Project commissioned by the Ministry of the Environment in FY2022

City-to-City Collaboration for Zero-Carbon Society in FY2022

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

Report

March 2023

Japan NUS Co., Ltd.

Toyama City

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Table of Abbreviations

Abbreviation	English	Japanese
ADB	Asian Development Bank	アジア開発銀行
Avgas	Aviation Gasoline	小型機向け航空ガソリン
BOG	Boil off gas	気化ガス
BRT	Bus Rapid Transit	バス高速輸送システム
CDM	Clean Development Mechnisum	クリーン開発メカニズム
CHEC	China Harbour Engineering Company Ltd	中国港湾工程
CNG	Complessed natural gas	圧縮天然ガス
EPC	Engineering, Procurement and Constluction	設計、調達、建設
EV	Electric Vehicle	電気自動車
FCF	Free cash flow	フリーキャッシュフロー
FIT	Feed in Tariff	再生可能エネルギーの全量電力固定価格買取制度
FSRU	Floating Storage and Regasification Unit	浮体式貯蔵再ガス化設備
GEF	Global Environment Facility	地球環境ファシリティ
GHG	Green house gas	温室効果ガス
IRR	Internal Rate of Return	内部収益率
JCM	Joint Crediting Mechanism	二国間クレジット制度
JFJCM	The Japan Fund for the Joint Crediting Mechanism	JCM 日本基金
LNG	Liquefied Natural Gas	液化天然ガス
LPG	Liquefied petroleum gas	液化石油ガス
LRT	Light Rail Transit	次世代型路面電車システム、軽量軌道交通
MATI	Maldives Association of Tourism Industry	モルディブ観光産業協会
MMA	Maldives Monetary Authority	モルディブ金融管理局
MMBtu	Million British thermal unit	百万英国熱量単位
MoED	Ministry of Economic Development	モルディブ経済開発省
MoEn	Ministry of Environment of the Maldives	モルディブ環境省
MoF	Ministry of Finance	モルディブ財務省
MRT	Mass Rapid Transit	大量高速輸送
MRV	Measurement, Reporting and Verification	温室効果ガス排出量の測定、報告及び検証
NDC	Nationally Determined Contributions	パリ協定における自国が決定する貢献
ODA	Official development assistance	政府開発援助
PMS	People mover system	旅客輸送システム
PPA	Power Purchase Agreement	電力販売契約
PV	Photovoltaics	太陽光発電
SAP	Strategic Action Plan	国家戦略行動計画
STELCO	State Electric Company Limited	モルディブ国営電力
TA	Technical Assistans	ADB 技術協力プログラム
UNFCCC	United Nations Framework Convention on Climate Change	国連気候変動枠組条約

1. Purpose and background of the task

1.1. Purpose

With a consensus document produced at the 2021 United Nations Climate Change Conference (COP26) held in November 2021, it was confirmed that a new global goal is to keep the increase in air temperature since the industrial revolution by no more than 1.5℃. In order to attain this goal, it is indispensable to accelerate initiatives at various levels, including provincial, municipal, and ward levels, in each country. The Japanese government, too, declared that it aims to realize a decarbonized society by decreasing the net emissions of greenhouse gases to zero by 2050, and the number of municipalities that have declared that they will decrease the net CO_2 emissions to zero increased rapidly to over 600 (as of April 30, 2022). Based on the roadmap for decarbonization in each region, which was formulated in June 2021, advanced measures have been designed in each region, and activities for spreading them nationwide are ongoing.

Accordingly, the roles of cities and local governments in discussing and implementing specific local climate change measures and projects are becoming increasingly important. In order to realize a decarbonized society all over the world, it is necessary to accelerate the movement toward building a sustainable decarbonized society, especially in Asia where economic growth is remarkable. There is a growing international movement to support the efforts of cities to decarbonize and lower the carbon footprint of their activities, as these cities are the places that support social and economic development.

In addition, amid the lingering COVID-19 pandemic, cities have to deal with the challenges related to the spread of the infection and readjust and discuss new measures to achieve sustainable development, so collaboration among cities to build new methods and new cities is extremely important.

In this project, Japanese research institutes, private companies, universities, etc. as well as Japanese cities that have experience and know-how in building a carbon-free society will conduct a research project to support overseas local governments in their efforts to build a carbon-free or low-carbon society and to install equipment that will contribute to the realization of a carbon-free or low-carbon society.

Based on the above, the purpose of this research project targeting the Maldives was to discuss the establishment of a sustainable eco-conscious city in Malé, the capital of the Maldives, which has been significantly affected by climate change, in cooperation and collaboration with Toyama City, based on the excellent environmental technologies and know-how possessed by companies in Toyama City.

1.2. Background

The Maldives is a small island nation in the Indian Ocean consisting of approximately 1,200 atoll islands of various sizes, and is vulnerable to sea-level changes and natural disasters caused by climate change. Accordingly, there has been concern over the direct impact of global warming on the living environment and the serious effects on tourism and fisheries, which are major industries. As a mitigation measure, the Maldivian government has announced a "Carbon Neutral Country"

declaration to achieve zero net emissions by reducing the use of fossil fuels and curbing greenhouse gas emissions. They set an ambitious goal of having 60% of electricity in the Maldives come from renewable energy sources, but this goal is still far from being achieved[1].

In the Maldives, one-third of the population, or 145,000 people, reside in the Greater Malé Metropolitan Area, among which the Malé Island, which houses government offices, diplomatic missions, and other capital functions, is known as one of the most densely populated areas in the world. In order to disperse this overcrowding and to accommodate the expected refugees from the islands that will be submerged in the future due to rising sea levels, the construction of a 4-km^2 artificial island, Hulhumalé, began in 1997. So far, 4.28 km^2 of area has been developed, and it is expected that 240,000 people will move to the area in the future. The area is divided into Phases I and II according to the stage of development, with 60,000 to 65,000 people currently living in Phase I, where reclamation and development are largely complete. Phase II, which is under development, has completed high-rise housing and will soon have 30,000 people moving in[2].

The government of Malé is planning to develop the Hulhumalé area as a smart, compact, and environment-friendly city, and has requested the support of Toyama City, which is a city of the future in terms of renewable energy, waste disposal, transportation infrastructure, energy conservation, and institution building, all of which are essential for environment-friendliness.

The connection with Toyama City came about through a training course on inter-city collaborative projects for the realization of a low-carbon society organized by the Ministry of the Environment, which was held in Toyama City in November 2019. The Hulhumalé Housing Development Cooperation (HDC) of Malé, which participated in the training program, was highly interested in Toyama City's compact city policy centering on the LRT (Light Rail Transit: a next-generation streetcar system, hereafter referred to as "light rail") and the environmental technology possessed by the city's companies, and requested support from the Embassy of Japan in the Maldives. In response, in January 2020, the Ambassadors of the Embassy of Japan in the Maldives and the Embassy of the Maldives in Tokyo paid a courtesy call on the Mayor of Toyama City and confirmed their intention to work together.

In FY 2020, as the first year of the inter-city collaboration project, the data on the traffic situation, energy consumption situation, waste generation situation, and related policies in Malé was collected for planning and study, and a system for collaboration was established with the Full Malé Development Corporation and related ministries.

2. Overview of the Maldives and Malé City

2.1. Basic information[3]

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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

[2] Mainichi Asia Business Research Institute, "Feature: Maldives, Pearl of the Indian Ocean on the Move" (https://mainichi.asia/2108maldives_hdc/)

[3] The Ministry of Foreign Affairs of Japan's website: Basic Data of the Republic of Maldives (https://www.mofa.go.jp/mofaj/area/maldives/data.html)

The Maldives is an island nation in the Indian Ocean, located southwest of India. It has an area of 298 square kilometers, which is about half the size of Tokyo's 23 wards, and is an island nation consisting of 1,192 islands.

The population as of 2020 is 557,000, of which 379,000 are Maldivians and 178,000 are foreigners. The main industries are fisheries and tourism, with a GDP of US$4.89 billion in 2021, and a GDP growth rate of 31.0%, partly due to the recovery from the previous year's impact of COVID-19 on the tourism industry.

The fisheries industry accounts for 5.0% of GDP, but 96% of export products (2020). The main fish species are skipjack (70% of landings) and tuna (29% of landings), and bonito flakes are produced as a specialty product.

Tourism is the main source of foreign currency earning, accounting for about 26.3% of GDP, and 145 of the nation's 1,192 islands are resort islands in accordance with the "One Island, One Resort" Plan. In 2019, 1.7 million tourists visited the islands, mainly from China (284,000), Germany (166,000), and Italy (136,000). Japan is in ninth place with 44,000 tourists.

As a traditionally pro-Japanese country, the Maldives has maintained friendly and cooperative relations with Japan through cooperation in international forums. In addition, the Maldives is located at a strategic point on Japan's sea lanes and has geopolitical importance, so Japan has a policy of supporting the Maldives through the effective and efficient use of ODA so that the country can overcome its development challenges as a small island nation and achieve sustainable economic development and further socioeconomic development. In the country assistance policy for the Maldives, the basic policy of assistance is to "address vulnerabilities and support sustainable economic growth," and the priority areas are "development of local industries" and "measures for conserving the environment and coping with climate change, and disaster prevention.

2.2. Government of the Maldives

The political system of the Maldives is republican and the head of state is President H.E. Mr. Ibrahim Mohamed Solih as of 2022. Under the president, the vice president and the attorney general are appointed, and there are 19 ministries in charge of administration.

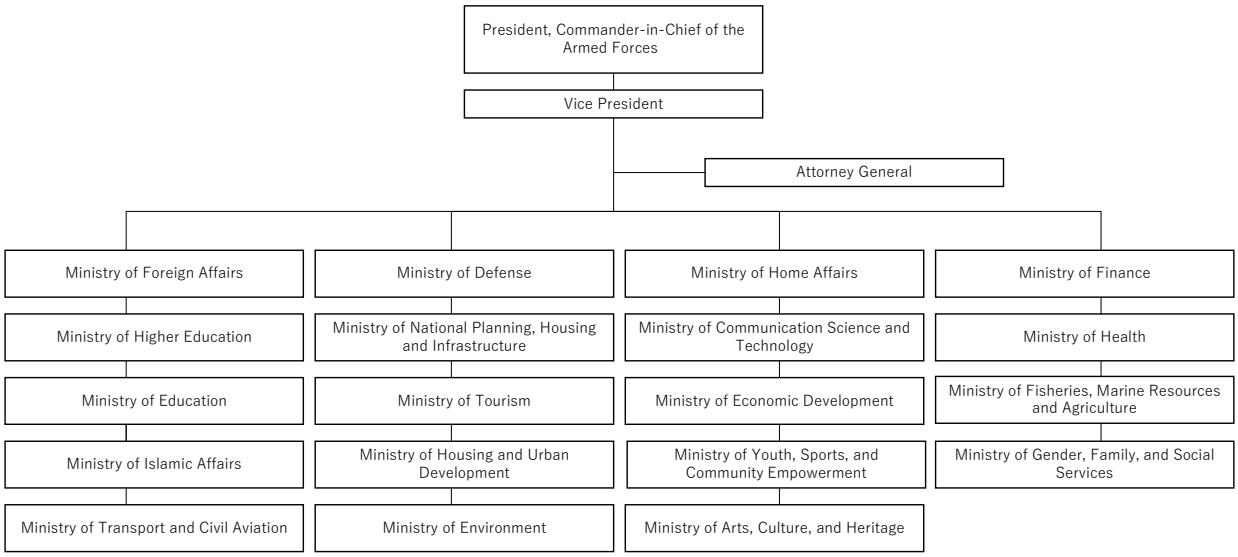


Figure 2-1 National governance structure of the Maldives[4]

Local governments have long been governed under a centralized system. Specifically, during the Maumoon Abdul Gayoom administration (1978-2008), the administrative sector consisted of 20 administrative atolls, with the central government in Male assuming administrative authority.

The government of Mohamed Nasheed, which came to power in 2008, attempted to decentralize the government and established 189 electoral districts in 7 provinces, 17 atolls, 4 cities and 189 islands.

A city is considered to be an area with a population of 10,000 or more, and is responsible for forming a city council, exercising local administrative authority, communicating with the central government, and managing uninhabited islands and resorts within the designated area. The designated cities are currently Malé, Addu, Hvamla, and Kulhudusi.

As an administrative division, "atolls" are islands within the geographical division of atolls, each of which has its own administrative island council that gathers to form the Atoll Council, which manages the uninhabited islands and resort islands within the district, and also plays the role of communicating with the central government. Island councils have been established on each of the 189 inhabited islands, and are responsible for the island's administration.

2.2.1. Major political measures and policies

The mainstay of political measures and policies in the Maldives is the Strategic Action Plan (SAP), which is a five-year plan. The plan is currently in its implementation period from 2019 to 2023 and is positioned as the central policy framework and written plan that will guide the direction of development in the Maldives over the next five years.

SAP also integrates the government manifesto with existing sector priorities and has a monitoring

[4] Prepared by Japan NUS Corporation from "The cabinet," the website of Maldives Presidential Office
https://web.archive.org/web/20150920062619/http://www.presidencymaldives.gov.mv/Index.aspx?lid=16

function to track the progress of government policies and development priorities. It has just been formally applied to the operations of relevant ministries and agencies since October 1, 2019.

SAP is composed of five main sectors: Policy, Target, Strategy, and Action, with 33 sub-sectors.

Figure 2-2 Five major policy sectors and subsectors in SAP

Source[5]: Prepared by Japan NUS Co., Ltd. based on the Strategic Action Plan

In addition, the Maldives Climate Change Policy Framework (MCCPF 2014-2024) has been established with the aim to promote and guide national action plans against climate change effects, promote coordination among all national stakeholders in setting strategic priorities to address climate change, and establish and strengthen policies, concrete business plans and institutions and regimes. Climate change measures are supposed to be integrated into all relevant sectoral plans. The eight principles of climate leadership, intergenerational equity, mainstreaming of climate change measures, relevant international commitments, financial support from partner organizations and countries, technology transfer, and climate resilience are identified as measures to realize this policy framework[6].

2.2.2. Environmental problems and countermeasures in the Maldives and Malé City

In 1987, an "unusually high tidal wave" in the Indian Ocean flooded a quarter of the urban area of Malé, the capital of the Maldives, flooded farms, and swept away landfills with water. At the UN

[5] Government of Maldives, "Strategic Action Plan 2019-2023" (https://presidency.gov.mv/SAP/)
[6] JICA, "Report of the Survey on the Collection and Confirmation of Information on Meteorological Disasters in the Malé Metropolitan Area, Republic of Maldives," https://libopac.jica.go.jp/images/report/12368775.pdf

General Assembly that year, Maldivian President Maumoon Abdul Gayoom made the first proposal to the international community on the need to tackle climate change[7]. In his argument, President Gayoom cited scientific evidence that “human activity releases greenhouse gases that cause global warming, which in turn causes glaciers to melt and seawater to expand, ultimately raising the world's sea level.” Subsequent surveys and studies have revealed that the Maldives, where 80% of the land area is less than one meter above sea level, is at risk of being submerged if global warming progresses to the fullest extent. After that, the Maldives positioned global warming as an issue that leads to national security and implemented countermeasures.

First of all, the construction of an artificial island of Hulhumalé began in 1997 as a countermeasure against rising sea levels that could lead to the nation's destruction. Originally, the main purpose of the project was to create a migration site from the overcrowded Malé, but it was also intended as a relocation site in the event that future sea-level rise forces people to move[8]. In addition, as mentioned above, the government has set a policy to become carbon neutral by 2020, and has been promoting renewable energy expansion programs and other initiatives to support this goal[9]. The history of the creation of the Hulhumalé Island is shown below.

