM026 states that CNG-diesel hybrid equipment is newly installed to the public transport buses which have already been in operation or are newly

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[28] New Energy and Industrial Technology Development Organization (NEDO), International Demonstration Project on Japan's Energy Efficiency Technologies, 2008 Edition, Attachment 8, Model Project "Converting a Diesel Generator to Dual-fuel Operation (India)," Project for Increased Efficiency of International Energy Consumption, Infrastructure Improvement Project for Rationalization of International Energy Use https://www.nedo.go.jp/content/100084801.pdf

[29] The 0.6th power rule is a method used in cost estimation, etc., of chemical industry plants, etc. For example, experience teaches us that the cost of a plant with a double-scale difference is not proportional, but falls within a difference calculated as 2 ^ 0.6 = 1.52.

procured. Based on this idea, it is expected that requirements for our project will be defined as “CNG-diesel hybrid equipment is newly installed to diesel power generation facilities which have already been in operation or are newly procured.”

3) Emission source and target gas

The greenhouse gases calculated in Methodology AM026 are diesel fuel used for public transportation buses and CO2 emitted from CNG. It is assumed that transportation from the CNG procurement site to the usage site will be carried out using a tank lorry. However, the greenhouse gas emitted at that time is sufficiently small compared to the project emissions, so the greenhouse gas is excluded from target emission sources. Based on this idea, in our project, we can set the target as diesel fuel used for generators and CO2 derived from CNG.

Table 3-18 Emission Sources and Target Gases

Category	Emissions source	Target GHG
Reference emissions	Combustion of diesel fuel	CO2
Project emissions	Combustion of diesel fuel	CO2
	Combustion of CNG fuel	CO2

4) Method of calculating reference emissions

a. Basis and premise of calculations

Methodology AM026 calculates the CO2 emissions from diesel fuel combustion, which is reduced by replacing diesel fuel (a fuel type with a high CO2 emissions factor) with CNG fuel that has a low CO2 emission factor. This replacement is done after installing the equipment. Furthermore, based on similar cases from the past, it is known that the introduction of facilities will increase the combustion efficiency of fuel, improve the fuel efficiency of vehicles, and reduce CO2 emissions by an amount that is greater than the difference in CO2 emission factors. Therefore, the methodology is used to evaluate this known effect.

The definition of reference emissions in this methodology is the amount of greenhouse gases that are expected to be emitted if the project is not executed during the applicable project period; that is, if no equipment is installed. Additionally, the project emissions are the CNG consumption and diesel consumption of the project facilities. The project emissions are calculated from the net heating value of CNG and diesel, the CO2 emissions factor of diesel, and the fuel consumption of the project facilities and reference facilities.

b. Calculation formula, etc.

The calculation formula in Methodology AM026 is as follows.

$$RE_p = \sum_i \left\{ \left[\left(FC_{PJ,CNG,i,p} \times NCV_{CNG} \right) + \left(FC_{PJ,diesel,i,p} \times NCV_{diesel} \right) \right] \times \frac{\eta_{PJ,i,p}}{\eta_{RE,i}} \right\} \times EF_{diesel}$$

RE_p	Reference emissions during the period p [tCO2/p]
$FC_{PJ,CNG,i,p}$	CNG consumption by project facility i during the period p [t/p] [t/p]
NCV_{CNG}	Net heating value of CNG [GJ/t]
$FC_{PJ,diesel,i,p}$	Diesel fuel consumption by project facility i during the period p [kl/p]
NCV_{diesel}	Net heating value of diesel fuel [GJ/kl]
$\eta_{PJ,i,p}$	Fuel efficiency of project facility i during the period p [km/l]
$\eta_{RE,i}$	Fuel efficiency of reference facility i [km/l]

EF_{diesel}	CO2 emission factor of diesel fuel [t-CO2/GJ]
i	Identification number of project facilities

In Methodology AM026, the term "project facility" refers to public buses. However, when the calculation formula is applied to this project, the term "project facility" will refer to diesel generators. In that case, the point to keep in mind when referring to this project is fuel efficiency (energy efficiency). In regards to fuel efficiency, it is necessary to use kW/l for the unit "fuel efficiency of project facility i during the period p" and "fuel efficiency of reference facility i."

In Methodology AM026, the fuel consumption ($\eta_{PJ,i,p}$) of the project facility i in the period p is determined based on the monitoring data after the project is implemented. It is calculated by the following formula in order to reflect the actual fuel consumption.

$$\eta_{PJ,i,p} = \frac{TD_{PJ,i,p}}{HFC_{PJ,diesel,i,p} \times 10^3}$$

$$HFC_{PJ,diesel,i,p} = \sum_i FC_{PJ,CNG,i,p} \times \frac{NCV_{CNG}}{NCV_{diesel}} + \sum_i FC_{PJ,diesel,i,p}$$

$\eta_{PJ,i,p}$	Fuel efficiency of project facility i during the period p [km/l]
$TD_{PJ,i,p}$	Total drive distance of project facility i during the period p [km/p]
$HFC_{PJ,diesel,i,p}$	Hypothetical total diesel fuel consumption by project facility i during the period p [kl/p]
$FC_{PJ,CNG,i,p}$	CNG consumption by project facility i during the period p [t/p]
NCV_{CNG}	Net heating value of CNG [GJ/t]
NCV_{diesel}	Net heating value of diesel fuel [GJ/kl]
$FC_{PJ,diesel,i,p}$	Diesel fuel consumption by project facility i during the period p [kl/p]
i	Identification number of project facilities

Similarly, in regards to this point, we will consider substituting kW/l for fuel efficiency and kWh for distance traveled.

In Methodology AM026, in order to guarantee a substantial emissions reduction, fuel efficiency in the reference scenario is predetermined using one of the following three options in a conservative manner.

(Option 1)

Daily data sets of drive distance and diesel fuel consumption of bus i are collected prior to installation of CNG-diesel hybrid equipment for at least 60 days. The highest value (the most efficient value) from the measured data sets is selected and determined as fuel efficiency of reference bus i.

(Option 2)

The catalog value of the fuel consumption of bus i converted from diesel fuel combustion to CNG diesel hybrid combustion in the project is determined as the fuel consumption of reference bus i. Catalog values usually indicate better fuel economy than calculated values for a bus in operation. Therefore, it is conservative to set default values for reference bus fuel economy based on catalog values.

(Option 3)

The default value set using this method it applied as the fuel efficiency of reference bus i. The default value is determined from the catalogues of public buses manufactured by Japanese manufacturers. Catalog values usually indicate better fuel economy than calculated values for a bus in operation, so this is a conservative approach.

Similarly, in our project, it is conceivable to collect the fuel consumption (kW / l) value of the existing power plant, or to quote the value of the manufacturer's catalog or the value of the latest diesel generator on the same scale, such as one produced by a Japanese manufacturer.

5) How to calculate project emissions

In Methodology AM026, the following formula is used to calculate the greenhouse gas generated by the combustion of diesel and CNG consumed during the project period.

$$PE_p = PE_{CNG,p} + PE_{diesel,p}$$

$$PE_{CNG,p} = \sum_i \left(FC_{PJ,CNG,i,p} \times NCV_{CNG} \times EF_{CNG}\right)$$

$$PE_{disel,p} = \sum_i \left(FC_{PJ,diesel,i,p} \times NCV_{diesel} \times EF_{diesel}\right)$$

PE_p	Project emissions during the period p [tCO2/p]
$PE_{CNG,p}$	Project emissions from CNG consumption by project facilities during the period p [tCO2/p]
$PE_{diesel,p}$	Project emissions from diesel fuel consumption by project buses during the period p [tCO2/p]
$FC_{PJ,CNG,i,p}$	CNG consumption by project bus i during the period p [t/p]
NCV_{CNG}	Net heating value of CNG [GJ/t]
EF_{CNG}	CO2 emission factor of CNG [t-CO2/GJ]
$FC_{PJ,diesel,i,p}$	Diesel fuel consumption by project facility i during the period p [kl/p]
NCV_{diesel}	Net heating value of diesel fuel [GJ/kl]
EF_{diesel}	CO2 emission factor of diesel fuel [t-CO2/GJ]
i	Identification number of project facilities

The emissions reductions is calculated by subtracting the project emissions from the reference emissions, and then using the following formula.

$$ER_p = RE_p - PE_p$$

ER_p	Emission reductions during the period p [tCO2/p]
RE_p	Reference emissions during the period p [tCO2/p]
PE_p	Project emissions during the period p [tCO2/p]

7) Main default values

Based on the values set in Methodology AM026, the main default values can be set as follows.

Table 3-19 Main Default Values (see Methodology AM026)

Parameter	Description of data	Source
NCV_{CNG}	Net heating value of CNG [GJ/t]	In the order of preference: a) value provided by fuel supplier; b) value measured by the project participants; c) regional or national default value; or d) IPCC default value provided in table 1.2 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied.
NCV_{diesel}	Net heating value of diesel fuel [GJ/kl]	In the order of preference: a) value provided by fuel supplier; b) value measured by the project participants; c) regional or national default value; or d) IPCC default value provided in table 1.2 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied
EF_{CNG}	CO2 emission factor of CNG [tCO2/GJ]	In the order of preference: a) value provided by fuel supplier; b) value measured by the project participants; c) regional or national default value; or d) IPCC default value provided in table 1.2 of Ch.2 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied.
EF_{diesel}	CO2 emission factor of diesel fuel [tCO2/GJ]	In the order of preference: a) value provided by fuel supplier; b) value measured by the project participants; c) regional or national default value; or d) IPCC default value provided in table 1.2 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied.
$\eta_{RE,i}$	Fuel efficiency of reference facility i [km/l] Fuel efficiency of reference facility is determined ex-ante in the following manner. [Option 1] Fuel efficiency of reference facility i is determined based on measured data of facility i prior to installation of CNG-diesel hybrid equipment. Daily data sets of drive distance and diesel fuel consumption of facility i are collected prior to installation of CNG-diesel hybrid equipment for at least 60 days. The highest value (the most efficient value) from the measured data sets is selected and determined as fuel efficiency of reference facility i. [Option 2] Catalog value of fuel efficiency of facility i which is converted from mono diesel fuel combustion to CNG-diesel hybrid combustion in the project is determined as fuel efficiency of	[Option 1] Measured data. [Option 2] Catalogue values of fuel efficiency provided by facility manufacturer. [Option 3] The catalog values of similarly-sized facilities manufactured in Japan.

	reference facility i. [Option 3] Refer to the catalogue value of new Japanese facilities which are the same size as the project facilities.	

8) Main monitoring items

A main monitoring item in Methodology AM026 is total drive distance, which is a value required for calculation of fuel efficiency, etc. An odometer or GPS is used to measure the total drive distance. Conversely, in our project targeting diesel generators, fuel efficiency is calculated based on the amount of power generation and the amount of fuel used. Therefore, our target is measurement for the amount of power generated. This value is indispensable for the control of the power plant. Since the amount of power generated is constantly monitored and recorded through equipment such as a grid connection board, the data can be easily obtained. In regards to the amount of fuel used, in addition to diesel refueling equipment, it is necessary to install instrumentation that can measure the amount of fuel used in newly installed CNG refueling equipment.

Table 3-20 Main Monitoring Items

Parameter	Measuring device
$TD_{PJ,i,p}$	Grid connection board, etc., installed in project facility i
$FC_{PJ,diesel,i,p}$	Diesel refueling equipment
$FC_{PJ,CNG,i,p}$	CNG refueling equipment

Based on the similarity of co-firing diesel fuel facilities with CNG, we examined application while referring to Methodology AM026.

During application, one point which must be kept in mind is the concept of fuel efficiency. In the case of engines for vehicles such as public buses, gas fuel is more ignitable than diesel, which tends to cause unburned fuel depending on the load and fuel quality. Therefore, fuel efficiency is likely to improve when using gas fuel. Accordingly, Methodology AM026 develops a calculation method that also considers the effect of improving fuel efficiency.

Conversely, in the case of power generation facilities to be examined in our project, there are differences in the premise of equipment operation. For example, there is a need to reduce the power generation efficiency from the value of the existing facilities in consideration of knocking countermeasures and equipment durability. In the future, it is necessary to proceed with the development of the methodology while taking these points into consideration.

3.2.4. Implementation System and Schedule

The implementation system of our project is an international consortium. The representative company is Hokusan Co., Ltd., an energy company based in Toyama City. The local Maldavian company is STELCO, a national electric power company that owns and operates a diesel power plant in the Malé metropolitan area.

As mentioned above, STELCO's management policy calls for the widespread use of natural gas in the future. It is expected that natural gas supply will be based on a supply contract with a gas import company in the Maldives. Stable gas supply is the key to the establishment of our project. Therefore, it is necessary to consider strengthening the business foundation by inviting corporations involved in the natural gas supply chain to join the international consortium as appropriate.

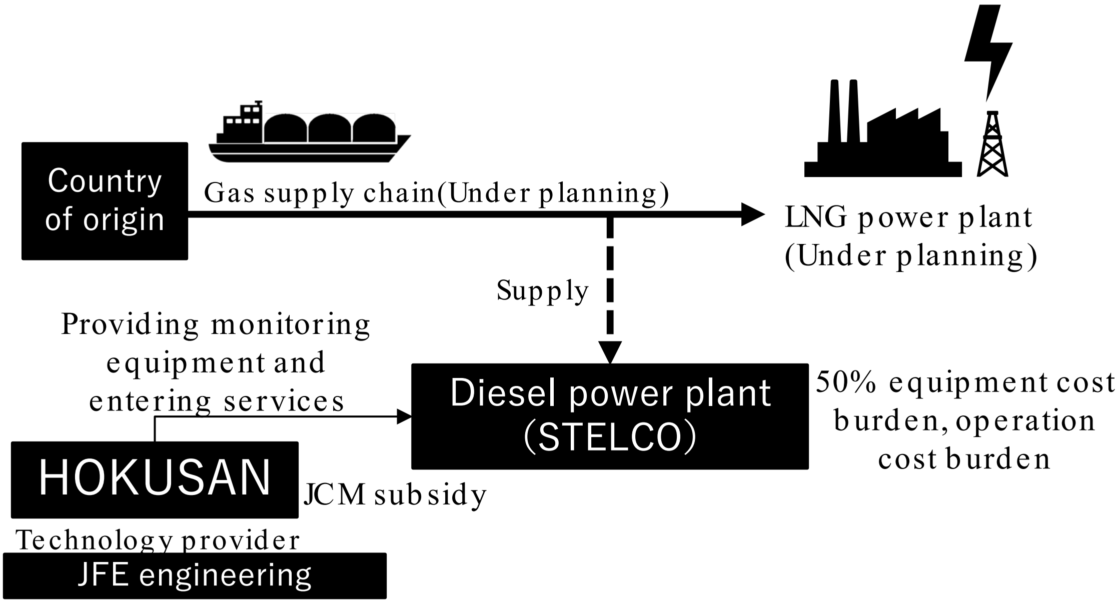


Figure 3-23 Image of Implementation System

For our project's schedule, it is necessary to wait for the establishment of the natural gas supply chain. According to the ADB's "A Brighter Future for Maldives Powered by Renewables: Road Map for the Energy Sector 2020–2030,"[30] here is the possibility of investment for the development of LNG receipt terminals being made between 2020 and 2023.