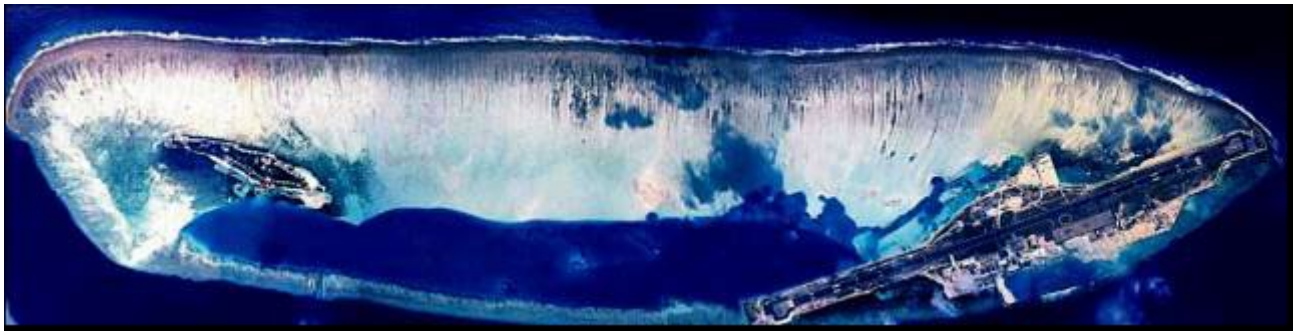


Figure 2-3 Hulhumalé Island before reclamation in 1997

[7] Janet Larsen, Earth Policy Institute, Plan B Updates, “Rising Seas and Powerful Storms Threaten Global Security,” OCTOBER 09. 2008. (https://www.earthpolicy.org/plan_b_updates/2008/update76.html)
[8] Asahi Shimbun, "Maldives moves ahead with expansion to double artificial island area to accommodate migration," March 21, 2018 (https://www.asahi.com/articles/ASL3P41DTL3PULBJ002.html)
[9] Dr. Maryam Shakira, Minister of Environment and Energy, Republic of Maldives, "Climate Change and Coral Reef Conservation," Panel Discussion at the International Conference on Global Warming Prevention and Coral Reef Conservation - Islands and Island Nations in Coexistence with Nature: From the Perspective of Global Warming Countermeasures and Coral Reef Conservation - Presentation Material, 2013 (https://www.env.go.jp/nature/biodic/coralreefs/iccccrc2013/pdf/year2013629/panel/mariyam.pdf)

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

Figure 2-5 Hulhumalé Island in 2018 (The reclaimed area on the left is Hulhumalé Phase II)

Source: Materials provided by HDC

In addition to measures against global warming, environmental measures such as coral reef conservation and measures against marine plastic waste are also being implemented from the perspective of preserving the marine ecosystem, which is a resource for the tourism and fishing industries that account for 90% of the Maldives' GDP[9].

The city of Malé, which is the subject of this study, has a population of about 145,000, which not only has about 1/4 to 1/3 of the total population of the Maldives, but also accommodates a large number of foreign workers. In addition to being the political and economic center of the Maldives, it is a trading port that receives imports to the islands. From the perspective of energy consumption and waste issues, it can be said that Malé has a large contribution to the entire country of the Maldives, so the urgency of the measures is high.

A kickoff meeting was held among Toyama City, the Ministry of Environment of the Maldives, Malé City and HDC to discuss the environmental issues in the Maldives and Malé City[10], and the following major issues were identified.

1. **Climate change mitigation**: Climate change mitigation policies are needed in the Maldives. Although CO_2 emissions are not high on a global scale, diesel fuel accounts for 99% of the energy used, and it is necessary to replace it with energy with lower CO_2 emissions. The project is also considering plans to use LNG in the future, and has already introduced and promoted the use of solar power generation. In addition, an energy plan (roadmap) is scheduled to be completed soon, and the plan is to promote decarbonization with an eye to utilizing waste power generation and ocean energy.
2. **Coping with climate change**: vulnerability to the impact of climate change, such as coastal erosion and tsunamis.
3. **Public transportation problems**: Public transportation infrastructure is inadequate. In particular, the city of Malé has a heavy traffic volume, and the lack of parking space and air pollution caused by exhaust gas is a problem.

[10] Implemented by Microsoft Teams on October 8, 2020.

4. **Waste problem**: In the Maldives, waste is currently collected in each of the five districts, but there are problems with collection and disposal. The waste will be incinerated at a waste power plant to be built on the Tirafushi Island.

The Maldives has been actively accepting support from international organizations and foreign countries for implementing measures to address these major environmental issues. In addition to receiving long-term financial resources and technical cooperation from the United Nations and other international organizations, the country receives bilateral cooperation from a variety of other countries. For example, the United States is supporting the Maldives in improving economic resilience and democratic governance, maintaining and creating a sustainable environment, strengthening capacity for ocean management, and implementing measures to monitor and adapt to the effects of natural disasters. In Japan, the Asian Development Bank (hereinafter referred to as "ADB") is planning to contribute funds to a waste power generation project on the Tirafushi Island in the capital region of Malé through the JFJCM (Japan Fund for JCM), which applies the JCM system to loans from ADB. In addition, Japan and the Maldives concluded the Low Carbon Growth Partnership in 2013 as an eligible country for the JCM equipment subsidy project, and have been promoting the spread of excellent low-carbon technologies by establishing the JCM Joint Committee. In July 2019, it decided to issue the first JCM credit in the Maldives for a 15-month monitoring period from 2017 to 2018 for the "Project for Installation of Photovoltaic System on School Building Roofs."

With regard to policies related to decarbonization, it is necessary to mention Nationally Determined Contribution (NDC). The Paris Agreement (adopted in December 2015 and enforced in November 2016) obligates all countries to submit and update their greenhouse gas emission reduction targets every five years as Nationally Determined Contributions (NDC), and the Maldives submitted an updated version in 2020.

The updated NDC sets out a plan to reduce GHG emissions by 26% from 2011 levels by 2030, and states that the country will strive to achieve net zero emissions by 2030 if sufficient international assistance and support are available. The following five measures are outlined to achieve this goal.

- To increase the amount of electricity generated from renewable energy (RE) sources through power storage and grid stabilization. Strive to increase the share of renewable energy in the energy mix, including the public and private sectors, to 15%.
- To increase supply-side and demand-side efficiency. It is essential to increase the efficiency of generators and improve the grid to minimize transmission losses, and to significantly improve the existing generation infrastructure through regular maintenance, synchronization and optimization of generation, and reduce grid losses to at least 5%. In addition, demand-side management will include the implementation of standard labeling programs and improved construction standards for energy efficiency.

- To convert waste to energy. An 8 MW waste-to-energy plant will be built in Tirafushi and a 1.5 MW waste-to-energy plant will be built in the city of Addou. These systems will be optimized for grid connection and power generation.
- Emission standards for vehicles and vessels will be set and an efficient transportation management system will be established to promote the use of hybrid vehicles.
- Liquefied natural gas (LNG) will be used to generate electricity in the Malé area. To replace the current main source of power, diesel, with LNG-fired power by connecting the Malé metropolitan area to the grid via an interconnection bridge with an LNG-fired power plant to be built in Tirahsi.

Aiming to contribute to the achievement of the goals set in the NDC, Toyama City is expected to cooperate in the efforts to achieve further low-carbon and decarbonization in this project, and we will work together to promote the project mainly through the JCM equipment subsidy program.

2.3. Background of cooperation with Toyama City

The background for the implementation of the research project in the Maldives under this inter-city collaboration is as follows.

In November 2019, the Hulhumale Development Corporation of the City of Malé participated in a training course on inter-city collaborative projects held in Toyama City (training course sponsored by the Ministry of the Environment and IGES, "Training on Inter-city Collaborative Projects for the Realization of a Low-Carbon Society"), and showed great interest in learning about Toyama City's efforts to achieve a decarbonized society and its renewable energy and energy-saving technologies, in addition to its excellent transportation systems such as Light Rail. Subsequently, expectations for the inter-city collaboration project were raised by Malé City, and in January 2020, the Japanese Ambassador to the Maldives and the Maldivian Ambassador to Tokyo paid a courtesy visit to Toyama City and exchanged opinions with Mayor Mori. During the discussion, the following needs were identified, especially for the development of the Hulhumale area: improvement of public transportation, low carbon emission through the use of natural gas, optimization of energy consumption through the spread of energy-saving technologies, and introduction of technologies such as energy utilization for waste disposal. In response to this, information was disseminated to the companies involved in the design and construction of the light rail in Toyama City, as well as other companies in the city that have low-carbon technologies, to gain expressions of interest and build a system of support by Toyama City and the companies in the city.

In March 2020, discussions with Malé City were scheduled to conclude a cooperation agreement and further specify each project, but this could not be realized due to the spread of COVID-19. However, with the cooperation of the Embassy of Japan in the Maldives, discussions were held remotely, getting expressions of interest and determining the details of each project, which led to the proposal for and adoption of the project, and this year is the second year of the three-year project.

2019 Intercity Collaboration Seminar[11]

Courtesy visit by the two ambassadors to the

[11] IGES website (https://www.iges.or.jp/jp/events/20191127)

Mayor of Toyama City (January 2020)

Figure 2-6　Activities leading up to inter-city collaboration between Toyama City and Malé City

When considering decarbonization measures for local governments, it is essential to collaborate with agencies that have regulatory and management authority over urban planning and development. Usually, such authority and roles are given to municipalities, but in the Malé metropolitan area, the agency responsible for development planning and regulation is the Hulhumale Development Corporation, a state-owned company with 100% state capital. The Hulhumale Development Corporation was also merged with the Malé Metropolitan Industrial Corporation in 2020, and was given the authority to develop and manage the islands of Grifal and Tirafushi, which will be developed as industrial sites. In this way, it plays a role in planning and formulating a vision for the development of the Malé metropolitan area, as well as providing some of the infrastructure investment, as well as regulatory and administrative services.

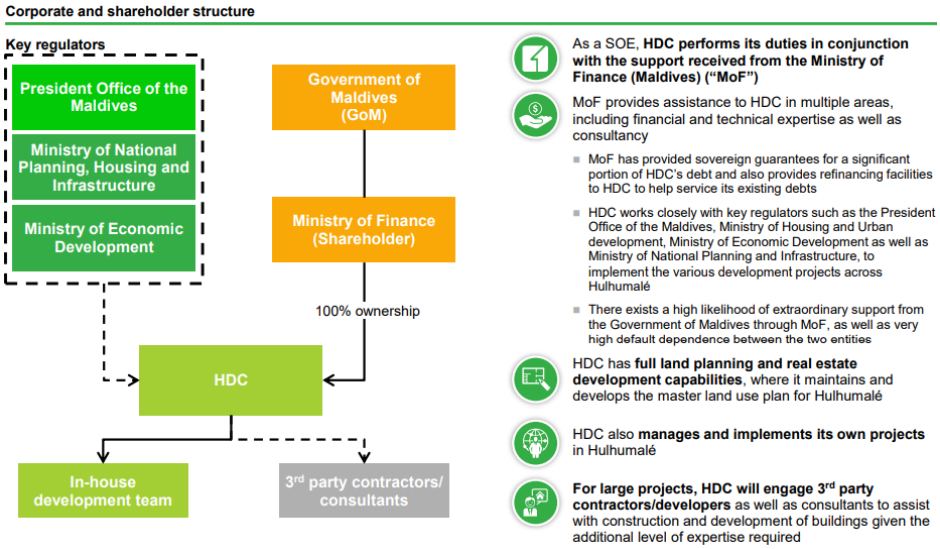
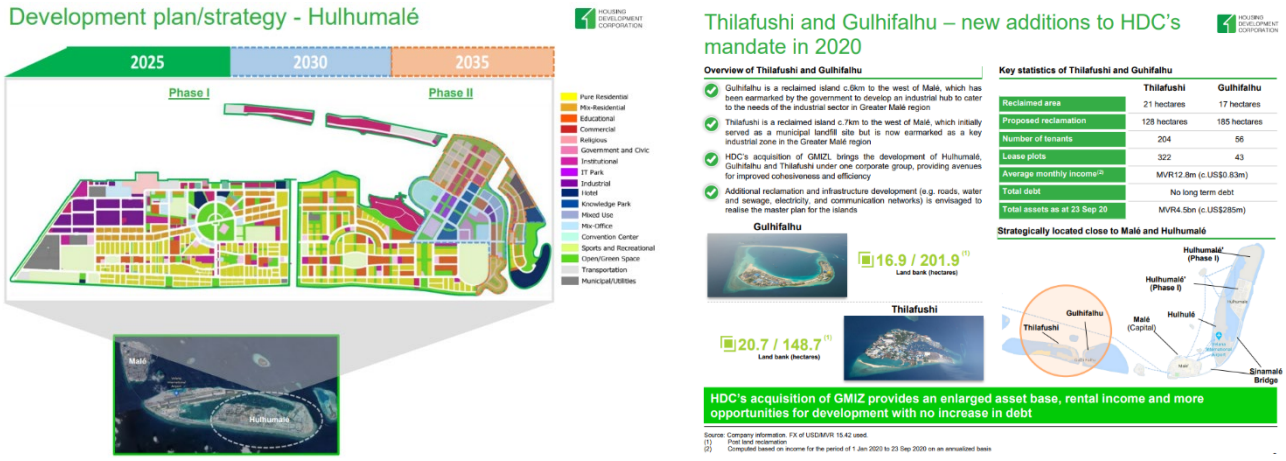


Figure 2-7　Structure, roles and powers of the Hulhumale Development Corporation

Source: Materials provided by Hulhumale Development Corporation



Hulhumale Island Development Plan　　Tirafushi Island Development Plan

Figure 2-8　Formulating a master plan for HDC development

Source: Materials provided by Hulhumale Development Corporation

In the Toyama City Inter-city Cooperation Project, the city has decided to promote support for decarbonization by sharing policy recommendations, achievements, and experiences, and introducing owners of decarbonization technologies, etc., in cooperation with the Hulhumale Development Corporation, which has such a role and authority in the Malé metropolitan area, as well as with related ministries and agencies and Malé City. In addition, the Hulhumale Development Corporation has formulated a policy to deal with environmental issues including decarbonization, and through this inter-city cooperation, we discussed the formulation of a more committed policy equivalent to Toyama City's decarbonization declaration.

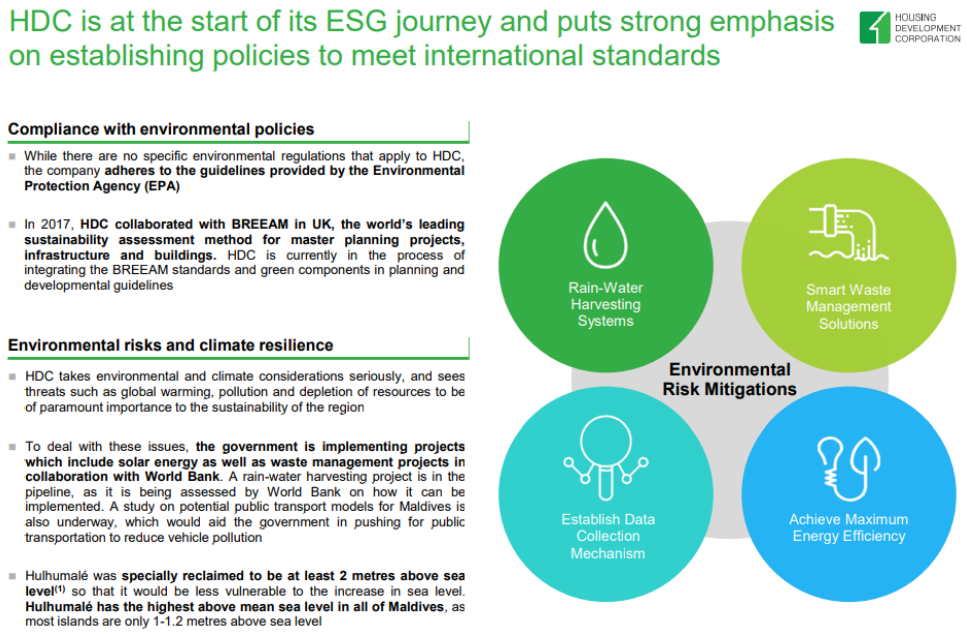


Figure 2-9 Policy for addressing environmental issues in the Hulhumale Development Corporation

Source: Materials provided by Hulhumale Development Corporation

3. Consideration of JCM project formation

In this study, we referred to the NDC as the national decarbonization policy and held discussions with the Hulhumalé Development Corporation. With the aim of reducing GHG emissions and forming JCM projects that contribute to climate change measures in the city of Malé, mainly in the Hulhumalé area, in the fields of transportation-derived CO_2 emissions reduction through public transportation improvement, low-carbon power generation through the use of nautral gas in diesel power facilities, renewable energy, and low carbonization through organic waste recycling, the following activities have been carried out.