2023 is also the target year for SAP. Therefore, it is expected that decisions regarding LNG receipt will be made by 2023, despite the impact of the COVID-19 pandemic. This will lead to the development of receipt terminals and the realization of procurement after the period of negotiations for LNG procurement contracts. Therefore, for the time being, we will continue to pay close attention to these trends and scrutinize the costs related to LNG procurement. We will also examine the operating status of the target facilities and the methods for energy supply on Malé Island. We plan to proceed with activities to develop proposals for methodologies and to build an implementation

[30] ADB" A BRIGHTER FUTURE FOR MALDIVES POWERED BY RENEWABLES, ROAD MAP FOR THE ENERGY SECTOR 2020–2030",November 2020.
https://www.adb.org/sites/default/files/publication/654021/renewables-roadmap-energy-sector-maldives.pdf

system.

3.3 Low-Carbon Fields through the Spread of Renewable Energy and Energy Saving

In regards to the possibility of introducing renewable energy in the Maldives, the abundant amount of solar radiation creates high potential for solar power generation. Solar power has already been introduced and popularized, but further introduction is expected by utilizing the roofs of the building. Since the Maldives is a maritime nation, consideration is also being given to the use of natural energy such as wind power, wave power, and tidal force. In terms of energy conservation, the majority of the electricity used is energy related to air conditioning; this is a common trend with homes, offices, and commercial facilities such as hotels. When considering that the electricity price is relatively high, there appears to be a situation in which cost-effective results can be obtained by introducing energy-saving facilities, etc., from Japan. Therefore, in our survey, we investigated the following items and examined the possibility of spreading renewable energy and energy-saving methods.

3.3.1 Analysis of Maldives National Energy Plan, Malé City Energy Plan (Solar Power Introduction Plan, fields such as promotion of energy saving, etc.)

In the Strategy Action Plan (SAP), policies on Jazeera Dhiriulhun (living in harmony with the island environment) are summarized in Chapter 4. Specifically, there are explanations on policies for local decentralization, transportation networks, environmental conservation, waste, water, sanitation, community, culture, etc. The description of renewable energy is also summarized in “4.4 Clean Energy.” SAP sets the target for 2023 of increasing the proportion of renewable energy by 20% compared to 2018, and for reducing the amount of diesel fuel used for power generation by 4,000 liters.

Other goals include using renewable energy for at least 30% of the power for IWMCs (Integrated Water Monitoring and Control System) and water/sewage facilities.

Specifically, “4.4 Policy 2” of SAP states goal of “expanding and developing the renewable energy sector.” Target 2.1 is “by 2023, share of renewable energy in the national energy mix increased by 20% compared to 2018 levels” and Target 2.2 is “by 2023, at least 10 MW of solar PV is installed under net metering regulation.[31]”

The strategies, actions, implementing agencies, and target years for achieving these targets are shown in the following table.

Table 3-21 Renewable Energy Dissemination Policy in SAP (4.4 Policy 2)

Strategies	Action	2019	2020	2021	2022	2023	Lead Implementing Agency	Other Implementing Agencies
Strategy 2.1: Create an enabling environment to upscale renewable energy investments	Action 2.1a: Encourage power companies to make payments in US dollars to foreign investors investing in renewable energy in the Maldives under Power Purchasing Agreement (PPA)		●				MoEn	MoED, MoF, MMA
	Action 2.1b: Introduce incentives for tourism sector to develop renewable energy portfolio		●	●	●	●	MoEn	MATI, Resorts, Moen
	Action 2.1c: Encourage financial institutions to		●				MoEn	SDFC, BML,

[31] Mechanism used by the power company to measure the flow direction of electricity between homes and the grid.

	provide loans with low interest rates for renewable energy investments							SBI,MIB, MCB, MMA
	Action 2.1d: Develop a standard to set the maximum purchasing price of renewable energy under Power Purchasing Agreement (PPA)		●				MoEn	MEA, STELCO, FCL, STO, PO
Strategy 2.2: Create an enabling environment for domestic users to adopt renewable energy	Action 2.2a: Scale up renewable energy sources for power production at island level and increase opportunities for households to invest in renewable energy power sources at household level		●	●	●		MoEn	MEA, STELCO, FCL, Private Companies, Financial institutions
	Action 2.2b: Conduct net metering program	●	●	●	●	●	MoEn	MEA, STELCO, FCL, Private Companies
	Action 2.2c: Conduct awareness programs to promote understanding of renewable energy technologies and its advantages	●	●	●	●	●	MoEn	Media, Public, NGOs
	Action 2.2d: Disseminate information to the public on the existing mechanism for private entities and/or households to supply excess renewable energy to the electricity network through net meters	●	●	●	●	●	MoEn	Media, Public, NGOs
	Action 2.2e: Coordinate with Business Center Corporation Limited (BCC) and MoED to support SMEs to transition to clean technology	●	●	●	●	●	MoEn	MoED, BCC, RE solution providers, MEA, STELCO, FCL
Strategy 2.3: Develop a mechanism to create ease in supplying renewable energy to the electricity network	Action 2.3a: Assess the maximum renewable energy capacity which can be fed into the electricity networks of the islands	●	●	●	●	●	MoEn	MEA, STELCO, FCL
	Action 2.3b: Revise the existing mechanism for private entities/ households to supply excess renewable energy to the electricity network through net meters	●	●	●	●	●	MoEn	MEA, STELCO, FCL
	Action 2.3c: Establish a mechanism for the utilities to purchase excess renewable energy from private entities and/or households		●	●	●	●	MoEn	MoEn, STELCO, FCL
Strategy 2.4: Enable the transportation industry to adopt vehicles that use renewable energy	Action 2.4a: Conduct a study to identify the fuel usage in transport sector		●				MoEn	MoTCA, MTA, MCAA, Local Councils, EPA
	Action 2.4b: Provide recommendations to the relevant authorities on setting fuel emission standards for vessels, vehicles, and aircrafts		●	●			MoEn	MoTCA, MTA, Local Councils, EPA, MCAA
	Action 2.4c: Support MoTCA to introduce solar powered and/or battery-operated taxis and buses, and charging stations for public transportation network		●	●			MoEn	MoTCA, MTA, EPA, MEA, MCAA

Policy 3 states the goal of "increasing national energy security through diversification of sources for energy production and expansion of energy storage." Target 3.1 is "by 2023, reduce fuel usage for electricity generation by 40 million liters." Target 3.2 is "by 2023, renewable energy storage capacity is increased to 30 MWh." The strategies, actions, implementing agencies, and target years for achieving these targets are shown in the following table.

Table 3-22 Renewable Energy Dissemination Policy in SAP (4.4 Policy 3)

Strategies	Action	2019	2020	2021	2022	2023	Lead Implementing Agency	Other Implementing Agencies
Strategy 3.1: Diversify energy sources for electricity production while reducing the reliance on imported fossil fuels	Action 3.1a: Conduct research on different renewable energy sources		●	●	●	●	MoEn	STELCO, FCL, Financial Institutions
	Action 3.1b: Scale up feasible pilot projects on new renewable energy technologies		●	●	●	●	MoEn	STELCO, FCL, Financial Institutions
	Action 3.1c: Set a mandatory annual renewable energy production target for utility companies		●	●	●	●	MoEn	STELCO, FCL, MWSC
	Action 3.1d: Revise and implement policies and regulations to mandate utility providers to meet a set target for renewable energy production and provision	●	●				MEA	STELCO, FCL, MoEn
Strategy 3.2: Establish safe and adequate energy and fuel storage systems	Action 3.2a: Increase energy storage by introducing battery energy systems in power systems of selected islands		●				MoEn	MEA, STELCO, FCL, MWSC
	Action 3.2b: Increase fuel storage capacity in all islands to cater for a minimum of 88 days		●				MoEn	STO, Local Councils, STELCO, FCL, MWSC

Policy 4 states the goal of "strengthening the institutional and regulatory framework of the energy sector." Target 4.1 is "by 2021, Utility Regulatory Authority (URA) for integrated utility services is functional." Target 4.2 is "by 2023, new public infrastructure projects shall have provision to install renewable energy." Finally, Target 4.3 is "by 2023, energy data is up to date and reliable and utilized for policy making."

The strategies, actions, implementing agencies, and target years for achieving these targets are shown in the following table.

Table 3-23 Renewable Energy Dissemination Policy in SAP (4.4 Policy 4)

Strategies	Action	2019	2020	2021	2022	2023	Lead Implementing Agency	Other Implementing Agencies
4.1 Strategy 4.1: Provide electricity through an integrated utility service provision model and decentralize the utilities to ensure cost-effectiveness	Action 4.1a: Provide technical advice to the government on integrating utility services	●	●				MoEn	PO, PCB, MEA, STELCO, FCL, MWSC
	Action 4.1b: Develop an organizational structure and a human resource development plan for the integrated utility service providers		●				PO	MoEn, STELCO, FCL, MWSC
	Action 4.1c: Establish the Utility Regulatory Authority (URA) for integrated utility services		●				PO	MoEn, STELCO, FCL, MWSC, MoF, PO
	Action 4.1d: Conduct annual regulatory, financial, and technical audit of utility operations and report to regulatory authorities	●	●	●	●	●	MoEn	MEA, STELCO, FCL, PCB, AGO, PO
	Action 4.1e: Decentralize utility provision at local level in line with decentralization policy to ensure cost-		●	●	●	●	MoEn	LGA, Local Councils, MoNPI

	effectiveness							
Strategy 4.2: Develop legal and regulatory framework to promote renewable energy production and usage	Action 4.2a: Develop and implement low emission-carbon resilient policy regulation for new resort development projects and for existing resorts to switch to renewable energy sources within a given timeframe		●				MoT	MoEn, MATI, Resort
	Action 4.2b: Develop regulations to ensure infrastructures developed under Public Sector Investment Projects (PSIP) are energy efficient and can be utilized for production of renewable energy		●				MoNPI	MoEn, MoF
	Action 4.2c: Develop a regulation for efficient utilization of roof spaces, public spaces (land), lagoons, etc., for solar PV (and other RE projects)		●				MoEn	MoNPI, MLSA, Local Councils
	Action 4.2d: Enact the Energy Law	●	●				MoEn	MEA, Local Councils, STELCO, FCL, AGO, PO, People's Majlis
	Action 4.2e: Develop and update regulations, codes, and standards for all energy sector products and services	●					MoEn	MEA, STELCO, FCL, Local Councils, AGO, PO
Strategy 4.3: Develop institutional and human resource capacity of the energy sector	Action 4.3a: Strengthen institutional and human resource capacity through trainings conducted for employees of the proposed Utility Regulatory Authority (URA) and utility companies to increase regulatory enforcement capacity, and to promote adoption of clean energy provision and technology	●	●	●	●	●	MoEn	STELCO, FCL, MoF, MoCST, MoHE, MoED, PSTI
	Action 4.3b: Conduct training programs for energy sector stakeholders to design, update, and ensure energy efficiency through the implementation of renewable energy programs	●	●	●	●	●	MoEn	MEA, URA, STELCO, MWSC, FCL, NGOs
	Action 4.3c: Coordinate with TVETA and MoHE to tailor short term programs for equipping youth with necessary skills to participate in clean energy related employment		●	●	●	●	MoEn	MoHE, TVETA, MoYSCE
Strategy 4.4: Develop a mechanism for reliable energy data collection and access	Action 4.4a: Monitor the statistics on the production and usage of energy in the Maldives and disseminate information to relevant stakeholders	●					MEA	MoEn, STELCO, FCL, MoT, Resorts, MATI, MoTCA, MCS, NBS, Local Councils
	Action 4.4b: Install and maintain fuel flow meters to collect accurate fuel consumption data		●				MoEn	Local Councils, STELCO, URA, FCL, MWSC
	Action 4.4c: Establish central data acquisition system (power system operational data, generated electricity, fuel consumption, generator parameters, lubricating oil consumption, battery charging discharging condition, and		●	●	●	●	MoEn	MEA, STELCO, FCL, NDC, NBS, URA, MWSC

	renewable energy generation/usage							

In addition, in regards to policies, targets, and strategies for "Water & Sanitation," SAP also states actions to scale up the use of renewable energy for various types of water facilities (4.6 Strategy 2.1).

The lead implementing agency for these activities is the Ministry of the Environment and Energy. The electric power company STELCO and other companies are the implementing agencies.

A major point in the composition of the renewable energy business is securing business feasibility through measures such as the FIT (Feed-in-tariff) system. Accordingly, we held a meeting with the Ministry of Environment and Energy for this survey. As a result, the FIT system has been in operation since 2011. Even so, we are currently considering revision of the system to realize prices that encourage private investment. While waiting for the details of the system, this survey identified potential sites that could be introduced and conducted technical studies in advance.

3.3.2. Identification of Potential Sites for Introducing Photovoltaic Power Generation and Estimate of Introduction Effects

As discussed above, as a result of referring to government policies related to renewable energy and solar power in SAP, we confirmed the policy of strongly promoting introduction at public facilities and government facilities. Due to the nature of the city-to-city collaboration project, we decided to use this survey to examine introduction to facilities under the jurisdiction of the government, such as in Malé City.

We selected specific potential locations by extracting candidates from aerial photographs on Google Map. We focused on unused land, rooftops of facilities, parking lots, etc., that are presumed to be owned or operated by the city. We then consulted with the Hulhumalé Development Corporation in regards to the feasibility of using those locations. Next, we used map applications such as Google Earth to calculate the area of the identified locations, after which we examined the panel installation layout and the installable capacity. Finally, we used the following formula to calculate the power generation potential.

Power generation calculation formula

$$Epd = \frac{U \cdot P}{Po} \cdot K' \cdot Kpt \cdot K''$$

Epd : Electric-generating capacity (kwh/day)
U : Daily cumulative amount of solar radiation (kwh/m2・day)
P : Solar cell capacity(kW)
P0 : Irradiance(1kw/m2)
K' : Correction coefficient (JIS)
Kpt : Temperature correction coefficient
K'' : Correction coefficient (other of JIS)

Table 3-24 shows a list of identified locations, installable capacity, and estimated power generation. We determined that the total amount of facilities that can be installed at the 9 identified locations is 1,145 kW, for a total estimated annual power generation of 1,666,946 kWh. The facility usage rate would be approximately 17.6%, which is slightly higher than the average value in Japan (13% to 14%).

Table 3-24 Potential Solar Site in Malé Metropolitan Area, Site Area, and Power Generation Forecast

No.	Location Name	Area [m2]	Installable Capacity [kW]	Estimated Annual Power Generation [kWh]
1	Dhoonidhoo Prison Island	462	47.5	57,332
2	Hulhumalé Island Ferry Port	984	114.4	130,871
3	HDC Building	752	96.8	112,896
4	Ghaazee School	2,990	269.3	415,044
5	Maldives Correctional Service	1,322	167.2	257,707
6	Dharubaaruge	2,599	234.1	360,790
7	Greater Male Bus Terminal	750	88.0	135,635
8	Malé Fire Department	367	39.6	61,036
9	Malé City Ferry Port	586	88.0	135,635
	Total	10,812	1,144.9	1,666,946

Next, in anticipation of application for the JCM Model Project, we estimated the project cost, greenhouse gas reduction amount, and greenhouse gas reduction cost when installing facilities.

First, for the estimated project cost, we referred to the project cost when installing equipment in Japan and calculated the items shown in Table 3-26. However, these costs currently do not include transportation costs and customs duties from the facilities manufacturing site to the Maldives. Next, when calculating the amount of greenhouse gas reduction, we used 0.533 t-CO2/MWh, which was announced as the power CO2 emissions factor of the JCM Model Project in 2020, as the value for the aforementioned estimated annual power generation[32]. We then multiplied this value by 17 years, which is the legal useful life of the solar power facilities. The greenhouse gas reduction cost was calculated by dividing the project cost by the amount of greenhouse gas reduction. These results are shown in Table 3-27. Compared to the solar power projects adopted for JCM Model Projects in the past, the amount of power generation and greenhouse gas reduction at each location is small. However, when totaling the 9 sites, a reduction of 15,989 t-CO2 will be achieved during the project period. The greenhouse reduction cost will be 8,948 yen/t-CO2. These calculations suggest that we can achieve an effect similar to JCM Model Projects in the past. Furthermore, although we calculated the project cost for each separate location, we expect that the cost will be suppressed to some extent due to batch implementation at multiple locations belonging to the same owner. This means that there is room to further reduce the greenhouse gas reduction cost.

Table 3-25 Breakdown of Project Costs

Facilities costs	・ Solar module ・ Inverter ・ Remote monitoring system

[32] http://gec.jp/jcm/jp/wp-content/uploads/2020/03/CO2EmissionFactor_20200325_tentative.pdf

	・ DC cable for PV ・ Alternating collection board ・ Fixtures for module installation ・ Mount for module
Construction costs	・ Panel/mount installation construction ・ Electrical work ・ Foundation construction for mounting installation ・ Material lifting costs ・ Temporary scaffolding costs ・ Consumables, miscellaneous materials ・ Shipping/transportation costs (local) ・ Test-run adjustment costs ・ On-site miscellaneous costs ・ Other expenses

Table 3-26 Approximate Project Cost, Greenhouse Gas Reduction Amount, CO2 Reduction Cost

No.	Location Name	Approximate Project Cost [yen]	Amount of Reduction in Greenhouse Gases [t-CO2]	Cost of Reduction in Greenhouse Gases [yen/t-CO2]
1	Dhoonidhoo Prison Island	5,733,200	664	8,639
2	Hulhumalé Island Ferry Port	13,087,100	1,598	8,191
3	HDC Building	11,289,600	1,352	8,351
4	Ghaazee School	30,389,400	3,761	8,081
5	Maldives Correctional Service	19,018,300	2,335	8,145
6	Dharubaaruge	38,146,400	3,269	11,669
7	Greater Male Bus Terminal	10,290,800	1,229	8,373
8	Malé Fire Department	4,825,000	553	8,724
9	Malé City Ferry Port	10,298,000	1,229	8,379
	Total	143,077,800	15,989	8,948

3.3.3. Identification of Licensing, Etc., for Introduction of Solar Power

As discussed above, the Maldives has been operating a FIT (Feed-in Tariff) system since March 2011 in order to promote private investment for the introduction of renewable energy. In the Maldives, about 10% of GDP is spent on importing fossil fuels to generate electricity. Even the most efficient facilities have a power generation cost of USD 0.23 per unit. In light of these circumstances, Minister of Environment Hussain Rasheed Hassan has stated that he will strongly promote policies for the introduction of renewable energy.[33]、Moreover, the FIT system sets different purchase prices in seven regions.

When selling electricity under the FIT system, it is necessary to obtain an electricity business license. Electricity standards and regulations in the Maldives are under the jurisdiction of the Maldives Energy Authority (MEA). The following four types of standards and regulations are enforced.

・Metering Scheme
・Service Provider’s Code
・Installation Standards
・Engineers Licensing

When connecting PV to the grid, the Guidelines on Technical Requirements for Photovoltaic Grid Connection must be observed. Additionally, an application must be submitted in accordance with the Manual for Photovoltaic Grid-connection Application, and an electricity sales contract must be signed with the grid owner (electric power company).[34]

The abovementioned manual also shows the following flow chart of procedures.

[33] Official news on the website of the Maldivians Ministry of the Environment, September 2020. https://www.environment.gov.mv/v2/en/news/10480

[34] Joint project between Denkyo Engineering Co., Ltd. and Okinawa Enetech Inc. “The Development of Solar and Diesel Hybrid Power Generation Systems in Island Regions; Japanese Ministry of Foreign Affairs Official Development Assistance—Overseas Economic Cooperation Project (Project to Promote the Support of Developing Nations Through the Utilization of Japanese Technology, Etc.),” 2014.
https://www.mofa.go.jp/mofaj/gaiko/oda/seisaku/kanmin/chusho_h25/pdfs/3a26-1.pdf

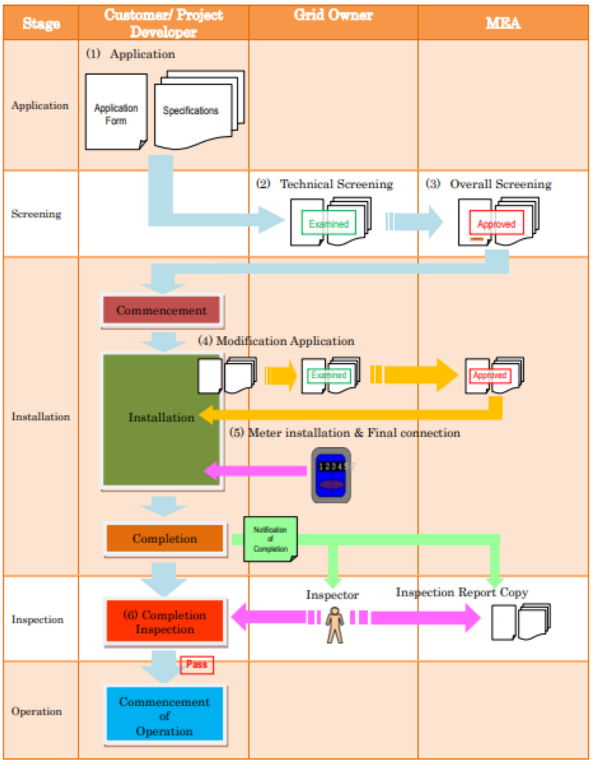


Figure 3-24　Application Flow in the PV Grid Connection Application Manual[35]

These procedures are discussed in the JCM Project Composition Survey "Installation of Solar PV and Storage Battery with Energy Management System (EMS),"[36] which was held in 2014 by Pacific Consultants Co., Ltd. The survey states that applicable licenses must be obtained in the case of electricity generation and distribution by different resorts and owners on each of the numerous resort islands in the Maldives. As a result, there are many cases in which contractors and business operators submit applications for power business and connection. The report states that permission can be obtained without any difficulties as long as the proper procedures are followed diligently.

As discussed above, in this survey, we are considering introduction to government facilities and are proceeding with commercialization together with the Maldives Ministry of the Environment under city-to-city cooperation with Malé City. Therefore, we expect even smoother acquisition when following the procedures.

On the other hand, cooperation with local construction companies is indispensable for the procurement (import), construction, electrical work, etc., of solar panels. After selecting local contractors for the installation of solar power equipment, it is necessary to construct a system in which the local companies will share responsibility for the arrangement of construction equipment, tools, workers, and other items necessary for construction, and Nihonkucho Hokuriku will

[35] Maldives Energy Authority, "Manual for Photovoltaic Grid-connection Application" https://policy.asiapacificenergy.org/sites/default/files/Manual_for_PV_Grid-connectin_Application_-_Feb_2013.pdf

[36] Pacific Consultants Co., Ltd., JCM Strategic Project Composition Study "Installation of Solar PV and Storage Battery with Energy Management System (EMS)," 2014. http://gec.jp/jcm/jp_old/projects/14ps_mdv_01/2014PS102_21j_rep.pdf

collaborate as a supervisor of design, procurement, and construction. To prepare for the selection of contractors, we are obtaining information on candidate contractors from organizations such as the Embassy of Japan in Maldives, JICA Maldives Branch, Malé City, and HDC, and we plan to select the optimal contractors at the time of the on-site survey.

Furthermore, JGC Corporation will provide the required support for equipment procurement, import/export procedures, etc. JGC Corporation is a group company of Japan NUS Co., Ltd., which is the organization implementing this survey, and possesses an extensive record of experience and achievement in infrastructure projects around the world. A draft of the implementation system including business owners is shown below.

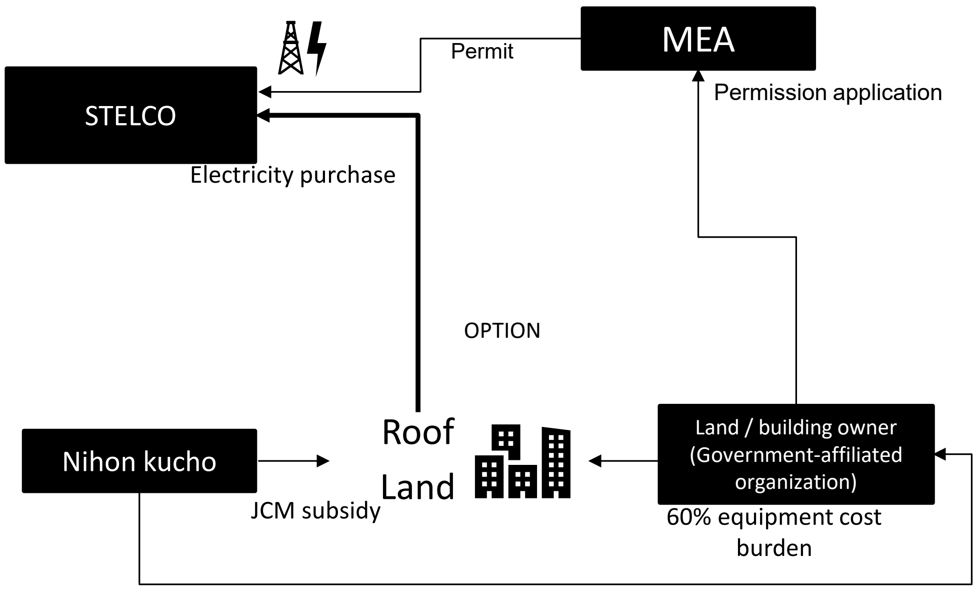


Figure 3-25 Draft of Implementation Schedule

3.3.4. Examination of Other Renewable Energy Technology Options and Introduction Potential

Thus far, the introduction of renewable energy technology has been considered by various programs in the Maldives. A list of technologies and businesses involved in past consideration is shown below in Table 3-28.

Table 3-27 List of Renewable Energy Projects by Japanese Companies That Have Been Considered in the Maldives

No.	Type of Energy	Year of Implementation	Related Businesses	Examination Contents, Business Contents, Etc.
1	Solar power	2009	Yachiyo Engineering Co., Ltd. Yonden Shikoku Electric Power Co., Ltd.	Feasibility study on the introduction of solar power generation
2	Solar power,	2019	Tamaden Kogyo K.K.	Introduction of a self-

	wind power, storage battery			sustaining hybrid power generation control system that combines multiple forms of renewable energies and storage batteries
3	Solar power	2016	Nissin Electric Co., Ltd.	Introduction of a supply and demand control device that combines solar power generation and ice machines
4	Wave power	2018	Okinawa Institute of Science and Technology Graduate University (OIST)	Introduction demonstration of wave power generator
5	Microgrid	2019	Nishizawa Ltd. Toshiba Energy Systems & Solutions Corporation	Introduction of a microgrid system and storage battery system
6	Solar power, wind power, storage battery	2014	Pacific Consultants Co., Ltd.	Feasibility study on the introduction of an energy management system that combines multiple renewable energies and introduction of facilities utilizing the JCM Model Project
7	Wind power	2016	Komaihaltec Inc. Takaoka Toko Co., Ltd. TEPCO Power Grid, Inc.	Pre-demonstration survey of wind power generation and renewable energy management system
8	Offshore solar	2018	Daiwa Energy & Infrastructure Co., Ltd.	Invested in Swimsol GmbbH (Australia), which develops floating solar power generation systems in the Maldives

As an example of a project that utilizes the characteristics of the Maldives as an island nation, Okinawa Institute of Science and Technology Graduate University (OIST) executed a project to demonstrate ocean energy such as wave power and tidal force from 2013. In this project, two prototype wave power generators equipped with turbines with a diameter of 35 centimeters were installed on Kandooma Island in the Maldives. The project group monitors the actual amount of power generated.

Source: https://www.oist.jp/ja/news-center/press-releases/32544

Figure 3-26 Overview of Demonstration and 1/2 Size Model

Based on the abovementioned demonstration cases that have been examined thus far and on growing expectations for a carbon-free society in the future, Malé City and the HDC have high expectations for further review of renewable energy options in the city-to-city collaboration project with Toyama City. Companies in Toyama City possess a wide range of technologies in areas such as renewable energy. From among these technologies, those which may be adopted in the Maldives in the future include the floating solar technology of Nihonkucho Hokuriku Co., Ltd. (Figure 3-27) and the utilization of hydrogen. Hokusan Co., Ltd. in Toyama City is the secretariat of the Toyama Hydrogen Energy Promotion Council. The company operates a hydrogen station for supplying hydrogen derived from renewable energy. In the future, solar power is expected to increase in Maldives. Accordingly, there is room for considering the production of hydrogen as a method of utilizing surplus electricity, etc., and then disseminating this technology in combination with technologies such as fuel cell vehicles and fuel cell ships.