(1) Mitigation of CO_2 emissions from transportation by improving public transportation
(2) Low-carbon power generation through the change of fuel for diesel power generation facilities

(3) Low-carbonization through the distribution of renewable energy
(4) Low-carbonization based on recycling of organic waste

In FY 2020, which is the first year of the project, we collected information that will serve as the basis for these studies and examined the feasibility of the project in consultation with related organizations. In FY 2021, based on these results, more detailed information was collected and organized through field surveys. In this final year of the project, based on the results of previous surveys, specific projects for commercialization were identified and preparations for such projects were made.

Chapters 3.1 through 3.4 below present the details and results of each study.

3.1. Areas for Reducing CO_2 Emissions from Transportation by Improving Public Transport

Despite its small area, the Malé Metropolitan Region has a large number of residents who own motorcycles and cars due to the lack of public transportation system. Accordingly, on-street parking that makes road space narrower and the resulting traffic congestion have become major issues. Since the capital island, the Hulhule Island, which has an airport, and the Hulhumale Island were connected via bridges, there has been an increase in the number of people living in Hulhule and commuting to work in Malé (and vice versa), and although there are still some people who travel by ferry, etc., demand for motorcycles and automobiles, which allow for more freedom of movement, has been increasing. In addition, as the number of cars owned increases, the rate of CO_2 emissions is also on the rise, and there is a need to develop more efficient and low-carbon means of public transportation.

Against this backdrop, the Hulhumale Development Corporation, which is responsible for the development policy of the Hulhumale Island, showed great interest in the introduction of the light rail system, which is a pillar of Toyama City's compact city policy.

The reason for this, according to the Hulhumale Development Corporation, is that "although the population of the Hulhumale Island is currently 45,000, 160,000 people are expected to migrate from the Malé Island in the future, and most of them are expected to commute to the Malé Island and other places, which may affect traffic congestion and increase CO_2 emissions in the transportation sector, thus making urgent low-carbon public development necessary."

Also, there is a strategy to meet tourism demand centered on the Hulhumale area by developing new tourist spots on the Hulhumale Island, as the flow of tourists has been from the airport directly to the resort. There are also plans for business centers, research centers, and other facilities to meet business demand. Therefore, it will be essential to improve the public transportation system to improve access to travel and accommodation for tourists and business travelers.

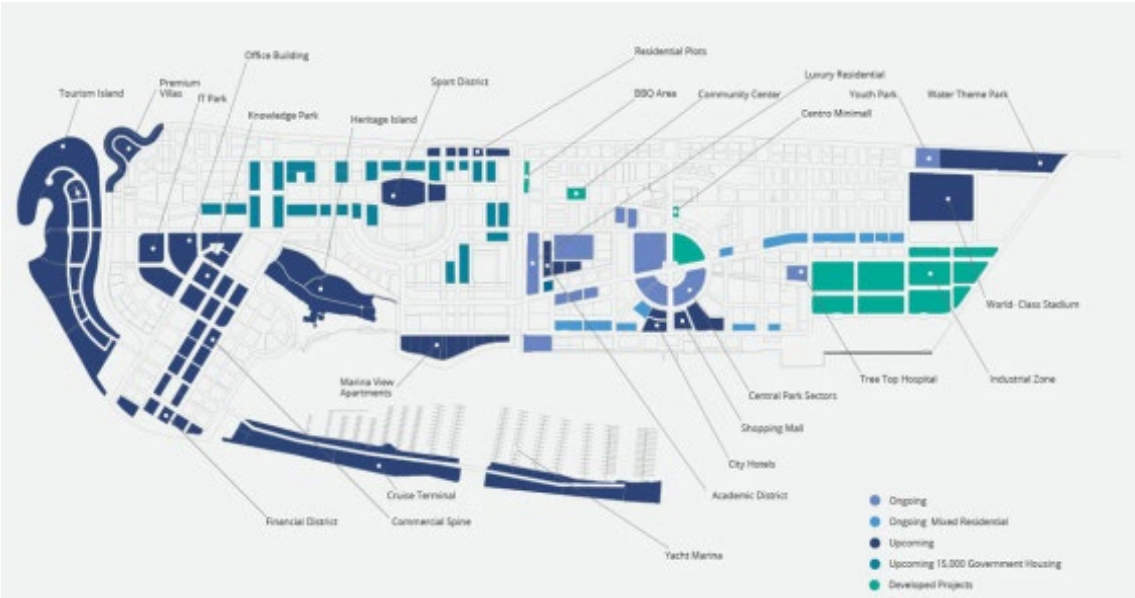


Figure 3-1 Development plan for tourism and business facilities in the Hulhumale Island

Source: Materials provided by Hulhumale Development Corporation

In the first-year survey, the possibility of introducing Light Rail was examined, but as detailed in the next chapter, it was found that it may not necessarily be an appropriate option given the size of the Hulhumale Island, the number of people to be transported, and the construction period.

Therefore, last year's study examined the optimal public transportation and the development of a transportation master plan as a long-term measure, and the decarbonization of public transportation as a short-term measure.

This fiscal year, the details of the studies found by each study were fleshed out. The results of the studies are shown below.

(1) Discussion on optimal public transportation and policy for developing a master transportation plan as a long-term measure (3.1.1)

-About the current public transportation situation found from last year's work (3.1.1 (1))

-Review of the policy for developing a master transportation plan (3.1.1(2))

(2) Discussion on decarbonization of public transport as a short-term measure (3.1.2)

-Coordination with new public transport sector decarbonization projects (3.1.2 (1))

-Existing public transport decarbonization projects (3.1.2 (2))

3.1.1. Discussion on optimal public transportation and policy for developing a master transportation plan as a long-term measure

(1) Current public transportation situation found from last year's work

In the survey conducted in FY 2020, policy documents such as development plans for transportation in the Maldives were collected from the Internet, Malé City, local cooperating organizations, etc. and organized. After understanding transportation systems and policies as well as public transportation plans and policy goals, we examined policy and institutional promotion measures for the introduction of Light Rail.

In the Maldives, the SAP, which presents the government's development goals and priorities, includes the following points on transportation as a policy (Policy 3) and target (Targets 3.1 and 3.2).

・To reduce vehicle congestion by 30% in the capital city of Malé from 2018.

・In the capital city of Malé, at least 60% of the population should use public transportation on a daily basis.

In order to achieve these goals, the strategy (Strategy 3.2) is to distribute efficient public transportation systems in Malé Metropolitan District.

The report that served as the basis for the discussion on the policy first mentions the increase rate of cars and motorcycles. The increase rate since 2000 is estimated to be 10% per year, and the total number of internal combustion engine vehicles as of 2012 is reported to be 556,497.

Since the completion of the bridges connecting the Malé Island to the airport island and the Hulhumale Island, which were built after the publication of this report, the number of privately

owned cars as a means of land transportation is expected to increase further.

This increase in the number of cars and motorcycles easily causes traffic congestion in the Malé metropolitan area, where land is small, and is considered a major urban challenge for the Malé metropolitan area.

In response to this situation, the Maldivian government and Malé City have been studying the solution to transportation issues through the introduction of public transportation as the People Mover System (hereinafter referred to as "PMS"). This is not only to address the transportation challenges caused by the increase in the number of motorcycles and cars, but also associated with the goal of low-carbon and decarbonization in the transportation sector. As specific public transportation systems, Monorail and Light Rail are being considered. Related plans include the "Hulhumalé Phase 1 and Phase 2 Master Plan & Urban Design Review 2015," which proposes the operation of the PMS on a one-way "circulation" route. However, the rationale behind the proposed route or why it was chosen as a "circular" route is not stated, and whether or not the route plan is in line with people's demand is open to examination. In addition, the economic and financial evaluation has not been completed.

Figure 3-2 Route map proposed in the "Maldivian Transport Master Plan Study"

Source: Materials provided by Hulhumale Development Corporation

In addition, there is the "9+6" Greater Malé program, which is a comprehensive development plan till 2050 for the Greater Malé region, centered on the Malé Island. This plan calls for the construction of bridges connecting the four islands (west: Villingilli and Gulhifalhu, east: Hulhulé ,Hulhumalé) with the capital city of Malé at the center, as well as a bridge between Thilafushi and Gulhifalhu in the west. Each island is characterized by its clearly defined role, for example, Gulhifalhu Island will serve as a hub for cargo transportation to other islands in the future, and Hulhumale is positioned as a residential island.

Figure 3-3 Plan for bridge connections in the Greater Malé region

Source: Materials provided by Hulhumale Development Corporation

This positioning is called the "7+1" island center program, and the following land use policies are outlined for each island as a development plan until 2050.

Malé

- To keep the population within 120,000.
- To relocate the cargo port to the west and move some of the residents to the east.

Vilingilli

- To become a cargo warehouse area
- Population is expected to be 15,000.

Hulhulé

- To become a business and airport area (transportation hub)
- Expectations for job creation

Hulhumalé I

- To become a residential area
- Population is expected to be 60,000.

Hulhumalé II

- Construction began in 2014. To become a residential area
- Population is expected to be 100,000.

Gulhifalhu

- It will have a port, warehouses and a mini-industrial area.

Funadhoo

- It will have a tourist industry and entertainment facilities.

The new bridge is to be built by India's ODA and is expected to be completed in 2023[12]. As

[12] NEXT IAS, ” Greater Malé Connectivity Project (GMCP)”. https://www.nextias.com/current-affairs/27-08-2021/greater-mal-connectivity-project-gmcp

mentioned above, residential, industrial, business, and other centers will be connected, so it is effective to predict and cover travel to each island rather than just to the Hulhumale Island in the assumption of public transportation. With these predictions in mind, this study examined the possibility of decarbonizing buses, which have already been introduced and are functioning as public transportation.

(2) Review of the results of last fiscal year's survey and the outline of the Master Transportation Plan

As mentioned above, the Hulhumale Development Corporation, which is in charge of the Hulhumale development, visited Toyama City during the 2019 JCM Intercity Cooperation Seminar, got interested in the city's convenient public transportation based on the Light Rail system, and requested cooperation in the Hulhumale development.

On the other hand, the development of public transportation needs to be linked to local development plans and policies and introduced in a purposeful manner, for which careful forecasting and planning are essential.

Let's take a look back at the history of Light Rail development in Toyama City. Toyama City has positioned the development of the Light Rail system as a solution to the problems of a declining and aging population, dependence on automobiles, and depopulation of the city center. The city has made efforts to improve the convenience of public transportation in the city by using the Light Rail system as a core project to realize "compact city development," which has resolved traffic congestion, improved the value of the city center, and raised land prices. The mayor Masashi Mori, who has served as mayor of Toyama since 2002, has personally led these projects, establishing the publicly- and privately-owned Toyama Light Rail Co. and promoting about 30 related revitalization projects, including the "Grand Plaza Development Project," the "City Train Loop Project (Centrum)," and the "Machinaka Residence Promotion Project."

The decision was made to convert the Toyama Port Line to a Light Rail system as a step toward shifting from automobile-dependent urban development to "compact urban development based on public transportation." This is because the use of public transportation, such as streetcars, is essential to Toyama City's urban development plan, which aims to connect urban areas scattered throughout the region by public transportation and to create a clustered urban structure "dango to kushi" (dumplings and skewers) rather than a concentrated urban structure. In addition to reusing abandoned railway lines, the city of Toyama has taken on the responsibility of supporting the project by purchasing the railcars and leasing them to the operating company, thereby avoiding the cost burden.

Thus, in addition to a strong policy backing for public transportation, it is important to choose the most appropriate mode of transportation based on local issues and future visions.

In order for the introduction of Light Rail to be effective in the Hulhumale area, it is important to further clarify the current master plan and to examine the most appropriate way to implement it in light of the policy goals. Based on this understanding, the following steps were proposed to the Hulhumale Development Corporation as a review procedure in the study.

1． To select the best means of transportation for Hulhumale
2． To survey the current situation and analyze the effects of the introduction of the system
3． To develop a master plan for implementation
4． Detailed survey and design
5． Equipment procurement (use of the JCM system)

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

Figure 3-4　Process for Formulating a Master Plan for Public Transportation

Source: Produced by NIPPON ENGINEERING CONSULTANTS CO., LTD.

Table 3-5 shows some of the common public transportation options.

Table 3-1　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: Prepared by Sato Kogyo Corporation from various materials

Here is a summary of the Malé City plan. After discussing and exchanging views with the Hulhumale Development Corporation on the above-mentioned study policies, it was found that the City of Malé has the following policy plans.

First of all, the priority for public transportation should be the implementation of alternative means of transportation to bikes and cars, so the policy was to give top priority to convenience for residents. While the cost of construction and operation will be taken into consideration, the top priority is

convenience, and they wanted to design a route that would allow people to walk to the bus stop in four minutes, no matter where they live on the Hulhumale Island. The standard of 4 minutes was based on the fact that the distance between stops in the transportation system is 200-300 meters (about 5 minutes on foot), but given this distance between stops, it may be difficult to operate the Light Rail or Tram because it is less than the acceleration/deceleration interval required for their operation. Therefore, given the distance of the stops, operation by bus becomes a more suitable means.

The advantage of bus operation is that it can also be used for inter-island travel. The city of Malé has a plan to connect all the islands in the Greater Malé region with bridges, as described above in the "9+6" Greater Malé program," and is considering a transportation network across these islands. With the construction of the bridges, they intend to make vehicles the main means of inter-island travel, and they also plan to reduce the amount of travel by boat.

The current bridge connecting Hulhumale and Malé and the planned bridge connecting Malé to other islands are not expected to be equipped with steel tracks in terms of strength and road width, making it difficult to use Light Rail.

Even in the case of Light Rail installation only within the Hulhumale Island, securing a temporary site for construction, in addition to the road width, will be an issue. For the Hulhumale Island, while the Phase II site on the east side is available, the Phase I area on the west side is already developed and inhabited by residents, making it difficult to secure a temporary site. In addition, a certain number of lanes must be maintained during the construction period in order to minimize disruption to existing traffic. Also, during operation, it is necessary to secure a yard (garage). Although land for the terminal has been secured for the current public bus service, it is necessary to secure land when considering a new means of transportation.

These studies are summarized as preliminary findings in TRANSPORT MASTERPLAN REPORT 2019. The report includes preliminary engineering studies on long-term planning, long-term road network development planning, bus and other transit networks, performance assessment of existing networks, economic and financial evaluation, staging decisions and their implementation, and transit system security. Four types of PMSs, BRT, MRT, LRT, and AGT, are discussed, and each is considered as an option.

The transportation characteristics needed for Hulhumale include not being a mass transit system as seen in large cities in other countries, short distances between stations, and high frequency of use.

While this demand is currently being met by cars and motorcycles, the development of bus routes is highly suitable as a low-carbon alternative to these modes of transportation. In addition, while Hulhumale is still in the process of development, residents are moving to the area and stores are opening in parallel, and the area is already functioning as a city, so there are restrictions on the development of transportation infrastructure involving large-scale construction.

In addition, it is necessary to consider the movement characteristics of all the islands that can be accessed by land transportation, not only within Hulhumale, but also on the islands of Male and Hulhule, which are connected by bridges, and on the island of Tirafushi, which is planned to be connected by a bridge in the future.

Given this situation, it is assumed that decarbonization of bus routes already in operation and

enhancement of convenience will be most effective.

On the other hand, in order to guide people to decarbonized public transportation, it was mentioned earlier that it is necessary to establish a policy as a master plan that takes into account urban development, land planning, and decarbonization policies, based on mobility characteristics based on in-depth surveys as mentioned above, and to promote various measures based on this policy.