Source: http://www.nikku-hokuriku.co.jp/business/eco.html

Figure 3-27 Floating Solar Power Facilities Constructed by Nihonkucho Hokuriku Ltd.

Source :http://www.hokusan.co.jp/service/project.html

Figure 3-28 Hydrogen Station Operated by Hokusan Co., Ltd. in Toyama City

3.3.5. Examination of Technical Options and Effects Related to Energy Saving Mainly for Air Conditioning

In the Maldives, the majority of electricity used for energy related to air conditioning. This is true for homes, offices, and commercial facilities such as hotels. Therefore, in our survey, we interviewed the Hulhumalé Development Corporation (our counterpart) in regards to the installation status and usage status of air conditioning equipment in facilities that consume a large amount of electricity. As a result, we learned that almost all facilities in Malé and Hulhumalé have individually managed air-conditioning systems in which air-conditioning equipment is installed in each room. We also learned that relatively efficient equipment is being installed, including equipment made in Japan. Therefore, we determined that the energy-saving effect of renewing the equipment is small and it is difficult to achieve cost effectiveness.

Conversely, Malé International Airport was presented as a candidate for a facility that has central air conditioning. The Maldives is a tourism-oriented country. As its gateway, Male International Airport is visited by nearly 800,000 tourists every year, and there is a high demand for air conditioning throughout the year.

However, it was difficult to obtain numerical values for power demand due to factors such as the decreased number of tourists in 2020, which was caused by closure of national borders in response to COVID-19. Furthermore, we were told that time will be required for the organization and acquisition of recent data. This delay is due to airport facility managers being forced to respond to COVID-19 and lacking any spare capacity. Therefore, we organized the power demand that was investigated in the Program Organization Research of Multistage Deep Sea Water Utilization Infrastructure in the Republic of Maldives, which was part of the Dissemination and Promotion of Global Warming Countermeasure Technology Project and was held in 2012 as a consigned project by the New Energy and Industrial Technology Development Organization (NEDO). We then verified the effect of the organized numerical values.

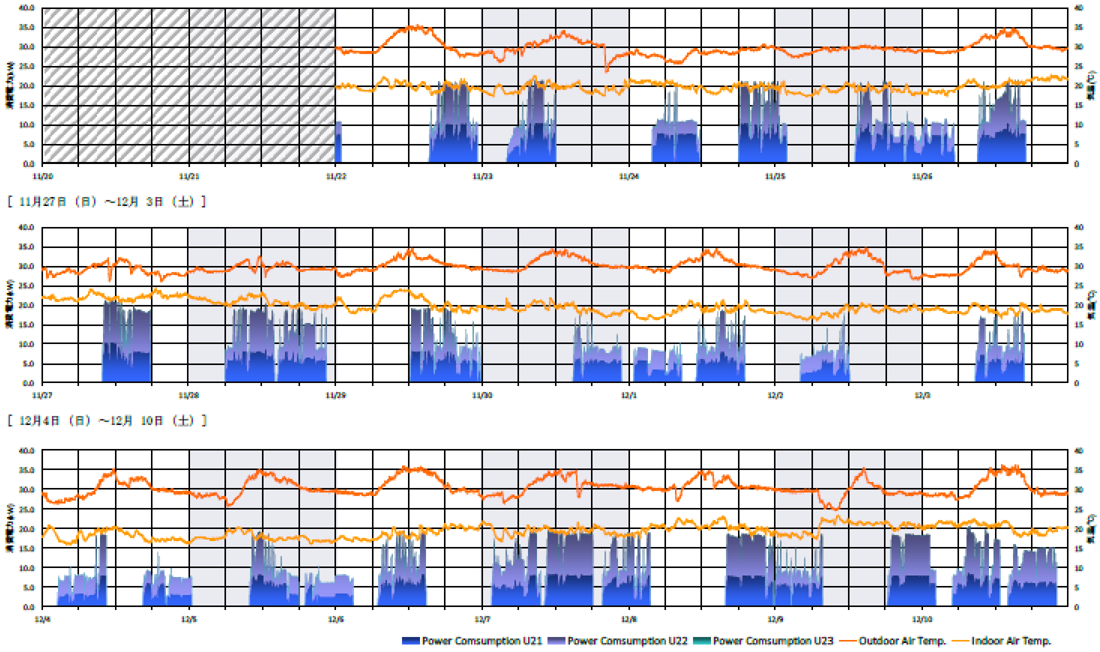
Table 3-29 shows an overview of air conditioning equipment installed in the airport lobby of Malé International Airport. The information in the table is based on the report from the abovementioned project. Furthermore, the results of monitoring the power usage status of different equipment measured in the project are as shown in Figure 3-29, Figure 3-30, and Figure 3-31. The figures show a 24-hour average load factor of 46.4%. In the Maldives, it is assumed that the load factor is constant throughout the year because the temperature fluctuation throughout the year is small (26°C to 33°C). When calculating the annual power consumption based on the above monitoring results, we determined that the total of the three air conditioners installed in the airport lobby is 408,496 kWh/year. Moreover, the annual power consumption is expected to increase further when considering the air conditioning equipment installed outside the airport lobby.

Table 3-28 Overview of Air Conditioning Equipment Installed in the Airport Lobby of Malé International Airport

Facilities Overview	Manufactured by Daikin: Rating of 33.5 kW *3 machines
Operation	Set temperature is 24℃ for 24-hour operation
COP	4.02

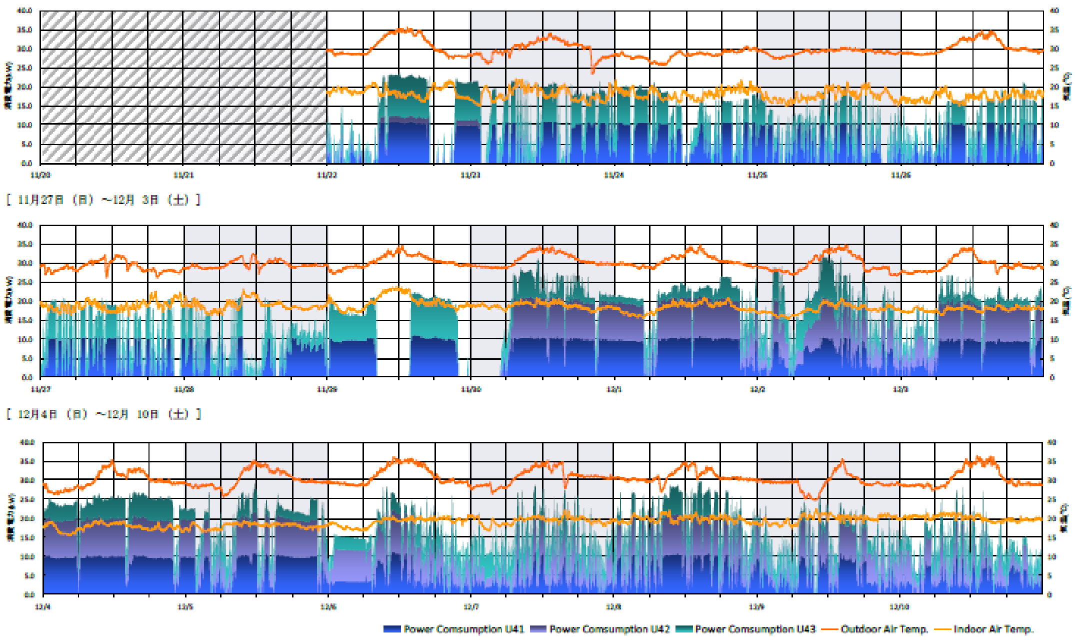
APF*	4.03

*Calculation from actual usage status



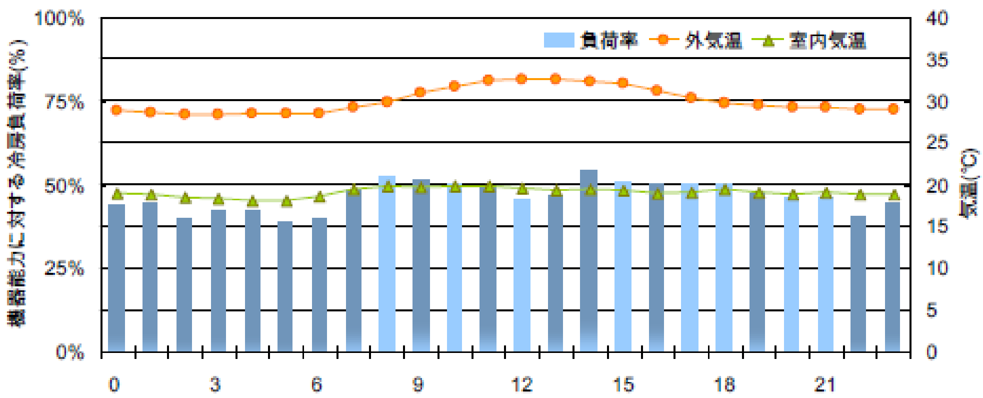
Source: Dissemination and Promotion of Global Warming Countermeasure Technology , Program Organization Research Report of Multistage Deep Sea Water Utilization Infrastructure in the Republic of Maldives

Figure 3-29 Results of Monitoring Status of Power Usage at Malé International Airport (1)



Source: Dissemination and Promotion of Global Warming Countermeasure Technology, Program Organization Research Report of Multistage Deep Sea Water Utilization Infrastructure in the Republic of Maldives

Figure 3-30 Results of Monitoring Status of Power Usage at Malé International Airport (2)



Source: Dissemination and Promotion of Global Warming Countermeasure Technology, Program Organization Research Report of Multistage Deep Sea Water Utilization Infrastructure in the Republic of Maldives

Figure 3-31 Results of Monitoring Status of Power Usage at Malé International Airport (3)

Since the energy-saving effect varies greatly depending on which equipment is selected, this survey assumes an annual power consumption reduction rate. We then used the rate to calculate the amount of possible reduction from annual power consumption and the amount of possible reduction from annual greenhouse gases. Table 3-30 shows the investable project cost calculated from the greenhouse gas reduction cost derived when utilizing the legal useful lifespan of 15 years for air conditioning equipment and the JCM Model Project. For example, when the energy-saving rate is 10%, the amount of greenhouse gases that can be reduced by implementing the project is 326.6 t-CO2, and the investable project cost is approximately 2.61 million yen.

Conversely, verification of the energy-saving effect varies greatly depending on the actual usage situation and the selected equipment. Therefore, it is necessary to collect and examine detailed energy consumption data from on-site surveys in the future.

Table 3-29 Verification of Energy Saving Effect and Result of Calculations for Greenhouse Gas Reductions and Investable Project Cost

Energy Saving Rate [%]	Energy Saving Rate [%]	Amount of Possible Reduction from Annual Greenhouse Gases [t-CO2/ year]	Amount of Possible Reduction from Greenhouse Gases in Project [t-CO2]	Investable Project Cost* [yen]
1	4,085	2.2	32.7	261,274
2	8,170	4.4	65.3	522,548
3	12,255	6.5	98.0	783,822
4	16,340	8.7	130.6	1,045,096
5	20,425	10.9	163.3	1,306,370

6	24,510	13.1	196.0	1,567,644
7	28,595	15.2	228.6	1,828,918
8	32,680	17.4	261.3	2,090,192
9	36,765	19.6	293.9	2,351,466
10	40,850	21.8	326.6	2,612,740
11	44,935	24.0	359.3	2,874,014
12	49,020	26.1	391.9	3,135,288
13	53,104	28.3	424.6	3,396,563
14	57,189	30.5	457.2	3,657,837
15	61,274	32.7	489.9	3,919,111
16	65,359	34.8	522.5	4,180,385
17	69,444	37.0	555.2	4,441,659
18	73,529	39.2	587.9	4,702,933
19	77,614	41.4	620.5	4,964,207
20	81,699	43.5	653.2	5,225,481

* Calculated assuming that the greenhouse gases reduction cost for the project cost is 8,000 yen per t-CO2

In the future, we will collect even more detailed data on airports and deepen our examination on the possibility of introducing high-efficiency equipment. In addition to saving energy in the consumer business sector, our policy is to proceed with the survey while considering demand for saving energy in plants for processing marine products, etc., where there is demand for high heat., and to calculate the effects.

3.4. Low-Carbon Fields with Biogas Power Generation Using Organic Waste

Waste is a major environmental issue in the Maldives and the Malé metropolitan area. Since the Maldives is an island nation, there are limited disposal sites. Proper disposal is not being promoted in the Maldives. In addition to concerns regarding the capacity of disposal sites, the impact of harmful substances and plastics on the ocean is another point of worry.

The Malé metropolitan area generates 9.5 tons of organic waste per day. Final disposal of this waste takes place on Thilafushi Island, a waste treatment site in the suburbs. Although there are plans to modernize the disposal site and introduce waste power generation at the site, the high water content of organic waste may adversely affect the efficiency of waste power generation planned at the site. Accordingly, it is possible that processing will take place at a newly established landfill site.

On the other hand, this waste is a resource that can be used for energy and composting after undergoing treatment by methane fermentation. Such recycling can contribute to solving waste problems and realizing a low-carbon society. We conducted a survey to examine the feasibility of methane fermentation treatment. We also examined the feasibility of introducing technologies such as biogas power generation.

3.4.1. Analysis of Waste Treatment Plans in the Maldives and Malé City

The Strategy Action Plan (SAP) sets targets for waste by 2023. These targets include the selection of technologies that are highly cost-effective and create profit from waste suitable for conditions in the Maldives, as well as the evaluation of mechanisms for generating fuel derived from waste.

Policy 1: Promote waste as a valuable resource for income generation

- Strategy 1.3: Establish a mechanism for waste collection, storage and management at the island level
  - ✧ Action 1.3f: Provide guidance for Island Councils to integrate waste collection as part of the Integrated Utility Service provision of the Government
- Strategy 1.4: Strengthen waste collection and management in Greater Male' Region
  - ✧ Action 1.4a: Roll out household waste segregation scheme
- Strategy 1.5: Strengthen waste management through evidence based policies
  - ✧ Action 1.5a: Conduct comprehensive waste audits across all islands to identify volume of different waste streams and to formulate reduction targets
- Strategy 1.7: Expand and Implement waste-to-energy and expand waste-to-wealth initiatives in local communities
  - ✧ Action 1.7a: Conduct research to identify technologies for converting waste to wealth that is cost effective and appropriate for the Maldivian context

In regards to the introduction of renewable energy, as mentioned in 3.3 Low-Carbon Fields through the Spread of Renewable Energy and Energy Saving, SAP defines targets for increasing the proportion of renewable energy by 20% compared to 2018, and for reducing the amount of diesel fuel used for power generation by 4,000 liters. This can be interpreted as expectations for a link with initiatives related to the waste energy discussed above.

When considering the utilization of waste for energy, it is important to first understand the amount, properties, and characteristics of waste generation (timing, location, etc.). The status of waste generation and treatment in the Malé metropolitan area are described below.

Waste collection in the Malé metropolitan area includes the Greater Malé Region, as well as 32 inhabited remote islands and 86 tourist resort islands in the surrounding Alif Alif Atoll, Alif Dhaal Atoll, Kaafu Atoll, and Vaavu Atoll. The total population in this area is 295,000, which is 53% of the total population in the Maldives. The waste from this area is disposed of by being buried at the waste disposal site on Thilafushi Island.

This disposal site was constructed in 1992. However, it is an open dumping site which has lacked pollution control measures since it was first established. As such, public health issues and environmental impact are becoming more serious. Smoke from spontaneous combustion causes air pollution, and the marine environment may be polluted by waste leachate for which no measures have been taken.

Under these circumstances, it is necessary to order to optimize the disposal of the 836 tons of waste that are generated daily in the area defined above and to realize energy utilization together with waste treatment. In response, in August 2020, the ADB and Maldivian government entered into an agreement for optimization of waste treatment and infrastructure development. Per the agreement, development of waste power generation infrastructure will be systematically implemented in conjunction with the following four measures.[37]

(i) Improved line of movement for solid waste, including collection and waste container transportation.

(ii) Until modern solid waste treatment and disposal facilities are operational, implement temporary measures such as storage of municipal solid waste as an interim solution to stop illegal dumping and incineration on Thilafushi Island.

(iii) Collection and treatment of construction waste and demolition waste.

(iv) Increase institutional capacity and raise public awareness for the provision of sustainable solid waste management (SWM) services.

This project led to approval as the "Greater Malé Waste-to-Energy Project," which utilizes the Japan Fund for the Joint Crediting Mechanism (JFJCM) of the Asian Development Bank. The project targets waste power plants with a capacity of 500 tons per day, and the emissions reduction is estimated to be approximately 40,417 tCO2 per year.

In our survey, based on the above waste power generation business, the targets were organic waste and sewage sludge in the Hulhumalé area. Due to the high water content of this organic waste, treatment via the Greater Malé Waste-to-Energy Project planned at Thilafushi Island will cause the

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[37] ADB Project data sheet" Maldives: Greater Male Waste-to-Energy Project",2020.
URL: https://www.adb.org/projects/51077-003/main#project-pds

heating value to decrease, thus creating the risk of increased fuel consumption. Although the organic waste can be used for waste power generation through dehydration or drying, such pre-treatment also requires energy input and time. Consequently, there is the possibility that the organic waste will be disposed of in a new landfill site.

Therefore, we will consider the application of gasification technology by methane fermentation, a method which enables treatment of substances with a high water content. From among the target waste, the Hulhumalé area has sewage treatment facilities which are managed by the Malé Water and Sewerage Corporation. The amount of sludge generated annually is 1,643 tons per year.

From among general waste collected in the Hulhumalé area, organic waste (green waste) centered on vegetation accounts for 1,825 tons per year and food waste is 405 tons per year. The total amount of waste generated in a year is 3,873 tons.

The Hulhumalé area has few tourists, so it is assumed that the majority of sludge and waste are derived from residents. There appears to be little fluctuation in waste depending on the season. When assuming that generated amount is constant throughout the year, the amount of waste generated per day is approximately 10.6 tons, which is the value obtained by dividing the 3,873 tons by 365 days.

Currently, this waste is disposed of via landfill at the final disposal site on Thilafushi Island. However, we will consider using the waste for generating power via biogas, or using it for composting.

In general, biogas can be effectively used for biogas power generation through methane fermentation. Even so, it is difficult to reduce the volume of waste, and disposal of post-fermentation residue becomes an issue. Accordingly, it is necessary to assume usage in the form of composting, etc.

The Hulhumalé area requires compost to maintain vegetation on roadside trees, parks and green spaces. The Hulhumalé area currently imports about USD 400,000 worth of fertilizer from overseas a year. Since the fermentation residue generated during methane-fermented biogas power generation can be used as compost, it is possible to replace the imported compost through the use of domestic waste. When examining the feasibility of said replacement, it is key to examine the material balance and economic efficiency. The results of this examination are shown in the next section.

3.4.2. Candidate Technology for Biogas Power Generation Equipment, Summary of Manufacturers, Etc., and Estimate of Introduction Effect

(1) Waste amount/composition and candidate facilities

As mentioned above, this survey targets sewage sludge of 1,643 tons per year, organic waste (green waste; mainly vegetation) of 1,825 tons per year, and food waste of 405 tons per year. This amounts to total waste of 3,873 tons per year.

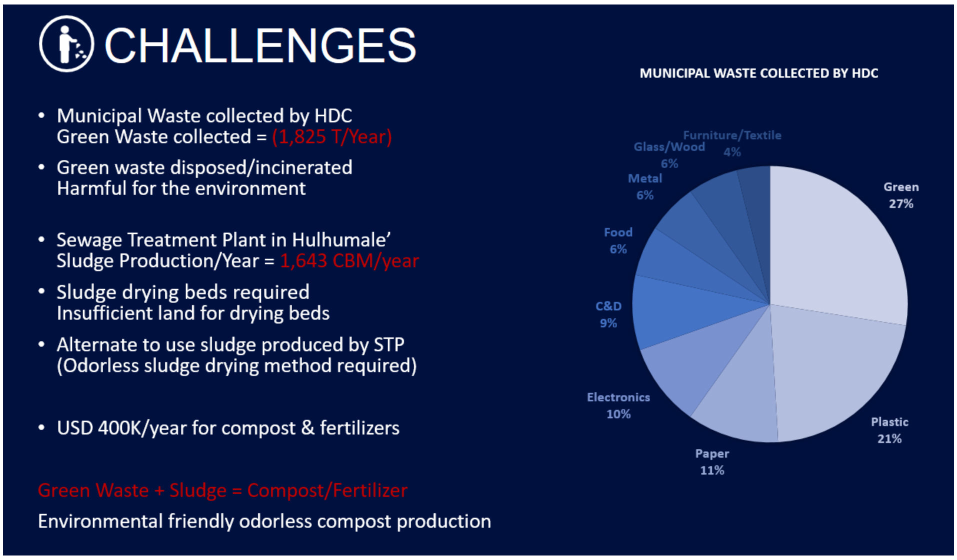


Figure 3-32 Amount and Ratio of Organic Waste Generated in Hulhumalé

Moisture accounts for the majority (approximately 97%) of sewage sludge. However, as shown below, technology for biogas power generation via methane fermentation can be used for fermentation at a solid content concentration of about 10% to 15%. Therefore, it achieves sufficient fermentation through the mixing and processing of solid organic waste.

There are two major types of methane fermentation technology: wet methane fermentation and dry methane fermentation. However, there is no clear distinction between the two types. While the wet type has a proven track record of stable operation, the dry type has the advantages of not requiring dilution of water and being possible using relatively compact equipment. The Maldives has a limited amount of land and water, so dry methane fermentation seems to be highly suitable.

Table 3-30 Features of Methane Fermentation Equipment

	Wet methane fermentation	Dry methane fermentation
Features	Input after adjusting the solid content concentration of the input to 10% or less	Input with solid content concentration of 15-40%
Merit	Abundant operation results Abundant variations in scale and processing volume Uniform and stable fermentation	No dilution required The amount of wastewater treated is small Low equipment cost

In general, in the case of a biomass power generation facility using methane fermentation, it is necessary to remove foreign substances that are not suitable for fermentation from the received material. This requires a sorting process by manual sorting or mechanical crushing or sorting, or a combination of both.

Afterwards, a solubilization process may be performed as a pre-treatment for promoting fermentation. The processes after pre-treatment require equipment such as a methane fermentation tank for fermenting organic substances, desulfurization equipment necessary for electricity creation and utilization of the generated biogas, gas holders, power generation facilities, and surplus gas combustion devices. The facilities to be introduced for fermentation residue depends on the purpose of use.

For example, there are cases in which all of the fermentation residue is sprayed as liquid fertilizer. The equipment required in such cases is forecasted to include liquid fertilizer storage tanks and, in the event that operators themselves spray the liquid fertilizer, vehicles for transporting and spraying the liquid fertilizer. In other cases, there are some facilities that perform solid-liquid separation processing. In this processing, the solid parts are composted, transformed into solid fuel, or dried and then incinerated as industrial waste. The liquid parts are processed as wastewater and then discharged into sewage. In this way, the facilities to be introduced differ depending on the method for processing the fermentation residue. The main equipment of methane fermentation biogasification facilities and the accompanying processing flow are shown below.

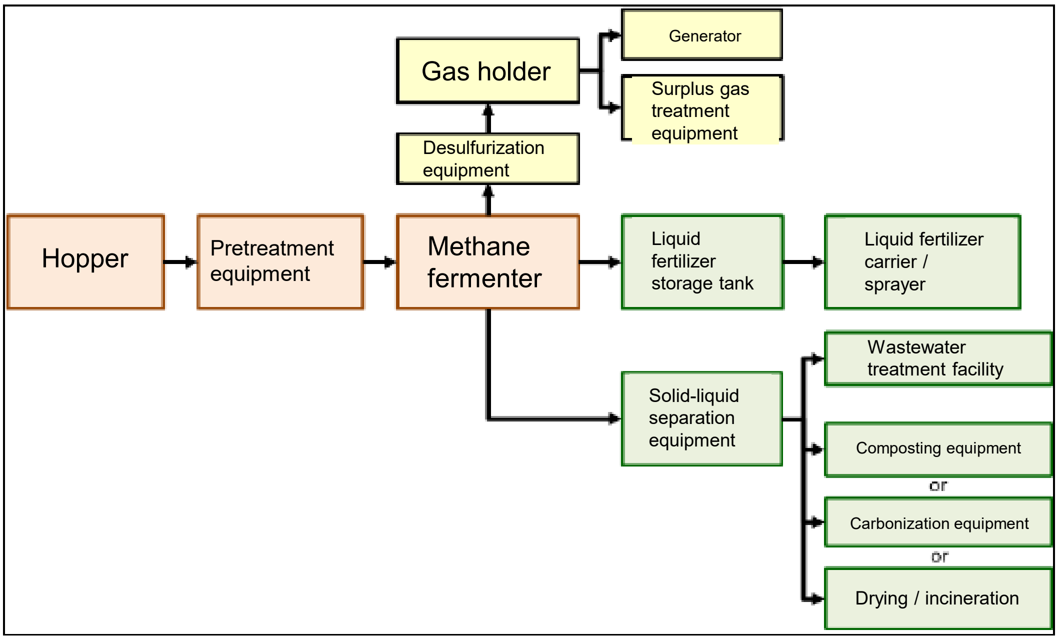


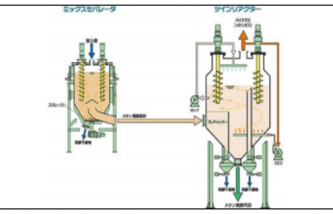
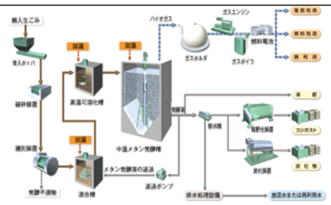
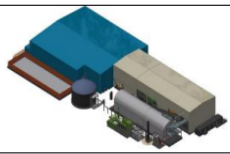
Figure 3-33 Main Equipment that Composes Methane Fermentation Biogasification Facilities

Source) Japanese Ministry of the Environment "FY2017 Report on Regional Circulation Area and Eco-Town Low Carbon Promotion Project"[38]

As shown by the above figure, the methane fermentation biogas facilities used to generate power are roughly divided into methane fermentation facilities and gas power generation facilities. From among these two types, Hitachi Zosen Corporation has a record of developing small-scale to large-scale systems for methane facilities equipment. The following is an example of facilities introduced by Hitachi Zosen Corporation.

[38] Japanese Ministry of the Environment "FY2017 Report on Regional Circulation Area and Eco-Town Low Carbon Promotion Project," Okinawa Prefecture, Japan NUS Co., Ltd., p. 101.

Table 3-31 Methane Fermentation Facilities of Hitachi Zosen Corporation and Introduction Examples

	HITz Mobius system	Hitz WTM system	Hitz component gas system
Target	Sludge, kitchen waste	kitchen waste	kitchen waste, vegetation, paper
Features	Space saving by high temperature methane fermentation equipment Can be combined with a human waste treatment facility	Fast fermentation without diluted water or auxiliary materials Strong against ammonia inhibition by medium temperature fermentation	Achievements in 82 locations in European countries such as Switzerland and Germany
Process flow			
Case study	Manure, sludge 149kl / day Garbage 1.8t / day Gas use: Boiler fuel use Fermentation residue: Use of compost	Food residue from hotels, restaurants, schools, hospitals, factories 50t / day Power generation capacity: 740kW Fermentation residue: composting and sewage discharge	Plant waste, food residue: 82t / day Power generation capacity: 730kW Fermentation residue: composting
	Cost: n/d	Cost: 30 million USD	Cost: 22 million USD
			

Source) Japanese Ministry of the Environment "FY2017 Report on Regional Circulation Area and Eco-Town Low Carbon Promotion Project" [38]

Methane gas is derived from biomass and is produced by fermentation derived from microorganisms. Methane fermentation is a reaction that takes place under anaerobic conditions. In the reaction, the organic matter contained in organic waste decomposes into methane and carbon dioxide due to the metabolic action of multiple types of anaerobic bacteria. However, the metabolism of microorganisms changes depending on the temperature and input material, so the composition of the generated gas is not always constant. Therefore, the power generation facilities must include a generator that can handle a wide range of gas compositions including inert gas.

Such facilities are also found in countries such as southern China, India, and Cambodia. In most cases, the receipt equipment and fermenter are constructed by inexpensive local companies. Conversely, there are many cases where Japanese technologies from companies such as Yanmar, Denyo, and Ohara are adopted for generators. We expect that it will also be possible to use such equipment in the Maldives.

One reason for the superiority of products from developed countries such as Japan is that low-performance generators cannot withstand usage when gas properties are unstable as described above. Japanese manufacturers of generators produce high-quality generators that can withstand such fluctuations in low-quality gas and methane gas concentrations. The introduction of such facilities is expected to excel in reducing carbon. The following manufacturers and lineups are the main power generation facilities based on the characteristics of the biomass power generation described above.