Naturally, the challenge with such an approach is that it requires many steps, including research and policy decision-making, before results can be achieved.

For the smooth implementation of these studies, there is room to consider the use of the ADB's Technical Assistance (TA) program and other programs, including the financing required for the infrastructure development phase. However, in order to ensure sufficient connections with this inter-city collaborative project and room for the participation of the companies involved, it is desirable to use the Japanese technical cooperation program.

A Japanese technical cooperation program that could be used is the JICA SATREPS program[13].

The SATREPS program includes the "Smart Transportation Strategy to Achieve THAILAND 4.0" project as a previous case of a project with a view to developing a master transportation plan as the project's exit strategy. In order to curb the rapidly increasing CO_2 emissions from automobiles in Bangkok, the capital of Thailand, this project aims to contribute to the realization of policy planning that balances the elimination of traffic problems, the realization of a low-carbon society, and the improvement of the total happiness of citizens by utilizing ICT technology to integrate and visualize big data and 3D data on the digital earth and constructing a policy evaluation system based on the quality of life of citizens.

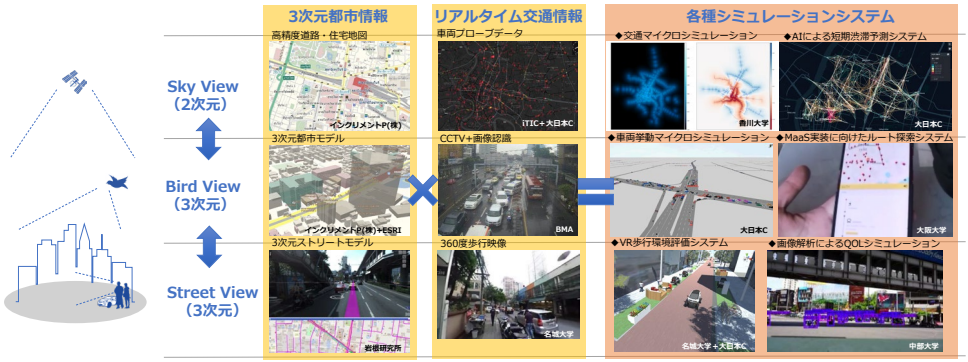


Figure 3-5 Outline of the project "Smart Transportation Strategy to Realize THAILAND 4.0"

Source: Materials provided by NIPPON ENGINEERING CONSULTANTS CO., LTD.

In addition to NIPPON ENGINEERING CONSULTANTS CO., LTD., Ltd., which is participating in this inter-city collaboration project, the University of Toyama is a member of the SATREPS program as a proposing corporation.

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[13] International Science and Technology Cooperation Program to Address Global Issues. This is a 3-to-5-year research program conducted jointly by the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA) to conduct joint research with researchers in developing countries.

Therefore, we decided to consider collaboration such as conducting a similar research and development project based on the situation in the Maldives and promoting the formulation of a master plan for public transportation in parallel and in coordination with this inter-city collaboration project.

(3) Discussion on the policy for formulating a master transportation plan

a) Grasping traffic dynamics and urban design

In formulating a master plan, it is essential to first collect data to serve as the basis for the plan in order to ensure the effectiveness of the plan in improving the convenience of public transportation and decarbonization, which are its main objectives.

However, since the Maldives lacks statistical information and sufficient data on transportation, and since the dynamics of the Malé metropolitan area are changing on a daily basis due to the resettlement that has begun with the Hulhumale development, referring to data on a certain temporal cross-section is not sufficient.

Therefore, utilizing the SATREPS program, we proposed an urban design study that includes appropriate mobility selection, starting with the construction of a transportation database.

b) Outline of the SATREPS program

In the international science and technology cooperation program SATREPS, a proposal for deriving an ideal urban design for the Maldives, which is facing not only transportation issues, but also climate change issues, may be in line with the purpose of the program.

Therefore, the SATREPS program is positioned as an urban design study that includes social experiments that contribute to the identification of issues and solutions, mainly in the area of transportation, from the perspective of climate change mitigation and adaptation. Based on the results of this study, the program aims to be linked with technical cooperation and infrastructure export.

Figure 3-6 SATREPS program framework and proposed exit strategy

Source: Materials provided by NIPPON ENGINEERING CONSULTANTS CO., LTD.

In transportation and urban design, we examined digitally-led urban design research. The digital-led refers to a method of collecting current urban data, using it to predict future risks and changes, and designing a future and urban design ahead of reality. In other words, it is a method that replicates current urban information as digital information, reproduces simulations of various changes digitally,

derives an optimal urban form, and reflects it in actual planning.

By constructing a digital city that reflects reality, it is possible to provide new smart services and integrated design that respond to various risks.

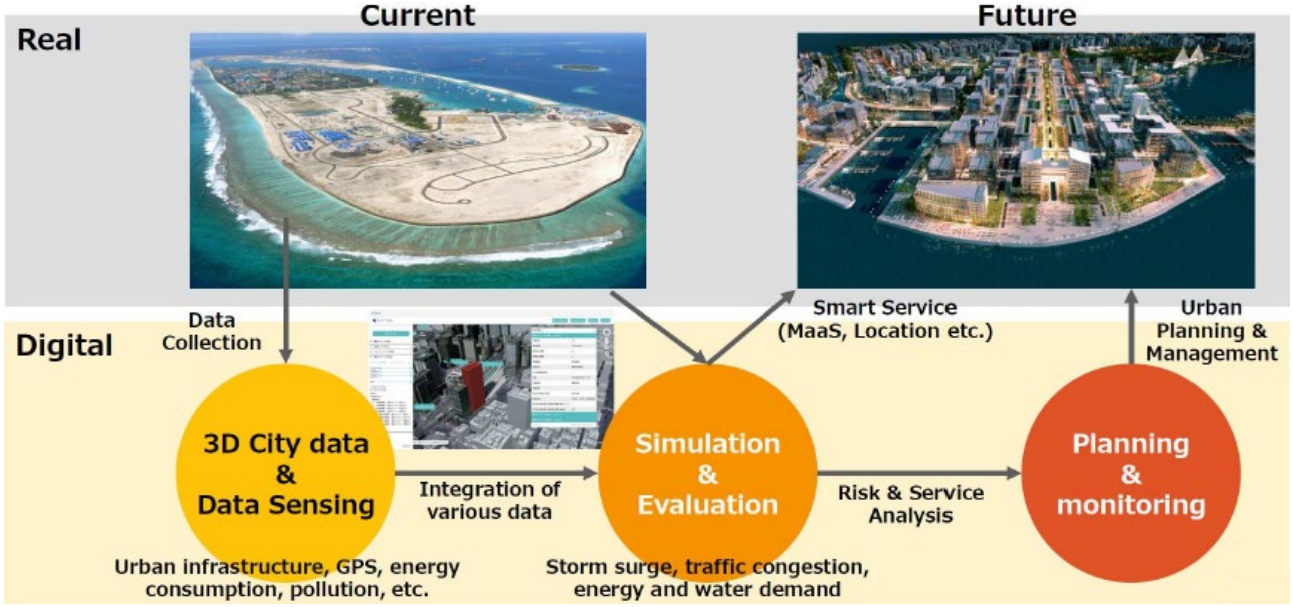

Figure 3-7 Concept of digital-led smart urban design

Source: Materials provided by NIPPON ENGINEERING CONSULTANTS CO., LTD.

By integrally executing various future forecasting simulations such as tidal surge, disaster prevention, and traffic in a digital city, it is possible to detect the impact of urban development and risks due to climate change at an early stage and produce urban design that addresses these risks.

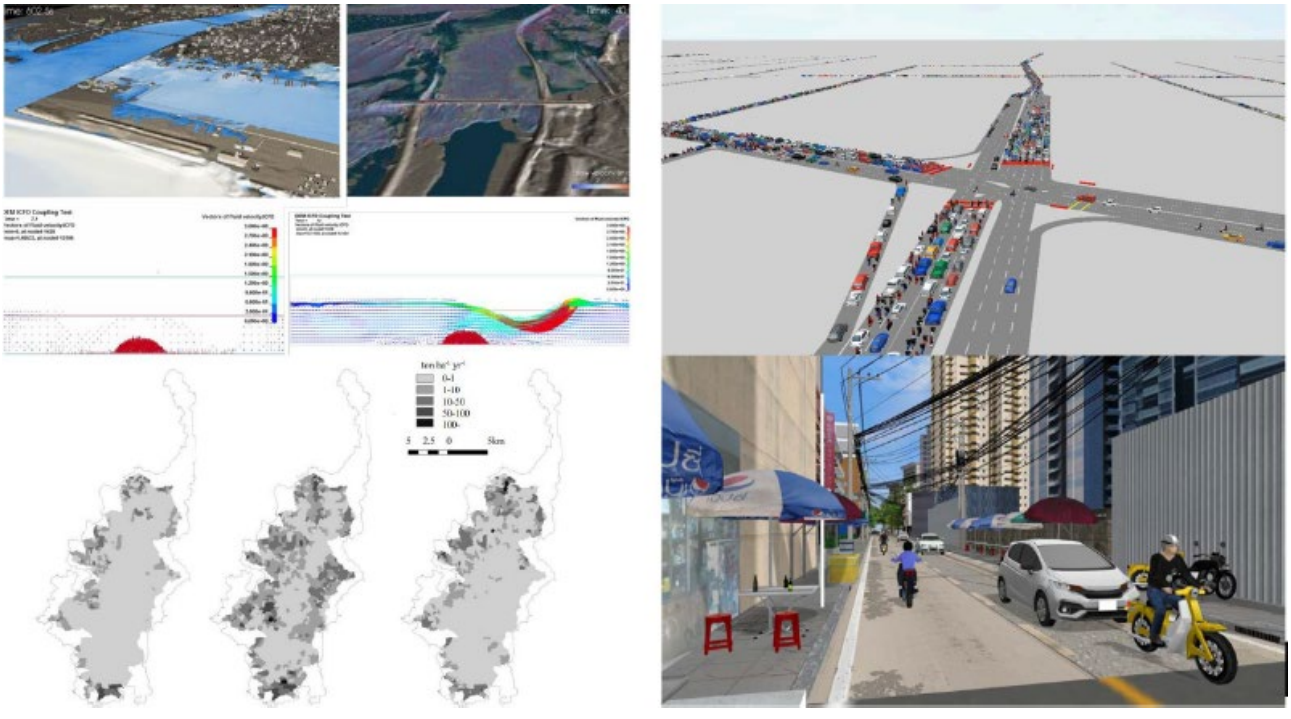

Figure 3-8 Images of future forecast simulation

Source: Materials provided by NIPPON ENGINEERING CONSULTANTS CO., LTD.

In SATREPS, in implementing the above-mentioned digitally led urban design, consideration will be given to the construction of a digitally led system based on a 3D urban GIS for Marais and Fulmarais, and the installation of infrastructure for future simulations of transportation, disaster prevention, and energy, integrating GPS data from cell phones and environmental sensor data.

In addition, urban planning should take into account not only the external environment, but also internal changes in the city due to population growth and increased resource use. For example, the impact of increased waste and water demand must be taken into account. Therefore, we will develop a model to measure and evaluate the footprint (demand for capacity) of waste, water, resources, and energy in the present and the future. The model will then be used to evaluate the future risks of future urban population and population growth, and how to prepare for them.

In order to solve these environmental and economic issues in an integrated manner, it is necessary to identify the factors that affect each other and seek comprehensive solutions, instead of solving each issue individually. Areas with interrelated aspects include transportation, energy, and natural resources. The goal is to view these as a single system and perform sensing, analysis, and planning.

In terms of space, the Maldives consists of approximately 1,200 atolls of various sizes, and the hierarchy differs between atolls and within each island. In other words, we will examine the optimal system construction considering the three scales of country level, atoll level, and island level.

As an example, the SATREPS project will include a proposal for an interconnected system of public transportation, inter-island transportation, and intra-island transportation, including a partial demonstration of such a system. The project will then support the development of future plans in a manner consistent with the current master plan.

c) Local structure for development of a master plan for public transportation and the SATREPS program

Discussions with the Hulhumaleh Development Corporation regarding the above SATREPS program proposal resulted in a proposal for exchanging views with the National University of Maldives as a local research institution required for the SATREPS program. We were also approached about the need to exchange views with the relevant ministries: the Ministry of Environment, the Ministry of Transport and Civil Aviation, and the state-owned MTCC as the operator of public transport.

Therefore, we set up meetings with each organization to listen to their opinions on this policy, as follows.

・Maldives National University (MNU)

Last fiscal year, we held an online meeting (September 21, 2021) involving the Vice President of the National University of Maldives as a participant, and had the opportunity to meet locally (October 31, 2021) with six experts at the National University of Maldives who specialize mainly in climate change, environmental sociology, and environmental science.

This fiscal year, the project team took the opportunity to travel on October 4, 2022, and held a hybrid online-physical meeting with the main proponents of the SATREPS program, Prof. Inoi and Prof. Wang from the University of Toyama, Prof. Nakamura from Nagoya University, and NIPPON ENGINEERING CONSULTANTS CO., LTD. in the presence of HDC.

Figure 3-9 Exchange of opinions with the National University of Maldives

At the meeting, NIPPON ENGINEERING CONSULTANTS provided an overview of the SATREPS project, its research structure and research plan, and Prof. Nakamura from Nagoya University, Prof. Inoi and Prof. Wang from the University of Toyama provided detailed explanations of their research and research plans under the SATREPS program.

MNU expressed high interest in the research policy and content, and agreed to consider the selection of researchers suitable for each research field. In addition, MNU prepared the format of the ODA request form that MNU had submitted in the past, and the Ministry of Foreign Affairs of Maldives confirmed the process of submitting the form to the Embassy of Japan.

・Related ministries and agencies

At the on-site meeting with the Ministry of Transport and Civil Aviation and MTCC, we shared the recognitions that there are issues of lack of coordination among the ministries and that there are issues of lack of integration among the multiple parallel programs of international organizations. In the development of the Transportation Master Plan, the participants commented that they hoped that the studies and research conducted by the SATREPS program and other programs would lead to coordination and integration of the current programs.

Figure 3-10 Discussions with the Ministry of Transport and Civil Aviation and MTCC

As mentioned above, the study of long-term decarbonization through the development of public transportation in the Malé metropolitan area will be conducted on a research and demonstration basis, starting with the collection of traffic data, and taking into account factors such as climate change and population growth, while using urban design simulation technology to optimize the transportation system, while working with relevant ministries and agencies to formulate a master plan.

The SATREPS program usually runs from September to December, while JICA's ODA request survey is conducted from June to early August each year. Although ODA request forms need to be prepared in advance, since the SATREPS program is also positioned as ODA, we have discussed with JICA our policy to proceed with preparations with the aim of submitting a proposal in the following fiscal year.

Therefore, we have concluded that the exit from the transportation sector through this inter-city cooperation project will be based on the actual situation understanding, issue identification, and policy recommendation conducted in this project, and will be connected to the SATREPS program in the next fiscal year or later.

3.1.2. Consideration of decarbonizing public transportation as a short-term measure

(1) Linkage with decarbonization projects in the transportation sector

a) Project to establish new electric bus routes by GEF and Maldives government

The Ministry of Transport and Civil Aviation of the Maldives (hereinafter referred to as the "Ministry of Transport of the Maldives") and the Ministry of Environment, Climate Change and Technology of the Maldives (hereinafter referred to as the "Ministry of Environment of the Maldives") have been studying the introduction of decarbonized public transportation not only in the Hulhumale Island, but also in other islands of the Male' Metropolitan Area in order to reduce traffic congestion and CO_2 emissions from traffic. A study was conducted with the support of the Global Environment Facility (GEF, hereinafter referred to as "GEF"). and the project has been scheduled to be implemented as "Integrated Sustainable Low Carbon Transport Project in Maldives" by 2023.

The project aims to develop an integrated transportation plan for the Malé metropolitan area, and to strengthen cooperation among government agencies to ensure energy security and reduce air pollution through low-carbon transportation and fossil fuel reduction. The project is made up of the following three elements.