Table 3-32 Main Manufacturers of Biogas Power Generation Equipment and Their Lineups

	Ohara-tekko(JAPAN)	Yanmar (JAPAN)	Jenbach (Germany)
Lineup	30kW, 60kW, 90kW Efficiency: 34-35% High efficiency by controlling the operation of multiple units System interconnection / waste heat recovery device can be installed as an option Extensive lineup with a scale of 150-500kW Efficiency: 38% or more Remote control	25kW Efficiency 32% Up to 8 units can be controlled with one controller 325kW Efficiency 37% Remote monitoring possible Fully automatic control operation possible	TYPE3 (500kW-1MW) TYPE4 (800kW-1.5MW) TYPE6 (1.5MW-4.4MW) TYPE9 (9.5MW) Power generation efficiency 40% or more Can be mixed with natural gas and other gases
Picture			

Source) Japanese Ministry of the Environment "FY2017 Report on Regional Circulation Area and Eco-Town Low Carbon Promotion Project"[38]

From 2002, Toyama City has engaged in the Eco-Town Project as an effort for promoting urban development in harmony with the environment, while at the same time seeking to invigorate regional society. The Eco-Town Project is based on the zero emissions concept, which aims to completely eliminate all waste through new utilization of all waste from industry as raw materials in other fields. Furthermore, an Eco-Town Industrial Park with an area of about 18 hectares has been established in Toyama City as a base for resource recycling facilities.

In the first phase of the project, Toyota City will develop four types of recycling facilities: a facility for food waste and pruned branches, a facility for hybrid waste plastic, a facility for wood-based waste, and a facility for automobiles. Using these facilities, the city will engage in intraregional resource circulation that prioritizes material recycling. In the second phase of the project, the city will develop recycling facilities for difficult-to-process fibers and mixed waste plastics, for waste cooking oil, and for waste energy. It will also open the Toyama City Eco-Town Exchange Promotion Center.

From among the aforementioned facilities, the recycling facility for food waste and pruned branches is handled by Toyama Green Food Recycling Inc. The facilities consist of methane fermentation treatment equipment for food waste and composting treatment equipment for pruned branches. Toyama Green Food Recycling has also introduced the organic waste recycling system *Metacules*. This system collects the biogas that is generated when decomposing food waste and other organic waste by using fixed-bed high-temperature methane fermentation technology that employs microorganisms. Through such technology, Toyama Green Food Recycling operates an environmental plan system for extracting electricity and heat. The main specifications are shown below.

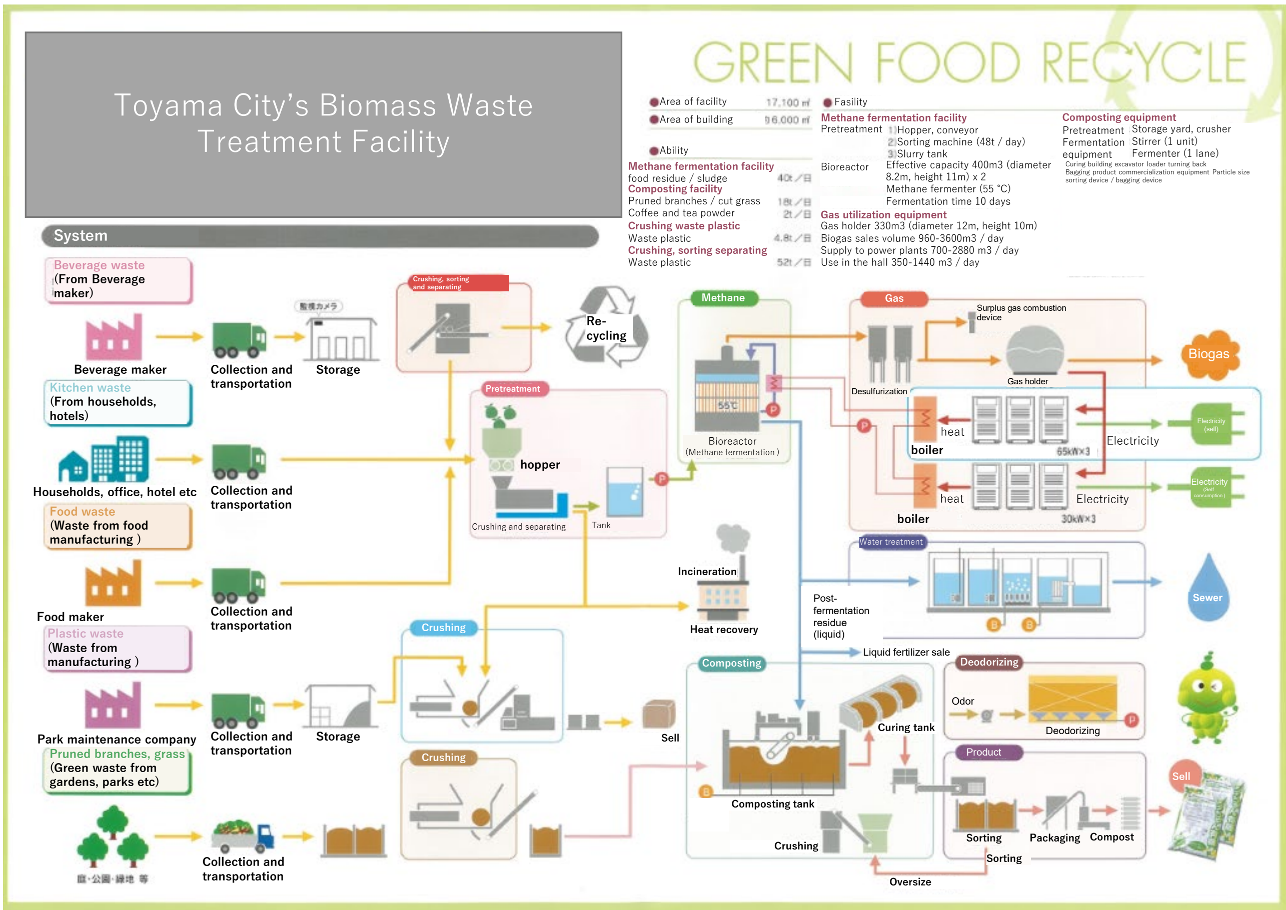


Figure 3-34　Overview of Facilities at Toyama Green Food Recycling, Inc.

Source) Website of Kajima Corporation, Website of Toyama Green Food Recycle, Inc.[39][40]

Toyama Green Food Recycling has a processing capacity of 40 tons per day at its methane fermentation facility and 20 tons per day at its composting facility. At the current point in time, this is a significantly larger scale than Hulhumalé. However, we held a meeting with Toyama Green Food Recycling with the expectation of obtaining useful information on equipment selection, operations, and business. The results of the meeting are listed below.

- Green waste is not suitable for methane fermentation because it possesses a large amount of fiber. This makes fermentation difficult and requires addition labor after processing. <u>A realistic method is to process food waste and sewage sludge at a methane fermentation facility, and to process green waste at a separate composting facility.</u>

[39] Website of Kajima Corporation (https://www.kajima.co.jp/news/digest/aug_2003/zoom/index-j.htm)
[40] Website of Toyama Green Food Recycle, Inc. (https://tgfr.net/_wp/wp-content/uploads/2020/04/flow.pdf)

- Liquid fertilizer has a faster outflow rate and thinner components than compost. Therefore, approximately 10 tons of liquid fertilizer is equivalent to 1 ton of compost. Given that Hulhumalé Island is currently under construction, there may be a greater need for solid fertilizer.
- The methane fermentation facility of Toyama Green Food Recycle uses the wet method. The amount of compost produced is equal to about half of the input waste.
- If the composting facilities conduct composting outdoors and use heavy machinery for stirring, the equipment cost can probably be suppressed to several tens of millions of yen.

Based on the meeting results listed above, we are considering the following operation for Hulhumalé: Food waste and sewage sludge will be treated at a methane fermentation facility. Green waste will be composted by being crushed and then mixed with methane fermentation residue at the composting facility.

(2) Examination of equipment scale and economic efficiency

As mentioned above, the amount of food waste and sewage sludge available generated in Hulhumalé is about 5.6 tons per day. An example of a relatively small-scale biomass power generation facility using methane fermentation is the Dairy Cow Manure Circulation Research Center , which is an affiliated farm of Rakuno Gakuen University in Hokkaido.

The facility uses fermentation raw materials such as dairy cow manure and rice straw to obtain 97,628 Nm3 of biogas per year. This is obtained from an average of 10 tons of biomass per day and 3,650 tons of biomass per year.

The facility uses the obtained biogas to generate 400 kWh of electricity per day. However, of the 400 kWh per day of electricity generated at the facility, about 130 kWh per day is used for electricity at the center. Therefore, the amount of electricity sold is estimated to be 270 kWh / day.

Assuming the introduction of similar facilities in Hulhumalé and setting the number of operating days to 300 days (82%) per year, the amount of electricity generated will be approximately 67,200 kWh per year. When presuming that the unit price of electricity for households in the Maldives is 11.96 yen, the monetary amount of electricity generated will be about 800,000 yen.

Additionally, the fermentation residue can be used as compost for roadside trees and gardens in Hulhumalé. The profit will be the USD 400,000 (about 40 million yen) which is currently spent to import compost.

The initial investment for the Dairy Cow Manure Circulation Research Center that is an affiliated farm of Rakuno Gakuen University in Hokkaido is reported to have been 130 million yen. The values shown in the following table are calculated by adopting this initial investment amount and examining the economic efficiency.

Table 3-33 Economic Study of Biogas Power Generation Equipment

Initial cost	130,000,000	JPY
Capacity	16.7	KW
Output/day	400	kWh
Output/year	120,000	kWh

Unit price	11.96	JPY/kWh
Compost	40,000,000	JPY/year

	0	1	2	3	4	5
Outflow						
Initial cost	130,000,000					
Inflow						
Electricity sell	1,435,200	1,435,200	1,435,200	1,435,200	1,435,200	1,435,200
Compost sell	40,000,000	40,000,000	40,000,000	40,000,000	40,000,000	40,000,000
FCF	-88,564,800	41,435,200	41,435,200	41,435,200	41,435,200	41,435,200
	-88,564,800	-47,129,600	-5,694,400	35,740,800	77,176,000	118,611,200

The table indicates high business feasibility with a model for recovering the initial cost in approximately 4 years. However, this analysis does not include interest rates, land acquisition costs, inflation rates, or operating costs. Moreover, when compared to the farm affiliated with Rakuno Gakuen University in Hokkaido, which uses dairy cow manure and rice straw as fermentation raw materials, a lower fermentation efficiency is forecasted when food waste and sewage sludge are used as fermentation raw materials. On the other hand, the population of Hulhumalé is expected to increase due to the promotion of relocation from Malé. Consequently, the amount of waste is also expected to increase. In the future, it will be necessary to collect the results of forecasts on the amount of waste and more detailed information on the composition and amount of waste. Based on this information, we must proceed with detailed design based on the local circumstances, perform a more detailed trial calculation for the amount of power generated, and study the economic efficiency.

Furthermore, since operations are related to sewage treatment and waste treatment, the project is strongly related to public works. Accordingly, a judgment may be made to prioritize public works over business efficiency. For example, there may be policy decisions such as supplying the generated electricity to sewage treatment plants instead of selling the electricity. SAP has a policy of using renewable energy for at least 30% of electricity used at sewage treatment plants by 2023. There is the possibility of the project contributing to the realization of such a policy.

Alternatively, the decision may be made to sell the generated methane as a substitute for LP gas instead of using it for power generation. Since Hokusan Co., Ltd. (the joint implementer of this project) possesses knowledge related to the supply of gas, it is possible to provide technical support for the transportation of gas.

(3) Future considerations

Based on the examination results discussed above, we confirmed with the Hulhumalé Development Cooperation that we will proceed with detailed facilities selection, design, cost estimation, and other procedures in the future.

- Collect detailed data on the composition and amount of waste

It is necessary to collect more detailed information on the composition and amount of waste, including forecasts for the future amount of waste generation. We are having the Hulhumalé Development Cooperation act as an intermediary to request the collection of information by waste management companies. We will use the acquired information to select facilities and to examine economic efficiency.

- Select equipment

We will select the optimal facilities based on the composition/amount of waste and the economic efficiency.

- Select candidate locations

Since we are planning to use sewage sludge, it is desirable to install facilities on the land adjacent to the sewage treatment plant. After considering the scale of the facilities to be introduced, we will select a candidate location that will ensure a sufficient area near the sewage treatment plant.

- Examine the detailed design (FEED)

According to meetings with manufacturers, information on the following items is required at the detailed design stage.

- Solid content concentration of waste
- Utilization of fermentation residue (liquid fertilizer or compost)
- In the case of liquid fertilizer, examination of carrier vehicles and sprayer vehicles for liquid fertilizer
- In the case of compost, facilities for separating solids and liquids
- Wastewater treatment method for liquids generated during compost production

- Examination of electricity usage methods

As mentioned above, the electricity generated by biogas power generation may be sold or it may be used for self-consumption; for example, use a sewage treatment plant. When selling electricity, we must coordinate with the electric power company STELCO. We must engage in detailed consideration of how to use electricity in view of local needs and economic efficiency.

- Examine economic efficiency

In parallel with consideration of the electricity utilization methods discussed above, we will also examine the economic efficiency. Revenues include compost sales revenue and electricity sales revenue. Based on an examination of economic efficiency, we must negotiate selling prices for electricity and compost with related parties.

3.4.3. Examination of Low-Carbon Effect of Biogas Power Generation Equipment and JCM Implementation

Since the electricity generated by biogas power generation is a form of renewable energy, we expect carbon to be reduced when the generated electricity is used in place of the power grid.

As an MRV methodology for anaerobic treatment of organic waste and utilization of biogas, we referred to the MRV methodology (VN_AM004) used in the case study “Anaerobic digestion of organic waste for biogas utilization within wholesale markets ” (Ho Chi Minh City, Vietnam). This methodology comprises measures to avoid the emissions of methane from organic waste that has been left to decay anaerobically at a waste disposal site and to calculate the reduction of greenhouse gas emissions by supplying users with biogas that displaces fossil fuel use (Table 3-35).

This methodology can be applied when sewage sludge, food residue, and green waste generated from Hulhumalé are landfilled instead of being processed at the waste power plant to be newly constructed. We will examine the methodology while ascertaining the operation plan for the waste power plant and processing facilities which are scheduled for construction in the future.

Table 3-34 Outline of Methodology (VN_AM004)

Greenhouse gas emission reduction measures	Avoid the emissions of methane from organic waste left to decay at a waste disposal site. Displace fossil fuels by supplying biogas.
Calculation of reference emissions	1. For avoidance of methane emissions, the reference emissions are calculated based on the weight of organic waste prevented from disposal at the waste disposal site using the FOD (First-order decay) model. (2006 IPCC Guidelines for National Greenhouse Gas Inventories) 2. Reference emissions are calculated based on the monitored amount of biogas supplied, Net Calorific Value (NCV) of the biogas and CO_2 emission factor of the reference fossil fuel.
Calculation of project emissions	Project emissions are calculated on the basis of monitored electricity consumption.
Monitoring parameters	● Amount of organic waste prevented from disposal at the waste disposal site (excluding sludge) ● Amount of processed biogas supplied to heat generation equipment

Details of the MRV methodology (VN_AM004) are shown below.

Reference emissions	
Emission sources	GHG types
Methane emissions from decay of organic waste	CH_4
Fossil fuel consumption by the heat generation equipment	CO_2
Project emissions	
Emission sources	GHG types
Electricity consumption by the waste management facility	CO_2

[Reference emissions]

Methane emissions from decay of organic waste

Calculated using the FOD model adopted in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

$$RE_p = RE_{CH4,p} + RE_{FF,p}$$

RE_p	Reference emissions during the period p [tCO2/p]
$RE_{CH4,p}$	Reference emissions from decay of organic waste during the period p [tCO2/p]
$RE_{FF,p}$	Reference emissions from fossil fuel consumption for heat generation during the period p [tCO2/p]

Since methane occurs significantly after disposal, RECH4,p calculates the amount of methane generated 13 months after disposal.

$$RE_{CH4,p} = \sum_{m=p\_start}^{p\_end} \left\{ (1-f) \times GWP_{CH4} \times (1-OX) \times \frac{16}{12} \times F \times DOC_f \times MCF \times \sum_{x=1}^{m-13} W_x \times DOC \times e^{-\frac{k}{12}(m-13-x)} \times \left(1-e^{-\frac{k}{12}}\right) \right\}$$

f	Fraction of methane captured at the waste disposal site and processed in a manner that prevents the emissions of methane to the atmosphere
GWP_{CH4}	Global warming potential (GWP) of methane
OX	Oxidation rate (amount of methane from waste disposal sites that is oxidized in the soil, etc.)
16/12	Molecular weight ratio of methane to carbon
F	Ratio of methane in gas from waste disposal sites
DOC_f	Ratio of degradable organic carbon that decomposes (by weight)
MCF	Methane correction factor[41]
Wx	Amount of organic waste prevented from disposal at a waste disposal site in month x (tons)
DOC	Fraction of degradable organic carbon (by weight)
k	Decay rate (1/year)
x	Period in which waste is disposed at a waste disposal site (month) (1 to m)
m	The Nth month from the first disposal of waste at the waste disposal site (start month: m=p_start, end month: m=p_end)
p_start	The Nth month from the first disposal of waste at the waste disposal site, which is the first month of the period p (If p_start is smaller than 14 due to methane gas occurring significantly after disposal and if p_end is greater than 13, p=start is set at 14)
p_end	The Nth month from the first disposal of waste at the waste disposal site, which is the last month of the period p

Fossil fuel consumed by the heating device

[41] 2006 IPCC guidelines for National Greenhouse Gas Inventories (Volume 5, Table 3.1)

$$RE_{FF,p} = RE_{BG,p} \times NCV_{BG} \times EF_{CO2,i}$$

$RE_{FF,p}$	Reference emissions from fossil fuel usage for heat generation during the period p [tCO2/p]]
$RE_{BG,p}$	Amount of processed biogas supplied to heat generation equipment during the period p [t/p]
NCV_{BG}	Net calorific value of the processed biogas [GJ/t]
$EF_{CO2,i}$	CO2 emission factor of fossil fuel i [tCO2/GJ]
i	Type of fossil fuel i consumed by the heat generation equipment

[Project emissions]

$$PE_p = PEC_p \times EF_{elec}$$

PE_p	Project emissions during the period p [tCO2/p]
PEC_p	Amount of electricity consumption by the waste management facility during the period p [MWh/p]
EF_{elec}	Emissions factor of electricity grid [tCO2/MWh]

[Reduction amount]

$$ER_p = RE_p - PE_p$$

ER_p	GHG emission reductions during the period p [tCO2/p]
RE_p	Reference emissions during the period p [tCO2/p]
PE_p	Project emissions during the period p [tCO2/p]

If the facilities in our project are classified as "internal combustion power or gas turbine power generation equipment," the legal useful lifespan will be 15 years. Similar to the MRV methodology above, we will use the FOD model[42] described in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and will calculate the reference emissions for avoiding methane emissions associated with the decay of organic waste in the Maldives. The values calculated during the lifespan are 16,465 t-CO2 for green waste (assuming vegetation only), 2,101 t-CO2 of food waste, and 4,262 t-CO2 of sewage sludge, for a total of 22,829 t-CO2. Similar to the example case in Vietnam, we use the minimum value for DOC in order to engage in conservative calculations. Also, we assume that the annual amount of waste generated is 1,643 tons per year for sewage sludge, 1,825 tons per year for green waste, and 405 tons per year for food waste.

Additionally, the power grid emissions factor in the Maldives is 0.533 tCO2/MW. If the abovementioned estimated power generation amount of 67,200 kWh is sold via grid connections, the reference emissions of fossil fuels consumed in power generation is approximately 36 t-CO2 per year, which equates to 537 t-CO2 over a 15-year period.

Based on the figures stated above, the total reference emissions are 23,367 t-CO2 over a 15-year

[42] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5 Waste , IPCC Waste Model (MS Excel) (https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol5.html)

period.

The reduction amount is the value obtained by subtracting the project emissions amount from the reference emissions amount. Since the power consumed by the methane fermentation/composting facility (the project emission amount) is unclear, we calculated the reduction cost per ton when using the reference emissions amount as the reduction amount.

In the abovementioned case of Hokkaido Rakuno Gakuen University, the on-site power is 130 kW per day; however, in view of the cold climate in Hokkaido, this value is assumed to include a large amount of energy used for keeping the fermentation tank warm. In the future, it will be necessary to closely examine the in-house power value, etc., by holding meetings with candidate vendors of facilities.

When using the case of Hokkaido Rakuno Gakuen University as a basis for assuming that the facilities cost is 130 million yen, the facilities subsidy amount will be 65 million yen per the subsidy rate of 50% for the JCM Model Project. This means that the reduction cost per ton is 2,781 yen. In the JCM Model Project, it is necessary to consider the cost-effectiveness of the reduction cost, the standard for which is 4,000 yen per t-CO2. Therefore, it can be said that there is sufficient cost-effectiveness when considering the entire project as a JCM Model Project.

On the other hand, one of the eligibility criteria for the MRV methodology cited above is "Criterion 3: The raw material to be put into the anaerobic digester is organic waste that will be landfilled if the project is not implemented." As discussed above, the construction of a waste power plant is currently planned in the Maldives as part of the ADB project. If sewage sludge is incinerated at the waste power plant, the methane emission avoidance amount cannot be used as the reference emission amount. In the future, it will be necessary to consider such factors while paying close attention to the local waste management policy.

3.4.4. Implementation System and Schedule

For the implementation system, we will consider a plan which positions the Toyama City gas company Hokusan Co., Ltd. as the representative company and forms an international consortium with the Hulhumalé Development Cooperation, which is responsible for sewage treatment facility management and green space management on Hulhumalé Island. Since the Hulhumalé Development Cooperation is responsible for the use of compost, it is an offtaker in this project. Furthermore, since the Cooperation is responsible for proper disposal of waste, it can be part of an implementation system that contributes to the stability and sustainability of the project.

In the future, we will proceed with the collection of more detailed data on the composition and amount of waste, as well as with selection of facilities, selection of candidate locations, and examination of detailed design. The expected schedule is shown in Figure 3-35.

We will continue to coordinate with the local government and collect local information such as the amount of waste generated. This actions will be carried out in cooperation with the Hulhumalé Development Cooperation and in cooperation with related organizations (administrative organizations, related companies, etc.) as necessary. Regarding the selection of equipment, we will make inquiries to manufacturers (Hitachi Zosen Corporation, etc.) of methane fermentation facilities, composting facilities, and biogas generators. We will select facilities that suit the local conditions and consider the possibility of having each manufacturer participate in our project.

Furthermore, we will hold discussions on the EPC and on-site construction system with JGC Corporation and facilities manufacturers. We will examine the entire operation obtaining advice from Toyama Green Food Recycling Inc., which operates a methane fermentation facility and a composting facility in Toyama City. Also, we will receive advice from Hokusan Co., Ltd. regarding the possibility of using biogas. In addition, with a view to participating as a business operator of Toyama City Eco-Town related companies such as Toyama Green Food Recycling Inc., our policy is to utilize Toyama City's environmental efforts and knowledge to construct a low-carbon society in the Maldives.

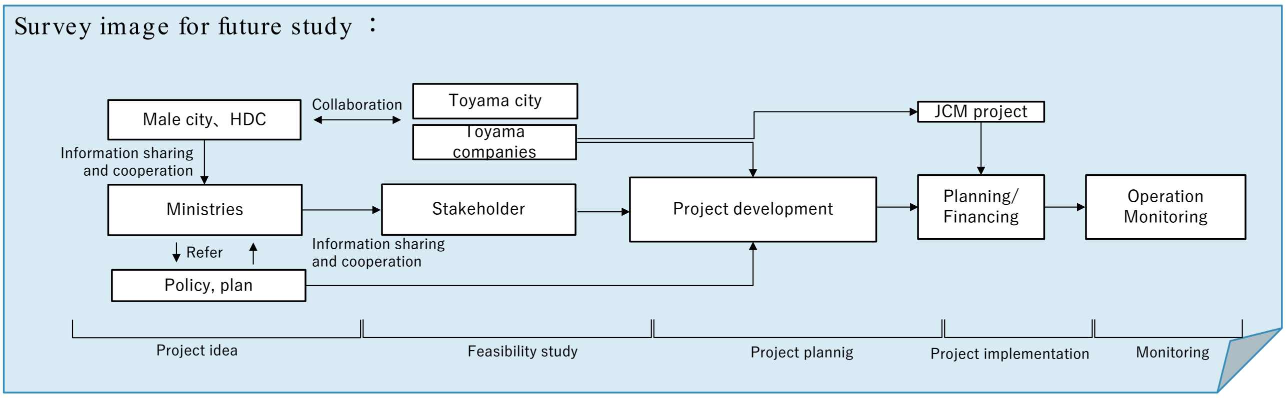


Figure 3-35 Implementation Schedule

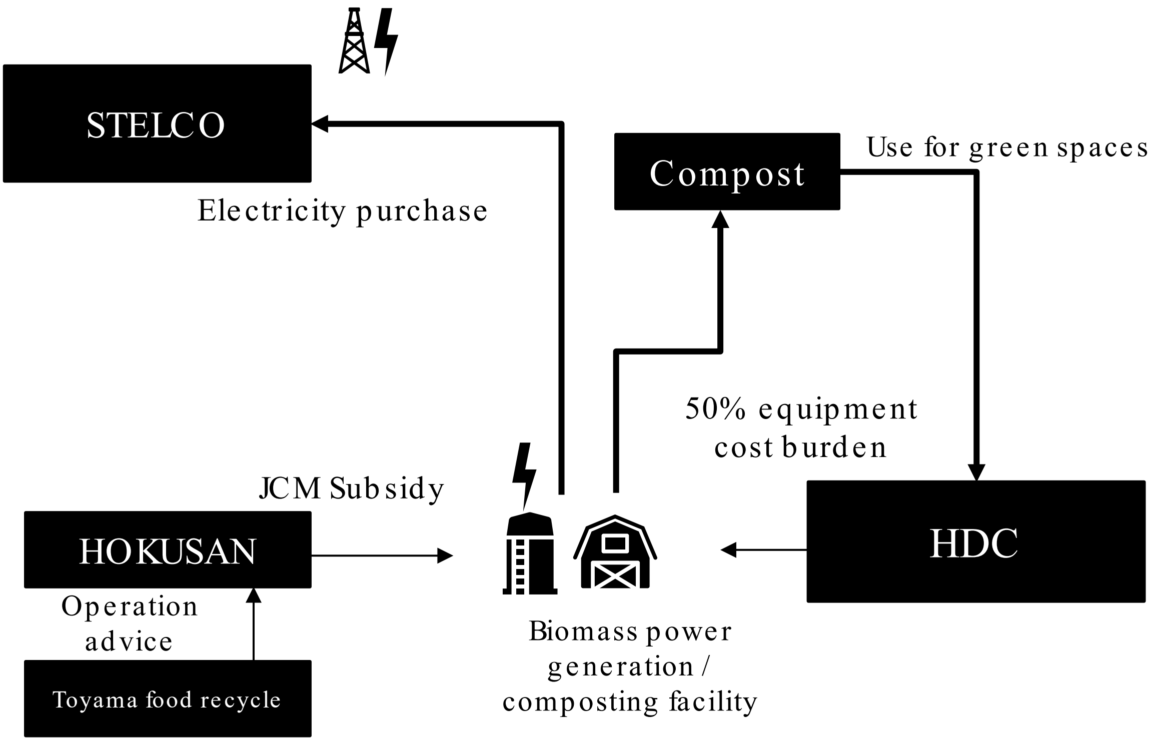


Figure 3-36 Draft of Implementation Schedule

4. City-to-City Collaboration for a Low-Carbon Society (invitation of local

stakeholders, holding of workshops)

4.1. Overview of City-to-City Collaboration Activities

The city-to-city collaboration project in this fiscal year was executed under unusual circumstances where field surveys and invitations could not be made due to the impact of COVID-19 pandemic. Through tools such as remote meetings and e-mails, we gained an understanding of the survey contents and activities from local stakeholders. We also strove to collect information through the cooperation of local counterparts, the Embassy of Japan in the Maldives, and the JICA Secretariat, and to engage in consideration.

The main activities are summarized below.