Element 1: Systematizing integrated, sustainable, low-carbon transportation

Element 2: Short-term solution through demonstration of low-carbon electric mobility

Element 3: Scale expansion and preparing for widespread adoption of integrated, sustainable, low-carbon transportation

Project Element 1 will develop and coordinate the government capacity to develop necessary policies and institutional frameworks for a transportation system focused on sustainable low-carbon options, and address policy gaps. It will also assist the government in developing a low-carbon transportation and electrification plan for the Malé region to develop a transportation sector that will improve the mobility of commuters.

Element 2 complements Element 1 through a feasibility study on the introduction of renewable-based electric boats, a demonstration of a public transportation system based on electric buses, and a scheme for sharing electric motorcycles. In addition, it will develop an electric mobility strategy that includes the financing mechanism.

Element 3 focuses on addressing information and awareness issues and increasing understanding of how sustainable low emission transport among large stakeholders can influence behavior.

b) Linkage with an existing project

As mentioned above, the existing project is a GEF-funded program. The GEF is a trust fund established at the World Bank as a financial mechanism for five environment-related conventions: the United Nations Framework Convention on Climate Change, the Convention on Biological Diversity, the Convention to Combat Desertification, the Stockholm Convention on Persistent Organic Pollutants (POPs Convention), and the Minamata Convention on Mercury.

Usually, international organizations, such as the World Bank, UNDP, and UNEP, implement projects using GEF funds. This project is led by UNEP.

In principle, the GEF provides grants for incremental costs incurred in implementing projects in response to global environmental issues, but does not provide full funding for individual projects (co-financing). The project is expected to serve as a lever for development projects to be planned in an environmentally friendly manner[14], but the funding for the project in the Maldives has been an issue in its dissemination.

Against this background, when the activities related to the inter-city collaboration project were presented to the Ministry of Environment of the Maldives and the Ministry of Transport of the Maldives during the field survey conducted in November 2021, they asked us to consider the linkage with this project.

Specifically, in the above-mentioned demonstration project for Element 2, the GEF project is supposed to support electric buses and infrastructure (including recharging facilities and solar power generation) as public transportation at the demonstration level, and we were asked to consider the possibility of leveraging the Intercity Collaboration Project and the JCM Equipment Subsidy Project for dissemination outside the scope of such support. The details of the subject bus and infrastructure specifications, route plans, etc. are shown below.

Table 3-2 Equipment to be installed through the GEF EV Introduction Project

Electric buses	• A total of 15 electric buses (12 in daily route operations, while 3 in reserve fleet) • Bus size: 6.53 × 2.23 × 2.8 m • 16 + 1 seats • Low floor and AC
Battery	• 68 kWh, Lithium-ion (LFP)
Charging Infra	• A total of 4 chargers • 150 kW DC fast charger • Location: Main depot • Time for full charge: less than 1.5 hours • Type of charging: Night charging at a depot
Depots and bus stops	• 15,000 sq. ft. Depot at Hulhumale • 23 bus stops on 2 routes
Route details	• 2 routes (RI and R2) (as shown in the diagram below) • Route length: R1 - 4.78 kms; R2 - 3.34 kms • No. of trips per day: 80 trips with 6 buses for R1 and R2 Considering trip length, battery size, and charger location, an electric bus needs to be recharged one or more times for Route R1. This aspect needs to be further discussed before procurement.
Bus service hours	• 5:30 am to twelve midnight

Source: Project Brief: Integrated, Sustainable and Low Emissions Transport in the Maldives

[14] Ministry of Foreign Affairs of Japan Website: Foreign Policy > ODA and Global Issues > Global Environment > Global Environment Facility (GEF)
https://www.mofa.go.jp/mofaj/gaiko/kankyo/kikan/gbl_env.html

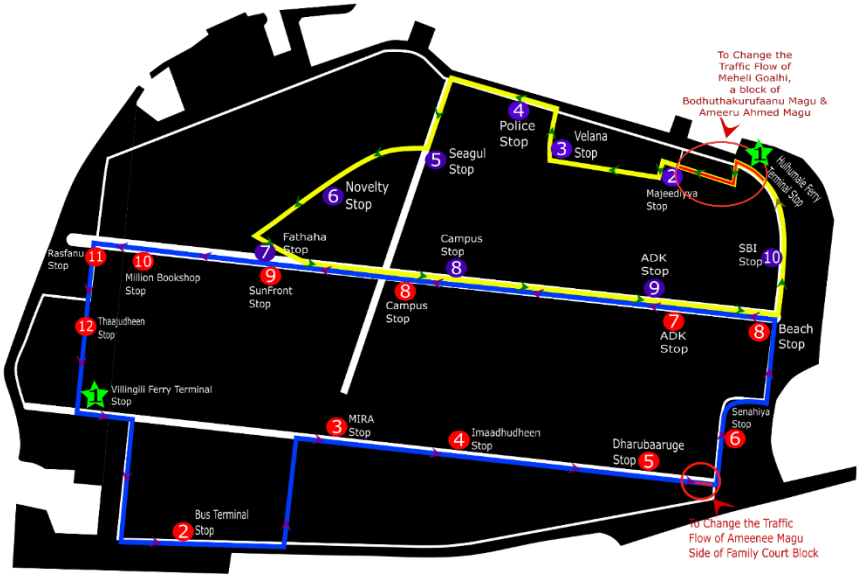

Figure 3-11 Bus routes planned for the GEF EV introduction project

Source: Materials provided by the Ministry of Environment, Maldives

In this study, the Maldives Public Transport Corporation (MTCC), a state-owned company, is responsible for conducting the feasibility study. MTCC has estimated the total capital investment to be US$26,36,384 and the monthly operating cost to be US$1,05,069.

Table 3-3 Cost Estimates for EV Introduction Projects by GEF

	Quantity	Unit price [US dollars]	Total [US dollars]	Rate
Electric buses (C6 Bj6650 Foton)	15	1,06,800	16,02,000	61%
Chargers (150 kW)	4	72,500	2,90,000	11%
Paving and Steel Canopy	1	2,20,000	2,20,000	8%
Bus Depot	1500	58	87,549	3%
Grid Connection	1	3,89,105	3,89,105	15%
Bus Stand	23	2,075	47,730	2%
Total Project Capex			26,36,384	100%
GEF Contribution (INV)			2,86,100	11%
Amount covered by Government of the Maldives			23,50,284	89%

Source: Materials provided by the Ministry of Environment, Maldives

As shown in the table above, the budget from the GEF will be used to procure two of a total of 15 electric buses and one of the four charging stations, accounting for 11% of the project capital investment. For the remaining budget, the Government of the Maldives is expected to utilize appropriate financing mechanisms, and in relation to that financing, the JCM equipment subsidy project attracted interest.

c) Possibility of utilizing the JCM equipment subsidy project.

Among the projects planned in the GEF project, the introduction of electric buses in Element 2, which has been strongly requested by the Ministry of Transport and Civil Aviation of the Maldives and the Ministry of Environment of the Maldives due to its particularly high CO_2 emission reduction effect, will be considered as a potential project for the JCM equipment subsidy project.

As mentioned above, the support of the GEF project is limited, covering the purchase of two of the 15 buses and four charging stations, amounting to 11% of the total installation cost. As for power sources, renewable energy power is expected, but support for solar power generation systems is not covered by the GEF project.

Other facilities such as pavements and buildings for depots are also supported in the GEF project, but from the perspective of the JCM equipment subsidy project, they are not eligible for support because they do not directly contribute to carbon dioxide emission reduction. The following figure illustrates the overall budget for the system.

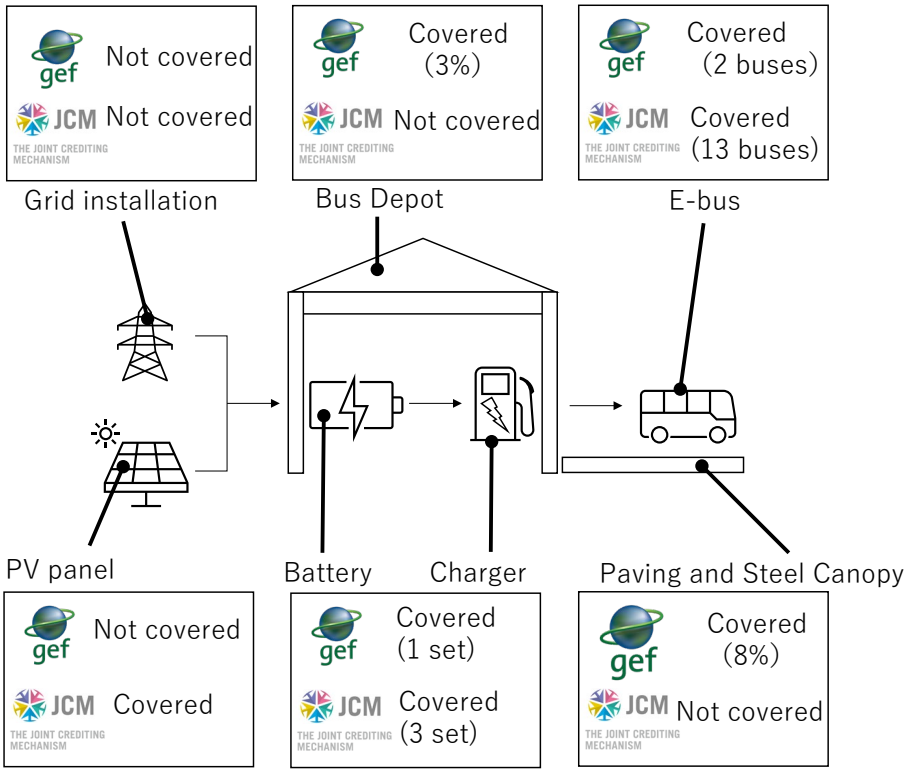

Figure 3-12 System overview and scope of JCM equipment subsidy

The CO_2 emission reductions, costs and feasibility of this assumption are described in detail in Chapter 3.1.3.

(2) Discussion on decarbonization projects for existing bus lines

In the GEF project, the adoption of electric buses on newly built bus routes is being considered. In the Malé Metropolitan Area, six routes connecting the islands of Malé, Hulhulé and Hulhumale are used by 32 buses. The organization that manages this is MTCC, the state-owned transport

corporation.

MTCC developed a plan to introduce electric buses when upgrading its bus fleet in 2019 from the perspective of decarbonization, and the study has been ongoing for three years.

However, due to the lack of funds, operational management, and technical knowledge of charging stations, they decided not to put off the installation of the system. However, they have plans to gradually switch to electric buses in conjunction with the GEF project, etc., and aim to fully shift to EVs within five years. In discussions with MTCC in the field, we have received a request for cooperation in this project.

Figure 3-13 MTCC's plan to adopt electric buses announced in 2019[15][16]

Figure 3-14 Exchange of opinions with MTCC (HDC's Facebook post on the right)

In order to consider the utilization of the JCM equipment subsidy project as a solution to the

[15] https://oneonline.mv/en/12553

[16] https://psmnews.mv/en/47500#:~:text=Maldives%20Transport%20and%20Contracting%20Company,in%20Male'%20City%20to%20MTCC.

financial and technical issues regarding this request, we requested the provision of the necessary data, namely the detailed specifications of the bus, fuel consumption, distance of the bus route, and the number of round trips. The data obtained are shown below.

Table 3-4 Public bus information provided by MTCC

Bus / Van	Brand	Fuel Type	Bus Type	Bus Length (M)	Engine Model	Average Fuel Consumption (based on last 3 months data)	Current Fuel Rate (MVR)	Status (as at 22/11/2021)
B0A T1107	Volvo	Diesel	City Bus	12	84004X2B7RLE EURO IV	-	11.63	Grounded
B0A T1108	Volvo	Diesel	City Bus	12	84004X2B7RLE EURO IV	-	11.63	Grounded
B0A T1109	Volvo	Diesel	City Bus	12	84004X2B7RLE EURO IV	1,957.33	11.63	Grounded
B0A T1110	Volvo	Diesel	City Bus	12	84004X2B7RLE EURO IV	421.67	11.63	Grounded
B0A C1128	Volvo	Diesel	Shuttle Bus	12	VOLVO 9100	1,637.00	11.63	Grounded
B0A C1129	Volvo	Diesel	Shuttle Bus	12	VOLVO 9100	-	11.63	Grounded
B0A C1135	Man	Diesel	Shuttle Bus	12	CLA16.220	236.67	11.63	Grounded
B0A C1174	Yutong	Diesel	Shuttle Bus	12	LZYTATE63J1020526	366.33	11.63	In Operation
B0A C1183	Yutong	Diesel	Shuttle Bus	12	LZYTATE61J1020525	986.00	11.63	In Operation
B0A C1136	Man	Diesel	Shuttle Bus	12	CLA16.220	-	11.63	Grounded
B0A C1154	Man	Diesel	Shuttle Bus	12	CLA16.220	526.67	11.63	Grounded
B0A C1156	Man	Diesel	Shuttle Bus	12	CLA16.220	-	11.63	Grounded
B0A C1175	Yutong	Diesel	City Bus	12	LZYTAGD67J1022868	2,984.33	11.63	In Operation
B0A C1176	Yutong	Diesel	City Bus	12	LZYTAGD60J022873	2,877.00	11.63	In Operation
B0A C1178	Yutong	Diesel	City Bus	12	LZYTAGD69J1022872	2,986.67	11.63	In Operation
B0A C1179	Yutong	Diesel	City Bus	12	LZYTAGD69J1022869	2,921.00	11.63	Grounded
B0A C1180	Yutong	Diesel	City Bus	12	LZYTAGD67J1022871	2,732.33	11.63	In Operation
B0A C1181	Yutong	Diesel	City Bus	12	LZYTAGD65J1022867	544.67	11.63	In Operation
B0A C1182	Yutong	Diesel	City Bus	12	LZYTAGD65J1022870	1,141.33	11.63	Grounded
B0A C1184	Yutong	Diesel	Shuttle Bus	12	LZYTAGD60J1024380	3,187.33	11.63	Grounded
B0A C1185	Yutong	Diesel	Shuttle Bus	12	LZYTATE67J1037054	2,682.67	11.63	In Operation
B0A C1186	Yutong	Diesel	Shuttle Bus	12	LZYTATE69J1037055	2,453.33	11.63	In Operation
B0A C1187	Yutong	Diesel	Shuttle Bus	12	LZYTATE60J1037056	2,263.67	11.63	In Operation
B0A C1189	Yutong	Diesel	Shuttle Bus	12	LZYTATE69J1037053	3,572.33	11.63	In Operation
B0A C1190	Yutong	Diesel	Shuttle Bus	12	LZYTATE63J1034790	3,000.00	11.63	In Operation
B0A C1191	Yutong	Diesel	Double Decker Bus	12	LZYTAGE61J1034786	3,961.67	11.63	In Operation
B0A C1192	Yutong	Diesel	Double Decker Bus	12	LZYTAGE67J1034797	-	11.63	In Operation
B0A C1193	Yutong	Diesel	Double Decker Bus	12	LZYTAGE63J1034787	3,205.00	11.63	In Operation
B0A C1194	Yutong	Diesel	Double Decker Bus	12	LZYTAGTAGE67J1034732	3,102.00	11.63	In Operation
B0A C1195	Yutong	Diesel	Double Decker Bus	12	LZYTAGTAGE65J1034788	2,981.33	11.63	Grounded
B0A C1196	Yutong	Diesel	Double Decker Bus	12	LZYTAGTAGE63J1034790	729.33	11.63	In Operation
B0A C1197	Yutong	Diesel	Double Decker Bus	12	LZYTAGTAGE65J1034791	1,791.33	11.63	Grounded

Source: Information provided by MTCC

Table 3-5 Public bus travel distances provided by MTCC

#	Route	Length (KM)	Scheduled Trips per day	Oneway	Round trip	Frequency (mins)	Service Time	Number of Stops	Commute Details (August)	Commute Details (September)	Commute Details (October)
Route 1	West Park Bus Stop – Hulhumale'	20.61	61	1257.21	2514.42	15 – Sunday to Thursday 20 – Fri/Sat/Holidays	05:30 – 23:30	21	94,027	102,036	105,224
Route 2	Carnival – Hulhumale'	15.63	56	875.28	1750.56	15 - Sunday to Thursday 30 - Friday excluding Friday prayer break time 20 - Saturday / Holidays	05:40 – 23:00	9	36,036	44,888	45,555
Route 3	West Park Bus Stop - VIA	13.45	19	255.55	511.1	60.00	06:00 – 00:40	7	3,069	3,427	4,144
Route 4	Hulhumale'- Velana International Airport	14.8	76	1124.8	2249.6	30.00	05:35 – 00:35	11	30,980	34,149	33,604
Route 6	Hulhumale Phase 1 – Phase 2 Connection Route	4.06	37	150.22	300.44	30.00	0545 – 2345	12	-	112	42,252
Total		68.55	249	3663.06	7326.12	-	-	-	-	-	-

Source: Information provided by MTCC

From the above table, the fuel consumption is 55,249 L per 3 months, or an average of 614 L per day, assuming that the 3 months equals 90 days. Route length is between 4 km and 20 km, the number of round trips is between 19 and 61, and total travel distance is 3,663 km/day. The fuel consumption value obtained by dividing the total travel distance and total fuel consumption is 5.96 km/L.