Table 4-1 Main Activities and Participating Organizations

Date	Activities	Participating Organizations
September 9, 2020	Confirmed the policy regarding survey contents with Toyama City and companies in Toyama City. Held discussions on necessary information and examination contents.	Toyama City, Hokusan Co., Ltd., Japan NUS Co., Ltd.
September 18, 2020	Kickoff Meeting	Ministry of the Environment, Toyama City, Sato Kogyo Co., Ltd., Hokusan Co., Ltd., Nihonkucho Hokuriku Ltd., Japan NUS Co., Ltd.
September 23, 2020	Confirmed the policy regarding survey contents with Hulhumalé Development Cooperation. Held discussions on necessary information and examination contents.	Hulhumalé Development Cooperation, Japan NUS Co., Ltd.
October 1, 2020	Discuss the allocation of survey responsibilities with companies in Toyama City.	Hokusan Co., Ltd., Japan NUS Co., Ltd.
October 8, 2020	Held discussions between Toyama City and Maldives-related organizations regarding survey contents, policies, division of roles, etc.	Toyama City, Ministry of Environment and Energy, Malé City, Hulhumalé Development Cooperation, Japan NUS Co., Ltd.
October 21, 2020	Explanation of business overview and request for cooperation to Embassy of Japan in Maldives.	Embassy of Japan in Maldives, Japan NUS Co., Ltd.

November 4, 2020	Explanation of business overview and request for cooperation to the Maldives Embassy in Tokyo.	Embassy of Maldives in Tokyo, Japan NUS Co., Ltd.
November 5, 2020	Explanation of business overview and request for cooperation to the Maldives JICA Office.	JICA Maldives Office, Japan NUS Co., Ltd.
November 25, 2020	Held discussions with parties related to the waste power generation business in the Maldives.	JGC Corporation, Japan NUS Co., Ltd.
December 11, 2020	Held discussions with Toyama City companies regarding the compilation of survey results related to the transportation field.	Sato Kogyo Co., Ltd., Kawada Industries, Inc., Nippon Engineering Consultants Co., Ltd., Japan NUS Co., Ltd.
January 13, 2021	Held interview-based surveys related to waste power generation.	Hitachi Zosen Corporation, JGC Corporation, Japan NUS Co., Ltd.
January 14, 2021	Shared survey results and requested additional information on public transportation with Hulhumalé Development Cooperation. Held discussions on examination policy with the Cooperation.	Hulhumalé Development Cooperation, Sato Kogyo Co., Ltd., Kawada Industries, Inc., Japan NUS Co., Ltd.
January 19, 2021	Confirmed the progress of survey contents regarding the renewable energy business with companies in Toyama City.	Nihonkucho Hokuriku Ltd., JGC Corporation, Japan NUS Co., Ltd.
January 21, 2021	Hearing the possibility of dispatching wave power generation manufacturers to the Maldives.	Soundpower Corporation, JGC Corporation, Japan NUS Co., Ltd.

The details of discussions with Toyama City, the Maldives Ministry of Environment and Energy, Malé City, and the Hulhumalé Development Cooperation are below. The contents of these discussions were significantly related to policy decisions for the survey in the current fiscal year and to future examination policy.

4.2. Kick-off Meeting by Toyama City, the Maldives Ministry of Environment and Energy, Malé City, and Hulhumalé Development Cooperation (October 8, 2020)

This discussion was held on October 8, 2020. Microsoft Teams was used to connect Toyama City and various locations of the Maldives. Japanese participants took measures to prevent infection and then went to Toyama City Hall. Participants from the Maldives are shown in Table 4-2.

Table 4-2 Attendees from Maldivian Government, Malé City, Hulhumalé Development Cooperation

Name	Position	Affiliation
Suhail Ahmed	Managing Director	HDC
Hussain Ziyath	Director, Planning	HDC
Shahid Ahmed Waheed	Senior Urban Planner	HDC
Ibrahim Jilan	Urban Planner	HDC
Ahmed Shahud Zuhair	Urban Planner	HDC
Ibrahim Naushad	Assistant Urban Planner	HDC
Ahmed Shadheen	Assistant Urban Planner	HDC
Ali Shareef	Director	Ministry of the Environment Maldives
Zammath Khaleel	Assistant Director	Ministry of the Environment Maldives
Sifa Mohamed	Mayor	Male City
Shamau Shareef	Deputy Mayor	Male City

At the Kick-Off Meeting, we introduced the project to the Maldavian Ministry of the Environment, the Mayor of Malé City, and the Hulhumalé Development Cooperation. We also requested cooperation for the survey and exchanged opinions on policies for future city-to-city collaboration.

First, Toyama City introduced its efforts up until this point in time. Next, Japan NUS Co., Ltd. introduced an overview of the project.

In response, the Hulhumalé Development Cooperation promised to collect information on the implementation of the project while cooperating with Malé City and the Maldivian Ministry of the Environment. After collecting the information, the Hulhumalé Development Cooperation will then organize the information and share it with Toyama City and Japan NUS Co., Ltd.

The Mayor of Malé City also promised to cooperate in providing as much information as possible. In addition to this project, there are various projects being implemented with Japan. The Mayor expressed his hopes for the success of this project with a view toward subsequent collaboration with other projects.

The Hulhumalé Development Cooperation and the Maldivian Ministry of the Environment stated that they have confirmed the possibility of providing the information requested by the Japanese side. Furthermore, we received the following comments in regards to each survey item.

<u>Public transportation</u>

A feasibility survey on the introduction of a monorail has just been conducted. However, at the time of the survey, there was no bridge connecting Malé Island and Hulhumalé Island,

and the survey only targeted the population of Hulhumalé Island. Now that the two islands are connected by a bridge and the population has increased, the scale of the monorail may be too small. The population targeted for public transportation is expected to be 400,000 to 500,000, and transportation options include monorail, light rail transit, and buses. The initial plan was to operate public transportation within Hulhumalé Island, but an option is now being considered to connect Malé Island and Hulhumalé Island via public transportation. Still, installing a railroad track on the bridge appears to pose significant difficulties. From 2010 to 2015, we also considered introducing a tram on Hulhumalé Island. We are also examining a method of beginning operation on Hulhumalé Island and then considering extension to other islands in the future.

Diesel and LNG co-firing

Several similar plans are being implemented by STELCO, etc. We may be able to facilitate realization by considering cooperation and collaboration with those other plans. It must also be noted that diesel and LNG co-firing requires infrastructure and other peripheral facilities. The introduction of LNG is also a goal of our nationally determined contributions (NDC). However, specific introduction locations have yet to be determined and consideration is still taking place within the ministry.

Introduction of renewable energy

A project for the introduction of solar panels has already been adopted by JCM. One problem in this project is the lack of space at the installation location (roofs), but we would still like to cooperate in a survey of installation locations. Please note that there are restrictions on installation. For details, please check with the department/person in charge. Due to the small land area of the Maldives, it may be a good idea to use solar panels which float on the sea. There is also the possibility of introducing solar panels through a contract with STELCO, and a PPA system is being prepared. We will confirm the companies and commercial facilities that are interested in in-house consumption.

Although there is no national subsidy system for introduction of renewable energy, there is a system for the exemption of import tax. There is also a FIT system. Through support from the World Bank (WB) and ADB, a solar power generation project utilizing the FIT system is underway.

In regards to energy saving, steam boilers are used at plants for processing marine products. Since these boiler consume relatively large amounts of energy, there may be the potential for introducing alternative forms of renewable energy.

Biogas power generation using organic waste

There is a plan to build a large-scale waste power plant (8 MW scale) on Thilafushi Island as a project of the Asian Development Bank (ADB). We would like to proceed with the project while coordinating with both parties.

In addition, the Maldivian Ministry of the Environment made particular reference to the following four points regarding major environmental issues.

1. The Malé metropolitan area is roughly divided into five areas. Our plan calls for waste to be collected in each area and incinerated at the waste power plant scheduled for construction on Thilafushi Island. There are problems associated with the collection of waste.
2. Since the Maldives is susceptible to coastal erosion, tsunami, and other impacts of climate change, it is necessary to consider adaptation measures at the same time as mitigation measures.
3. The development of public transportation is insufficient. In particular, Malé City has a large amount of traffic. There are problems such as lack of parking space and air pollution due to exhaust gas.
4. Climate change mitigation policies are needed. Although the Maldives does not have a high level of CO2 emissions when compared to other countries throughout the world, diesel fuel accounts for 99% of energy in the Maldives. It is necessary to replace diesel with energy that emits less CO2. In addition to plans for utilizing LNG in the future, the Maldives has already introduced solar power generation. An energy plan (roadmap) is scheduled for completion in the near future.

Results from the exchange of opinions listed above have been applied to each item in our survey. By doing so, we examined priorities and refined our course of action.

4.3. Workshop

Scheduled to be held on March 1.

5. Summary

5.1. Results in the Current Fiscal Year

The COVID-19 pandemic prevented us from holding on-site surveys in the current fiscal year. Instead, we used tools such as frequent remote meetings and e-mails to successfully obtain the information and data necessary for examination and to hold interview-based surveys.

This city-to-city collaboration project is expected to be implemented over a three-year period. In the current fiscal year, which is the first year of the project, we were able to achieve the implementation of future survey policies and basic consideration for commercialization. Additionally, as a city-to-city collaboration project, we were able to introduce Toyama City's efforts toward the realization of an environment-friendly city, exchange opinions, and implement policy proposals. A summary of results is shown in the following table.

Table 5-1 Summary of Results

Candidate Projects	Results
Public transportation	・ Confirmed the status of transportation policy and the policy position of public transportation ・ Ascertained that there are needs for public transportation; however, a master plan showing the ideal form of public transportation has not yet been developed ・ Confirmed that formulation of a master plan is indispensable for selecting optimal public transportation, procuring funds, and creating plans ・ Agreed on policies for future planning/proposal procedures and financing plans
Diesel power generation gas conversion	・ Ascertained the maintenance plan of the gas supply chain ・ Acquired information on the current status of generators and power generation facilities ・ Ascertained the effects of using DF
Renewable energy	・ Identified potential sites ・ Ascertained the effects ・ Arranged other renewable energy and energy saving technologies
Biomass waste methane fermentation	・ Ascertained the current amount of generated waste and treatment status ・ Ascertained the effects
Other	・ Collaborated with waste power generation project on Thilafushi Island
City-to-city collaboration activities	・ Made policy recommendations (introduction of Toyama City's efforts to realize an environmentally friendly city) ・ Gave advice on utilizing JCM

5.2. JCM Model Project Candidates and Implementation Issues

Assuming selection as a JCM Model Project, our survey targets the following four areas: (1) public transportation, (2) diesel power generation fuel conversion, (3) renewable energy/energy saving, and (4) biomass power generation using methane fermentation of organic waste are targeted.

As discussed above, during the current fiscal year, we obtained the required information on each theme and held discussions with related organizations through facilitation by the Hulhumalé Development Cooperation. We also identified sites, ascertained effects, identified the introduction technology, and examined drafts of implementation plans.

The following table is a list of JCM Model Projects and issues derived from each theme.

Table 5-2 JCM Project Candidates, Issues, and Countermeasures

Theme	JCM Model Project Candidates	Implementation Issues	Countermeasures
(1) Public transportation	・Light rail transit cars (candidates)	・ At the time of implementation, it is necessary to take steps such as formulating a master plan, identifying the technology to be introduced, and procuring funds for infrastructure.	・ Utilizing the characteristics of city-to-city collaboration projects, we will promote examination and implementation with cooperation from Toyama City, which has good examples of public transportation policies.
(2) Diesel power generation fuel conversion	・Malé Island: 8,700 kW2 terminal	・ Necessary to establish a gas infrastructure chain ・ Necessary to consider a gas transportation chain on Malé Island. ・ Lack of information required for modification of generator ・ Construction of JCM project structure	・ While grasping the plan execution status of SAP and STELCO, we will improve the evaluation accuracy of emission reduction effects, economic efficiency, etc., by obtaining detailed information on gas transportation and facilities on Malé Island. ・ Establish an international consortium with STELCO in collaboration with Malé City, the Hulhumalé Development Corporation, and the Maldivian Ministry of the Environment

(3) Renewable energy/energy saving	• Roofs of government facilities on Malé Island and Hulhumalé Island (solar power)	• Issues in the decision-making and financial strength of equipment owners	• Select a project in collaboration with the solar diffusion plan of the Maldivian Ministry of the Environment
(4) Biomass power generation using methane fermentation of organic waste	• Sewage sludge and organic waste from Hulhumalé Island	• Necessary to scrutinize waste composition details, and quality and price of compost for sale	• Currently requesting data collection by the Hulhumalé Development Cooperation

5.3. City-to-City Collaboration in the Next Fiscal Year and Future Proposals

In the next fiscal year, we will execute the survey contents corresponding to the "Countermeasures" shown above in Table 5.2. The following table shows the implementation details and plans envisioned for each theme to be considered in the future.

Table 5-3 Implementation Details and Plans for Themes to Be Considered

Project	2020	2021	2022	2023
(1)Public transportation	Planning	Effect calculation	Project development	JCM or another program
Public transport master plan formulation / introduction technology study (JICA)		Project development		
Infrastructure development and financing (ADB)		Negotiation		Loan
(2) Diesel power generation gas conversion	Planning Effect calculation	Decision making Propose for donor	JCM project	Monitoring
(3)Renewable energy	Site identification Effect calculation	Decision making Propose for donor	JCM project	Monitoring
Energy saving Another renewable energy	Site and technology identification	Decision making Propose for donor	JCM project	Monitoring
(4)Biomass waste methane fermentation	Planning Effect calculation	Decision making Propose for donor	JCM project	Monitoring

It is undeniable that the impact of the COVID-19 pandemic has limited the on-site confirmation and discussions with stakeholders which are indispensable for project implementation. We hope that it will be possible to travel to the Maldives in the future, but this may not be possible in the near term. Nevertheless, decision-making and setting of conditions is essential for realization of the project. This means that we must consider various measures such as further utilization of online tools and appointment of on-site coordinators.

Beginning from the next fiscal year onward, we aim to devise survey options based on the premise that travel restrictions will continue, and to implement projects of each theme by establishing necessary structures.

Further, in the times of worldwide acceleration towards decarbonization, it may be necessary to review the usage of natural gas. As mentioned above, the emission factor of natural gas is low and certainly a low carbonization technology. Meanwhile from the viewpoint of decarbonization, we will discuss the possibility of introduction of alternative energies (e.g. recyclable energy hydrogen, ammonia based on said hydrogen, MCH, energy career including methane and biomass), which are cleaner renewable energy.

Additionally, as a city-to-city collaboration project, our policy is to make proposals after considering the possibility of applying the initiatives and strategies of Toyama City as an SDGs Future City to Malé City. Specific measures include an idea of a development project which combines decarbonization and cooperation between fisheries and other industries as the economy of the Maldives which relies on tourism is devastated by the spread of COVID-19. As for the waste treatment and water treatment which have long been considered as development issues of the Maldives, there is also room for discussion on proposals combining decarbonization technology. By smoothly exchanging opinions with Malé City, we hope to conduct survey and consider the possibility of JCM project.

(End)