It is assumed that the electrification of buses will be phased in within five years. We decided to calculate the possibility of making use of the JCM equipment subsidy project and the effect of CO_2 emission reduction if the above 32 buses in the six routes are replaced with electric buses, and to discuss the use of the JCM equipment subsidy project with MTCC. The results of the reduction effect are shown in the next chapter.

3.1.3. Estimation of current traffic-derived CO_2 emissions and carbon reduction effects

As mentioned above, as a result of this fiscal year's project, we have received a request from the local community for cooperation in two projects regarding the introduction of electric buses: a new route business plan by the GEF and an existing route bus project by MTCC.

In the following, we calculate the CO_2 emission reduction effect for each project and discuss the possibility of utilizing the JCM equipment subsidy project.

(1) Estimation of the CO_2 emission reduction effect by the GEF project and the possibility of utilizing the JCM equipment subsidy project

As shown in Chapter 3.1.2, the GEF project includes a plan to operate two new bus routes with the introduction of electric buses. Route 1 is 4.78 km and 80 round trips, and Route 2 is 3.34 km and 80 round trips, for a total of 649.6 km/day or 237,104 km/year.

As a reference case, assuming that a diesel bus is used to travel the relevant operating distance. When assuming fuel consumption based on travel distance, fuel consumption values (km/L) must be set. In the JCM equipment subsidy project, when local data are not available, the value of the latest

equipment with high efficiency is used for the sake of conservative review. As values for the latest equipment with high efficiency in diesel buses, we referred to "Route bus and general bus fuel efficiency" in the fuel efficiency performance values for automobiles (March 2020), which are evaluated annually by the Ministry of Land, Infrastructure, Transport and Tourism based on the "Implementation Guidelines for Evaluation and Publication of Automobile Fuel Efficiency Performance (Notification No. 61 of the Ministry of Land, Infrastructure, Transport and Tourism, 2004).

In said performance values, fuel consumption data for vehicles of Isuzu, Toyota, Hino, and Mitsubishi Fuso Truck and Bus were organized, and fuel consumption values ranging from 3.95 km/L to 10 km/L were indicated. Therefore, the value of 10 km/L was referred to as the value of the latest equipment with the highest efficiency. Fuel consumption is obtained by dividing the driving distance by the fuel consumption value shown on the left, and can be estimated as 23,710 L based on the formula below.

237,104 km/year ÷ 10 km/L = 23,710 L/year (fuel consumption)

Since the CO_2 emission factor for diesel fuel is 2.619 kg-CO_2/L, the CO_2 emissions associated with the use of the above-mentioned fuel would be about 62 t-CO_2/year.

The useful life applied to the JCM equipment subsidy project is 5 years, as the project falls under the category of "passenger vehicles" in the "vehicles and transportation equipment" section of the Ministerial Ordinance on the Useful Life of Depreciable Assets (Appended Tables 1 and 2).

Therefore, the total emission reduction of this project is about 310 t-CO_2.

In the case of JCM equipment subsidy projects, for the first project in the relevant country, either 50% of the equipment that contributes to CO_2 emission reduction or the emission reduction cost guideline of 4,000 yen/t-CO_2, whichever is lower, will be applied.

In the case of the GEF project, 15 buses and charging stations are applicable as facilities that directly contribute to CO_2 emission reduction. The 15 buses are estimated to cost a total of 1,602,000 US dollars, and the charging stations are estimated to cost 290,000 US dollars. The total project cost is about 213 million yen, of which about 11% will be funded by the GEF, so about 1.9 million yen will be covered by JCM.

Since this is the first JCM equipment subsidy project for electric buses in the Maldives, approximately 95 million yen can be expected to be subsidized, when it is assumed that 50% is covered. However, based on the 4,000 yen cost-effectiveness standard for CO_2 emission reduction, the maximum subsidy amount is 1.24 million yen, which is 310 t-CO_2 multiplied by 4,000 yen/t-CO_2. The subsidy rate as a percentage of the project cost is less than 1%, which means that the subsidy effect is very small.

In addition to the significantly low financial merit of the equipment subsidy project, the suitability of the JCM equipment subsidy project from the perspective of credits is also low.

There are few examples of JCM/CDM application in the transportation sector, and while the CO_2 emitted by the transportation sector is said to be one-fourth of the total emissions, the reduction ratio

of the transportation sector among the CDM projects registered with the UNFCCC (United Nations Framework Convention on Climate Change Secretariat) is said to be 1/1119[17], suggesting the difficulty in applying the market mechanism to the transportation sector. In this project, too, the low-carbon effect on the equipment price is small, making it difficult to apply the JCM equipment subsidy project.

(2) Estimation of the CO_2 emission reduction effect of the MTCC project and the possibility of utilizing the JCM equipment subsidy project

On the other hand, in the MTCC project, six routes are used by 32 buses, which is a more promising target for reduction due to the high fuel consumption.

As mentioned above, the fuel consumption is 55,249 L/90 days, or 614 L/day. When it is multiplied by the CO_2 emission factor of 2.619 kg-CO_2/L, the CO_2 emission is about 1.6 t-CO_2/day, or about 587 t-CO_2/year assuming 365 days of operation per year.

Since it is expected that renewable energy will be used to the maximum extent as a power source for EV buses in the MTCC project, the installation of solar panels on the roofs of MTCC-managed facilities (bus terminals, etc.) is also considered here to supply electricity to the charging stations. The shortfall is to be compensated by grid electricity, and the project emissions are calculated using the electricity emission factor for grid electricity.

As for the amount of electricity required by the 32 electric buses, the total distance traveled by all the buses in a day is 7,326 km, and the electricity cost (electricity consumption per distance) of the electric buses is tentatively set at 1.2 kWh/km, adopting the value stated in the Guidelines for the Introduction of Electric Buses by the Ministry of Land, Infrastructure, Transport and Tourism[18]. 3,663 km multiplied by the amount of electricity needed to drive 1 km (1.2 kWh), or about 4,400 kWh, is the amount of electricity needed per day. Assuming 365 days of operation per year, the annual energy requirement is approximately 1,606,000 kWh. The charging stations will be set in three locations: two bus terminals and a maintenance area managed by MTCC. The following figure shows the location of the sites and what each site looks like.

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[17] Mitsubishi UFJ Morgan Stanley Securities, "Contribution: Toward solving transportation CDM issues," Monthly Energy Forum, December 2009.
https://www.sc.mufg.jp/company/sustainability/cef/article-04.html

[18] Ministry of Land, Infrastructure, Transport and Tourism, Bureau of Motor Vehicles, "Guidelines for Introducing Electric Buses," December 2018
https://www.mlit.go.jp/common/001265916.pdf

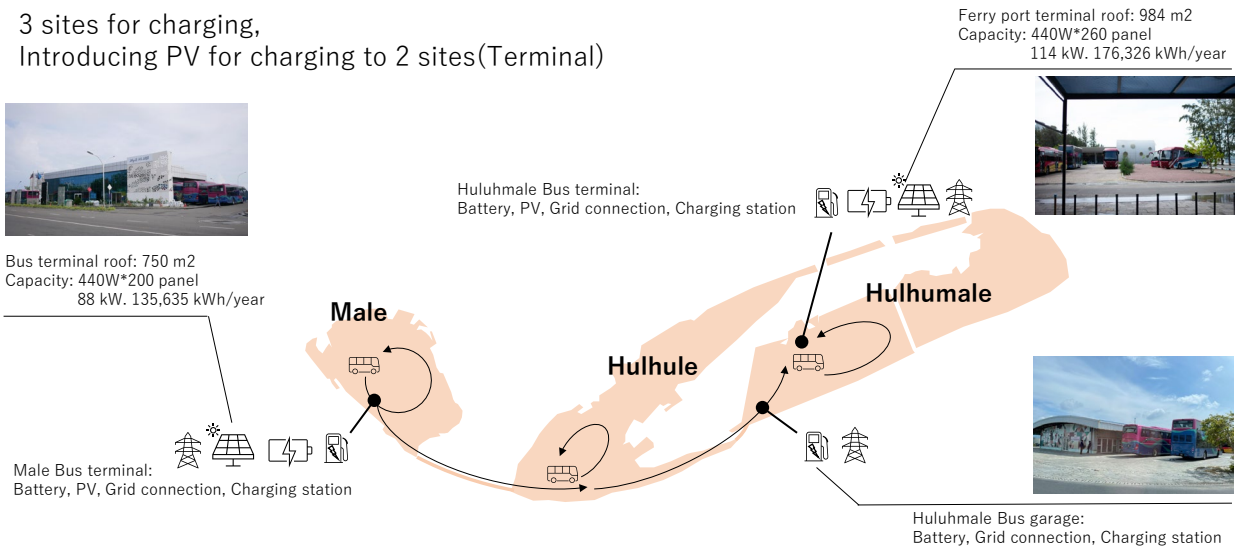

Figure 3-15 Proposal for solar power and charging station layout

Now, let's consider the contributions from renewable energy sources.

Facilities that are under MTCC management and are expected to be used for roofing are the Male Bus Terminal (750 m^2) and the Hulhumale Ferry Port (984 m^2). The number of panels installed, annual power generation, and installation costs for both facilities are as follows.

Table 3-6 Rooftop area and estimated solar power generation for MTCC-managed facilities

Site	Area [m2]	Site image	Capacity [kW]	Power generation [kWh]	Initial cost [USD]
Greater Male Bus Terminal	750		88.0kw 440W*200panel	135,635	102,908
Huluhmale Ferry port terminal	984		114.4kw 440W＊260panel	176,326	130,871
				Total 311,961 kWh	

Source: Material produced by Nihonkucho Hokuriku

The estimated amount of solar power generation at both locations is about 312,000 kWh, and the bus operation corresponding to this amount of electricity can be considered zero-emission.

1,294,000 kWh (312,000 kWh subtracted from 1,606,000 kWh required for electric bus operation) will be supplied from grid power.

The fuel efficiency, or the distance that can be traveled with 1 L of diesel, is 5.97 km as mentioned above, but if the same distance is to be traveled by electricity, 7.16 kWh of electric power is required

according to the following formula.

Distance traveled per liter of diesel (km) × Electric power per unit (kWh/km)

5.97 km × 1.2 kWh/km

= Required electric power equivalent to 1 liter of diesel

= 7.16 kWh

Since the grid emission factor in the Maldives is 0.533 t-CO_2/MWh, the CO_2 emission from running 1 km with 7.16 kWh generated from grid power is 0.0038 t-CO_2 according to the following equation.

Required electric power equivalent to 1L of diesel × Emission factor of Maldives Electricity Grid = Emission amount

7.16 kWh × 0.533 t-CO_2f/MWh / 1000 (unit adjustment) = 0.0038 t-CO_2

The CO_2 emission factor per 1L of diesel is 0.0026 t-CO_2/km, which means that in cases where grid-derived electricity is used as the power source, CO_2 emissions are calculated to be higher than for diesel. In other words, the project emissions exceed the reference emissions, and the JCM equipment subsidy project is not viable.

Therefore, instead of targeting 32 buses, the study will be based on the amount of renewable energy.

The amount of electricity that can be generated by solar power is about 312,000 kWh/year, and the distance that can be traveled with this electricity is about 260,000 km/year according to the following equation.

Annual solar power output ÷ Power consumption per distance = Travel distance with solar power (km/year)

(312,000 kWh/year) ÷ (1.2 kWh/km) = (260,000 km/year)

Since the project emissions for the above distance will be zero, the CO_2 emissions generated by driving the same distance with diesel fuel as a reference case will be equivalent to the reduction.

The diesel fuel required for a 260,000 km trip is about 43,000 L, according to the following equation.

Travel distance with solar power (km/year) ÷ Diesel bus fuel efficiency (km/L) = Diesel consumption (L/year)

(260,000 km/year) ÷ 6 km/L = 43,000 L/year

Based on the CO_2 emission factor for diesel fuel, the CO_2 emissions from the above usage are as follows:

Diesel consumption (L/year) x Diesel fuel emission factor = CO_2 emissions

43,000 L/year × 2.619 kg-CO_2/L ÷ 1,000 (unit adjustment) = 112 t-CO_2/year

Assuming that the legal useful life applicable to the electric buses and equipment is 5 years, the total emission reduction over the entire project period is 560 t-CO_2.

In light of the CO_2 emission reduction cost-effectiveness standard of 4,000 yen/t-CO_2, approximately 2.24 million yen can be considered as the upper limit of subsidy (if it is 50% or less of the project cost) based on the total emission reduction in question.

In the above study, the subject facilities are solar power and recharging stations and 32 electric buses, and the following costs are estimated based on a simple preliminary calculation.

Table 3-7 Project cost projection

	Unit	Price (USD)	Price (JPY)	Reference
Solar panel	1 unit	233,779	Approx. 27 million	Calculated by Nihonkucho Hokuriku *Cost of solar panels only, not including construction and transportation costs.
Charging station	3 units	870,000	Approx. 99 million	Figure in GEF project (Unit price: 290,000 US dollars)
Electric bus	32 buses	3,417,600	Approx. 392 million	Figures of GEF project (Unit price: 106,800 US dollars)

The total value is about 518 million yen, but the contribution of the subsidy is negligible based on the criteria of the JCM equipment subsidy project described above, and the subsidy effect is only marginal. Even if only solar panels, which directly contribute to CO_2 emission reduction, are included in the equipment, the subsidy effect is less than 10%, which is a level that makes it unlikely to make the JCM equipment subsidy project viable.

Here, we assume a solar power generation project. In the case of solar power, 17 years is applied as the useful life, and more emission reductions can be expected as the project life increases. The reduction effect when using solar power generation is 1,904 t-CO_2 according to the following equation.

Annual emission reduction × Lifetime of equipment = Emission reduction over the project period

112 t-CO_2/year × 17 years = 1,904 t-CO_2

In light of the CO_2 emission reduction cost-effectiveness standard of 4,000 yen/t-CO_2, the upper limit of the subsidy would be approximately 7.6 million yen based on the total emission reduction, which is equivalent to approximately 30% of the cost of 27 million yen for the solar power generation equipment mentioned above.

However, in this case, a comparison should be made with the case where solar power generation facilities are evaluated as an alternative to the electricity grid, and a methodology that can evaluate higher reduction effects should be considered.

The above estimates suggest the difficulty in applying the JCM equipment subsidy project in the transportation sector, both in terms of the subsidy effect and CO_2 emission reduction through the JCM equipment subsidy. On the other hand, the local government is also highly interested in reducing CO_2 emissions from public transportation, and there are high expectations that the JCM equipment subsidy project will provide a good example of CO_2 emission reduction in the transportation sector.

After sharing the results of these estimates with HDC, MTCC, and other interested parties, we were introduced to the fact that HDC is considering a demonstration project of charging stations for EVs and rental electric motorcycles in the Hulhumale area.

A conceptual diagram of HDC's project is shown below.

Figure 3-16 Concept of EV and Electric Motorcycle Charging Station by HDC

We requested consideration of installing solar power generation equipment at these charging stations, which we were told are being planned.

On the other hand, the use of solar panels for the charging stations was pointed out as an issue.

Specifically, this is an operational hurdle for STELCO, a state-owned electricity company.

The charging stations are expected to use power from the power grid in order to cope with power shortages from photovoltaic generation fluctuations. At that time, STELCO will need to manage the size and operation of the solar panel installations in order to manage the power grid. This will require an agreement with STELCO for implementation, as well as HDC or MTCC, who operate the charging stations, for the system's implementation. Moreover, the charging station operator will pay STELCO for the electricity generated by solar power generation, which means that the charging station operator's electricity price will be the same as purchasing electricity from the existing power grid,

with no economic benefits to the charging station operator. Therefore, the decision to install photovoltaic power generation at recharging stations is made by STELCO, but STELCO gives higher priority to the installation of general photovoltaic power generation because it is easier from a technical standpoint to increase the ratio of renewable energy in the entire grid than to install renewable energy at recharging stations alone.

Although the adoption of batteries and the net metering system in operation in the Maldives are viable options, the general solar power generation business model that utilizes the roofs of charging stations and reverse trend to STELCO's power grid is more realistic in terms of cost and time required for realization.

3.1.4. Implementation structure and schedule

(1) Discussion on a Master Plan for Public Transportation

As mentioned in Chapter 3.1.1, the Master Plan for Public Transportation will assume the use of the SATREPS program, an international science and technology cooperation program, and will promote proposals mainly from research institutions as required by the program.

The National University of the Maldives, the largest university in the Maldives, will be the research institute on the Maldivian side, and the University of Toyama is expected to be the representative research institute on the Japanese side.

As mentioned above, we have reached a general agreement on the proposal policy with researchers from both universities, and we intend to further exchange opinions with them and prepare necessary documents, aiming to submit proposals in FY 2023.

Since this is a project that was triggered by the Intercity Cooperation Project, Japan NUS Co., Ltd., the proposing corporation, and NIPPON ENGINEERING CONSULTANTS, the joint proposer, will be responsible for supporting the proposal process and various adjustments, and Toyama City, Hulhumaleh Development Corporation, Maldives Ministry of Environment, Maldives Ministry of Transport, and MTCC will collaborate.

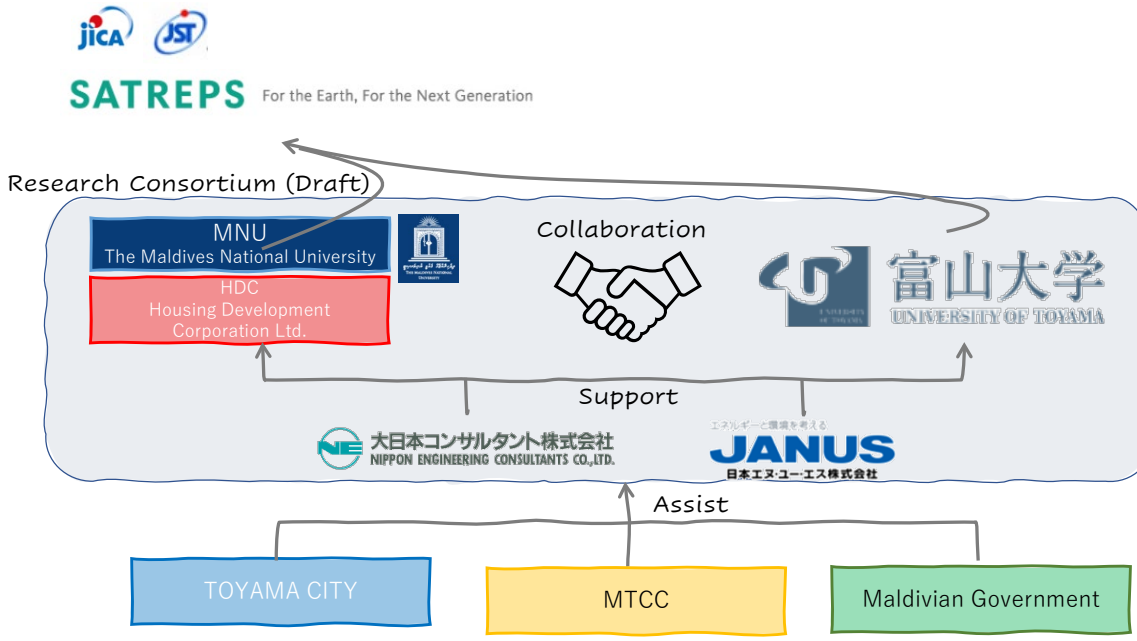

Figure 3-17 Proposed Implementation Structure for the Project for Formulating a Master Plan for Public Transportation

(2) JCM equipment subsidy project for electric buses

As summarized in Chapters 3.1.2 and 3.1.3, this work explored the JCM equipment subsidy project, which includes electric buses and infrastructure such as solar panels to power them, as a short-term measure to reduce CO_2 emissions from transportation. In the JCM equipment subsidy project, the participation of a Japanese company is required as a representative business operator, and we considered a system in collaboration with Nihonkucho Hokuriku Co., Ltd., which is located in Toyama City and a joint proposer of this project.

Nihonkucho Hokuriku has a large number of construction achievements mainly in Toyama City and the Hokuriku region, and has shown interest in supplying panels to the Maldives in line with the company's policy of overseas expansion. The company has a wealth of experience in building systems that combine solar power and storage batteries, and is capable of handling the design and technical studies required for electric bus charging stations.

On the other hand, it is essential to cooperate with local firms regarding local construction management and imports. As described in Section 3.1.3, the current costs are approximations, and it is necessary to proceed with detailed cost estimation and calculation of construction costs for each facility, as well as to work out a detailed plan with MTCC, which will be the owner of the electric bus project.

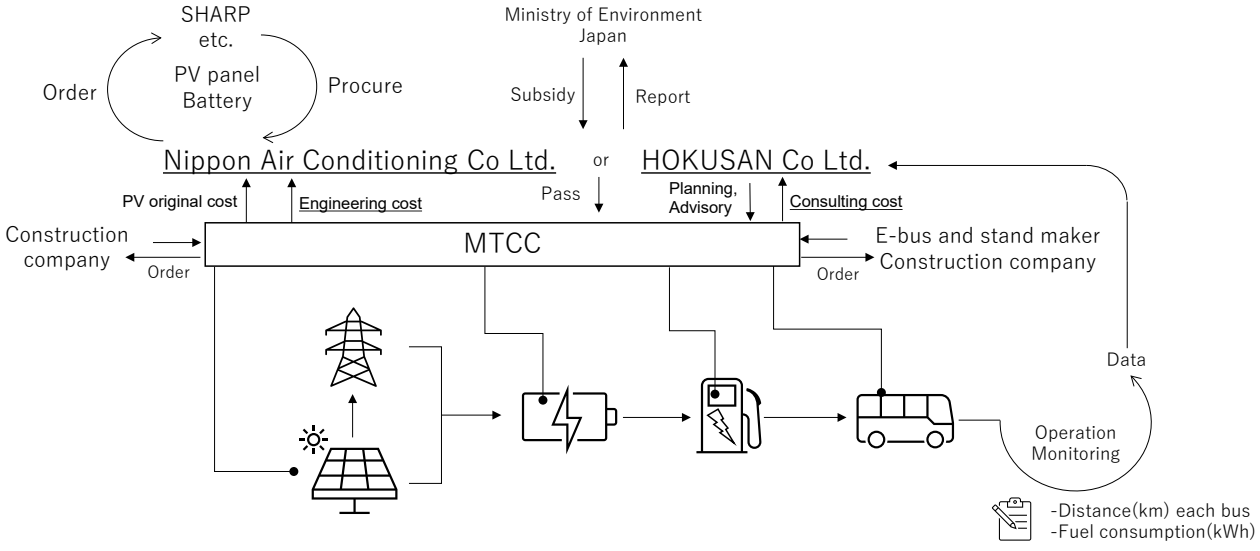

Figure 3-18 Proposed Implementation Structure for the JCM Equipment Subsidy Project for Electric Buses

3.2. Field of low-carbon power generation through the replacement of gas in diesel power generation equipment

In Maldives, electric power is generated mainly from diesel fuel, due to the limitations of land and resources, which are characteristic of island countries. Diesel power generation equipment is compact and lightweight for output, can be placed anywhere, and has good startup performance and high thermal efficiency, so this is a primary power source in remote islands around the world, including Japan. While renewable energy, such as solar power, is being distributed, there is no choice but to rely on diesel power generation as a baseload power source for tolerating load fluctuations.

The amount of electricity generated by diesel power in Hulhumalé and Malé is about 400 million kWh/year, diesel fuel consumption is about 100 million liters/year, and CO_2 emissions are 265,000 t-CO_2/year, accounting for about 20% of the total GHG emissions of the Maldives.

Population	15769
Area of Island (km²)	2.000
Distance from Male' (km)	4.1
Nearest Airport	Velana International Airport
Electricity Provider	STELCO
Peak Load Time	21:00
Total daily peak load (kw)	-
Total Installed Capacity (kW)	17400
Installed Gen sets	800, 1000x7, 1600x6
Monthly Average Usage (kWh)	4,272,559.50
Yearly electricity production (kWh/yr)	51,270,714.00
Yearly Billed Amount (kW)	46,034,939.00
Oil Consumption Yearly	13,536,795.00
Total Lube oil consumption (liter/yr)	68,916.00
Solar PV Installed (kw)/Year	-
Yearly Production from Solar PV (kwh)	-
Synchronizing Panel	Yes
Type of Synchronizing Panel	Auto
Electricity cable Installed Year	2003
Distribution Cable size/mm²	70185
CO2 emission (tCO_2)	36,040.36

Data on power output in the Hulhumalé Island

Population	127079
Area of Island (km²)	1.900
Distance from Male' (km)	0
Nearest Airport	Velana International Airport
Electricity Provider	STELCO
Peak Load Time	15:00
Maximum Peak Load (kW)	56048
Total Installed Capacity (kW)	80320
Total Generator Sets (kW)	1000x6, 1600x9, 2000x2, 2160x3, 4320, 5760, 6500x2, 8730x2, 8900
Monthly Average Usage (kWh)	28,080,134.33
Yearly electricity production (kWh/yr)	336,961,612.00
Yearly Billed Amount (kW)	27,772,229.00
Yearly Oil Consumption (Liters)	86,055,128.00
Total Lube oil consumption (liter/yr)	273,114.00
Solar PV Installed (kw)/Year	675kw / 2013
Yearly Production from Solar PV (kWh)	911325
Synchronizing Panel	Yes
Type of Synchronizing Panel	Auto
Electricity cable Installed Year	1949
Distribution Cable size/mm²	70180
CO2 emission (tCO_2)	229,113.17

Date on power output in the Malé Island

Figure 3-19 Power generation capacities, outputs, and diesel fuel consumptions in the Malé and Hulhumalé Islands

Source: ISLAND ELECTRICITY DATA BOOK 2018.[19]

[19] MINISTRY OF ENVIRONMENT AND ENERGY REPUBLIC OF MALDIVES," ISLAND ELECTRICITY DATA BOOK",2018 (http://www.environment.gov.mv/v2/wp-content/files/publications/20181105-pub-island-electricity-data-book-2018.pdf)

As a technological low-carbon option alternate to diesel power generation, we can consider the mixed combustion with natural gas in the existing dieasel power generation facilities.

Natural gas is considered to be a relatively clean energy source, with lower CO_2 emissions per unit of heat compared to diesel.

In FY 2020, we discussed the use of liquefied natural gas (LNG) to reduce carbon emissions, and the results indicated the possibility of significantly reducing CO_2 emissions from diesel power generation.

The use of natural gas is being considered not only by this project, but also by the Maldivian Ministry of Environment and STELCO, the state-owned electricity corporation, and Indian companies are planning to invest in the project. On the other hand, even in the Maldives, there are reports that question the use of natural gas being a fossil fuel as the country strives to decarbonize.

It has been pointed out that the development of natural gas (LNG) supply and utilization facilities require a large initial investment and a construction period, which may delay the achievement of carbon neutrality in the Maldives, and it has been argued that if initial investment and a long construction period are required, priority should be given to initiatives that aim for decarbonization.

However, there is no stable renewable energy option to meet the current electricity demand, and the CO_2 emissions from diesel power generation should not be left untouched while waiting for technological breakthroughs. Therefore, some people argue that the promotion of natural gas use should not be dismissed as the best option available, and it is a bit of a standoff.

In this situation, the skyrocketing of natural gas price progressed, in the wake of Russia's invasion of Ukraine in 2022. What is worse, the economy of Sri Lanka, which was a candidate natural gas supplier, collapsed. Accordingly, the discussion on adoption of LNG was virtually put on ice.

While seeing the uncertainty of the governmental policy of the Maldives and the turmoil in the global energy market, we tried to conduct comparison and summarized our proposal with an eye to the utilization of hydrogen as a reneable energy carrier in this survey.

3.2.1. Discussion on the possibility of adopting hydrogen derived from renewable energy

(1) Production and availability of hydrogen derived from renewable energy produced in the Maldives

a) Necessity of technologies using hydrogen

The most feasible power source in the Maldives among renewable energy is sunlight.

The output from solar power generation varies with the amount of sunlight, so it cannot become a base-load power source for realizing stable power supply.

In addition, the supply of electric power must be always equal to the demand for electric power, and the imbalance between supply and demand would disturbe power frequency, leading to trouble, such as a power outage. Accordingly, it is necessary to keep a stable power source idling to cover the fluctuation in solar power output as a backup for balancing supply and demand.

Namely, even if the ratio of solar power generation is increased in the Maldives, diesel power generation must be maintained to some degree, so there are problems with the costs for electric power and system management and operation management. In detail, advanced operation would be required

for controlling the operation of diesel power generators while taking into account not only the fluctuation in load (demand), but also the fluctuation in solar power output due to the weather. Therefore, suppliers, STELCO, would have the burden of operation management, and it would augment the costs for power generation and risks. These are technical bottlenecks to the popularization of solar power generation.

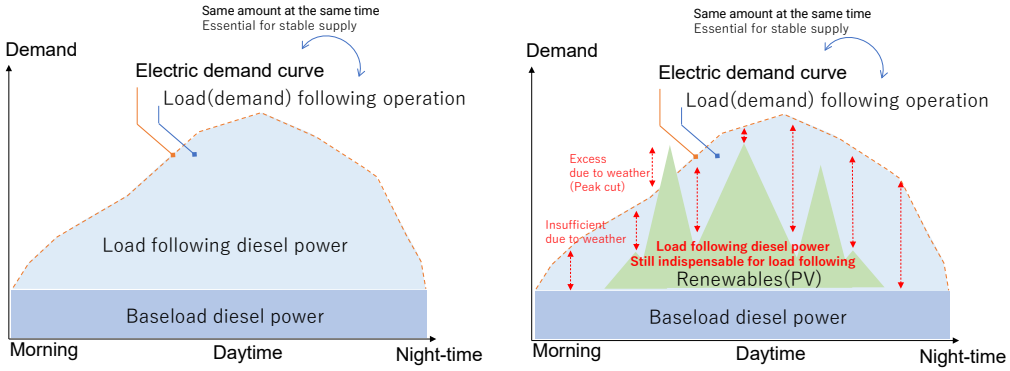

Figure 3-20 Estimated fluctuation in renewable energy

One solution for stably generating electric power is the use of storage batteries. The charge/discharge efficiency of lithium-ion batteries is said to be 90-95%. It they are connected to renewable energy power plants and core grids, surplus power will be stored and discharged when supply is sufficient, to stabilize grid power. In the case of storage batteries where power conversion and storage devices are integrated, a large number of batteries need to be installed for covering the load, so there are problems with costs and installation area, and when spontaneous discharge is taken into account, it is difficult to store power for several seasons or years.

In light of such constraints of storage batteries, Power to Gas (P2G) systems are attracting attention, because they can produce hydrogen via water electrolysis with unstable solar power, store it, and supply power with fuel cells. The efficiency of hydrogen power is considered to be around 44% (electrolysis efficiency: 80% × power generation efficiency of fuel cells: 55%) or 70% when a cogeneration system is assumed. Just by installing more hydrogen storage tanks, it is possible to boost capacity easily at low cost, and there is no spontaneous discharge from the storage tanks, so it is possible to store a lot of energy for several seasons or years[20].

This can be utilized not only for supplying electric power, but also as fuel for vehicles and vessels, so it is expected to remove the bottlenecks to the distribution of renewable energy. In particular, Toshiba Corporation has engaged in the development of systems for supplying electricity stably by taking advantage of storage batteries and hydrogen and making the best of unstable renewable energy.

[20] Fumio Nishiwaki, "Instability of renewable energy power generation should be covered by hydrogen," Toyo Keizai Online, 2018. (https://toyokeizai.net/articles/-/231887?page=3)

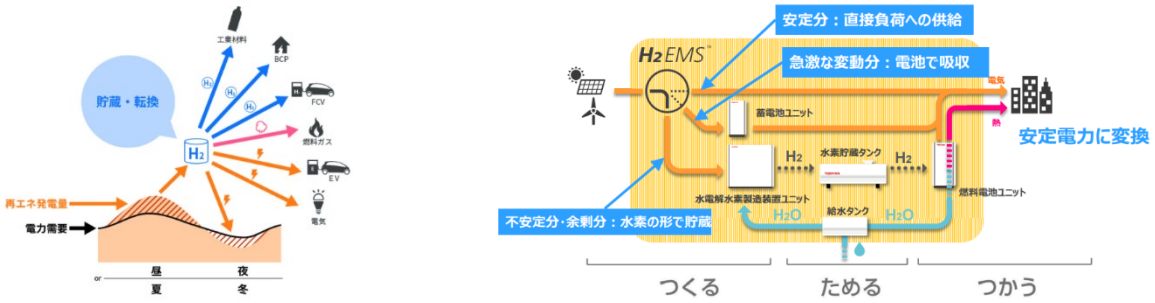

Figure 3-21 Hydrogen-based technology of Toshiba Corporation

Source: Toshiba Energy Systems & Solutions Corporation [21]

As an outcome of development, they commercialized a self-standing hydrogen energy supply system named H2One™, assuming that hydrogen would be produced and consumed in each region, and it was installed in Toyama City. As a model for producing and consuming hydrogen in each region, Toshiba Corporation is discussing methods for utilizing the system according to the following locational characteristics.

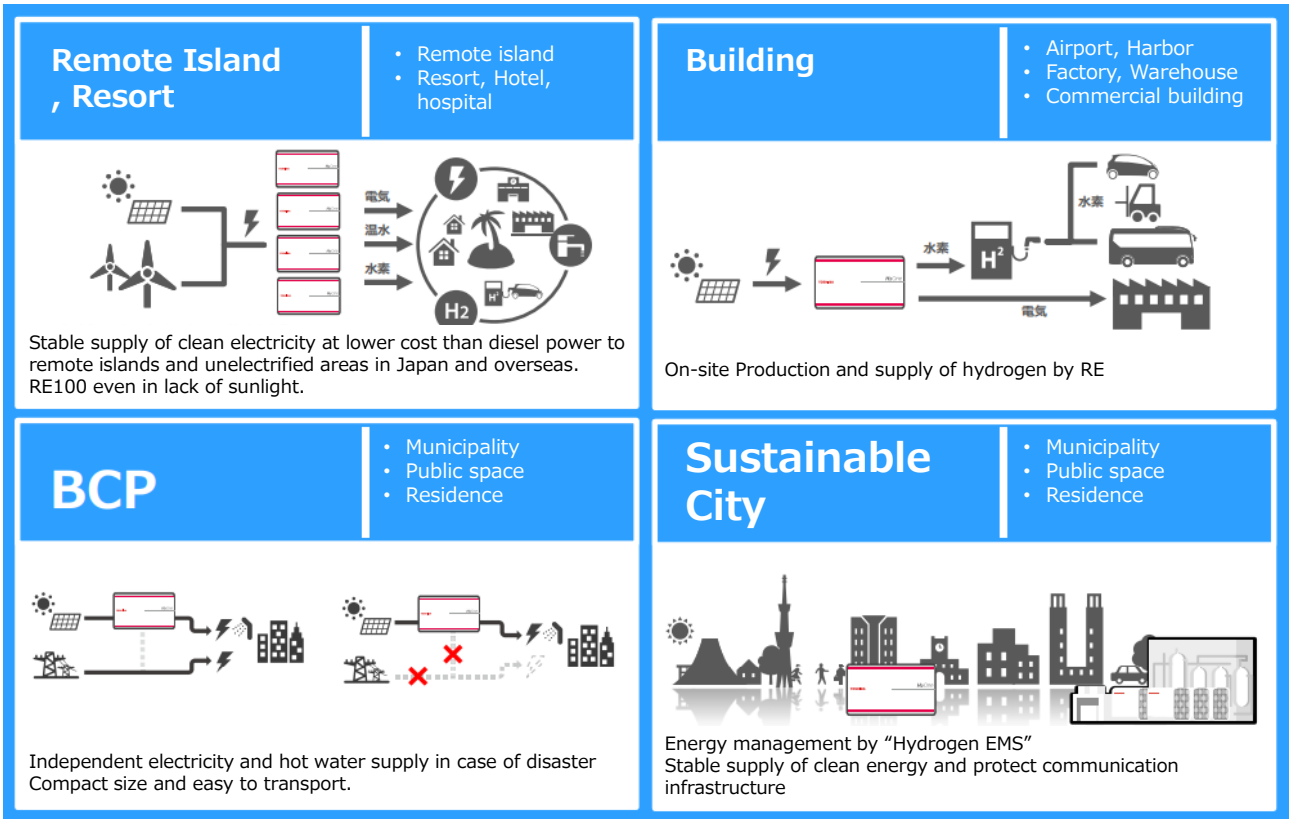

Figure 3-22 Strategies for distributing H2One™, a self-standing hydrogen energy supply system of Toshiba Corporation

Source: Toshiba Corporation [22]

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[21] Website of Toshiba Energy Systems & Solutions Corporation (https://www.toshiba-energy.com/hydrogen/product/)

[22] The first Tokyo Promotion Conference for Actualizing a Hydrogen Society in FY 2016:

Toyama City was planning to adopt renewable energy-derived hydrogen stations and industrial fuel-cell vehicles, to develop hydrogen infrastructure, as Toyama Council for Hydrogen Energy Promotion aimed to actualize a low-carbon society. By expanding H2One™, it is possible to utilize renewable energy-derived hydrogen for supplying electric power and hot water to buildings, etc., recharging EVs, and so on. Accordingly, it has been adopted as H2One Multi-station™, and is now in operation.

Figure 3-23　Hydrogen station in Toyama City

Source: Toshiba Energy Systems & Solutions Corporation[23]

b)　Needs for use of hydrogen in the Maldives

As mentioned above, hydrogen can be utilized for technically solving the problem with stable supply, which is a bottleneck to the distribution of renewable energy. However, their system needs to be recognized and understood by local officials, so we introduced the technology in this survey, and studied the needs from local officials.

① Ministry of the Environment of the Maldives

During the on-site survey, we had an opportunity to meet the officials of the Ministry of the Environment of the Maldives, and interviewed them about the outline of the intercity collaboration project and the policies for using hydrogen derived from renewable energy, etc. From the Ministry of the Environment, the vice minister and the officials in charge of climate change, waste, and energy divisions participated. Our side included Japan NUS Co., Ltd. and HDC.

They commented that they are interested in especially the utilization of hydrogen. They had discussed it, because it could be used as a technology for distributing renewable energy, but they considered that it is not feasible from the cost aspect.

Toshiba's initiatives for realizing a hydrogen society "utilization of the self-standing hydrogen energy supply system H2One and renewable energy-derived hydrogen," Jun. 27, 2016 (https://www.kankyo.metro.tokyo.lg.jp/climate/hydrogen/suishin27.files/28-1_presen1_toshiba.pdf)

[23] Press release of Toshiba Energy Systems & Solutions Corporation: Start of operation of H2One ST Unit™, a renewable energy-derived hydrogen station for local production and local consumption, for Toyama Council for Promoting Hydrogen Energy, Jan. 2020 (https://www.toshiba-energy.com/info/info2020_0123.htm)

Accordingly, they are planning to shift from the current diesel power generation to green hydrogen via LNG as a transitional technology. They also commented that the attractive characteristic of hydrogen is the possibility of using it as fuel for automobiles and for power generation.

Regarding renewable energy, they understood the above-mentioned problem with the coordination capacity and mentioned that it is necessary to deal with load fluctuations. Regarding solar power generation on land, the national power company STELCO, the World Bank, ADB, etc. are planning to install solar panels, while available rooftop area is limited. Accordingly, they advised that it is necessary to coordinate with their existing plans.

Regarding LNG for the transitional technology, they recognize it as key fuel for achieving net zero emissions in 2030, and informed us that the utilization of LNG is recommended in the net zero plan for 2030, which was produced with support from the World Bank, and the roadmap for net zero, which was produced with support from ADB. There is a plan to construct an LNG-fired power plant with an output of 200 MW in the Thilafushi Island, but discussions on decarbonization and costs are continued, and they have not reached a conclusion. Regarding green hydrogen, they commented that they would welcome a proposal for a solution to cost-related problems.

Figure 3-24　Scene of exchange of opinions with the Ministry of the Environment of the Maldives

② National power company STELCO

During the on-site survey, we met the staff of the national power company STELCO, which manages power generation and power systems in the capital area of Malé, and interviewed them about the outline of the intercity collaboration project, their power supply plan, and the possibility of discussing renewable energy-derived hydrogen.

Firstly, they mentioned that STELCO recognizes that the renewable energy that can be adopted in the Maldives is limited to solar power. Then, they informed us that there is a plan to install a solar power generation system with an output of 15 MW and storage batteries to cover load fluctuations. However, the capital area of Malé has land constraints for installing solar panels and storage batteries, so they recognize that LNG-based power generation is currently the best means for realizing a low-carbon society, because floating solar power generation systems and other technologies for renewable energy are still under development. Regarding hydrogen, they mentioned that they would like to shift gradually, but it is necessary to set systems far from residential areas for safety.

Figure 3-25　Outer appearance of STELCO

From the interviews with the Ministry of the Environment of the Maldives and STELCO, it was found that they consider solar power generation as the primary means for distributing renewable energy, recognize the problems of land constraints and fluctuations in power grids, and are keenly interested in hydrogen for realizing decarbonization, while thinking that LNG is a near-term solution for a low-carbon society.

The Ministry of the Environment found cost issues through discussions so far, while STELCO recognizes that it is necessary to discuss details from the aspect of safety, etc.

Considering these recognitions of local parties, we decided to discuss proposals for solutions to the above issues, to promote the installation of systems.

c)　Feasibility of use of hydrogen

Considering the fact that it is challenging to adopt renewable energy (solar power) as an energy source for hydrogen use, it is appropriate to install autonomous decentralized equipment in each facility or district rather than large-sized centralized equipment for solar power generation and hydrogen production through water electrolysis.

Enlargement would provide economics of scale, but it is necessary to stir demand while solving the issues related to development, such as the securing of land and costs, so it takes time to secure land and a budget, and make political decisions. Accordingly, an approach for distribution based on small-scale demonstration in a model spot suited for hydrogen use is considered effective.

For electric power, ENE-FARM (household fuel cells), which has been already distributed in Japan, could be utilized. ENE-FARM induces a chemical reaction between hydrogen extracted from city gas and LP gas and oxygen in the atmosphere to generate power, and provides hot water by using the generated heat. Since it contributes greatly to energy saving, it has been distributed.

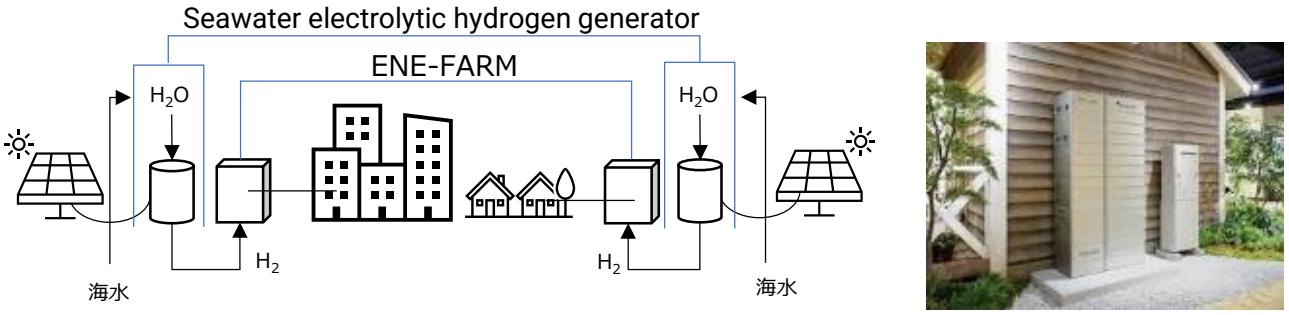


Figure 3-26　Schematic diagram of use of ENE-FARM

When renewable energy-derived hydrogen is used, it is unnecessary to install a reformer for extracting hydrogen from city gas or LP gas, so a simpler structure can be achieved. With the aim of distributing hydrogen infrastructure, they have developed ENE-FARM for directly using hydrogen by removing a reformer from the conventional model.

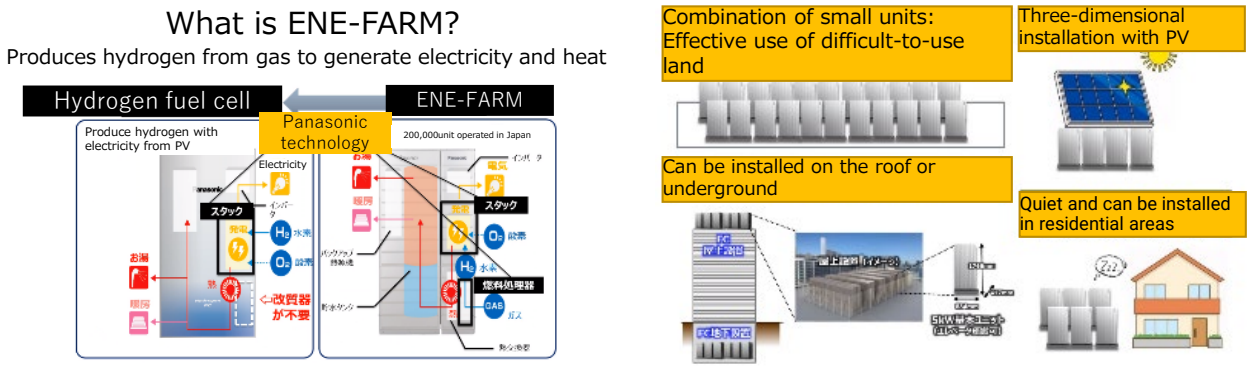


Figure 3-27　Mechanism and distribution of ENE-FARM

Source: produced by Hokusan Co., Ltd. based on reference material

ENE-FARM is designed for households, so it is quiet and can be installed underground or with solar panels, overcoming land constraints. In this survey, we seeked model spots, and received an inquiry about the “Green Building” Scheme, which utilizes renewable energy 100%, from HDC. The Green Building Scheme was designed based on the BREEAM (Building Research Establishment Environmental Assessment Method) of the U.K., which is an international index for gauging the sustainability of a building or region. In the Hulhumalé Development area, a model of the next-generation building is planned, and we reached an agreement that we will exchange opinions about the feasibility of installation of ENE-FARM.

The distribution of ENE-FARM may contribute to the stabilization of the power system in the capital area of Malé. For example, ENE-FARM is utilized in the Japanese electric power market, and about 1,500 units of ENE-FARM are used in the VPP aggregator demonstration project, to contribute to the stabilization of power grids, etc. by adjusting the output of fuel cells according to the power generation cycle with renewable energy, etc.

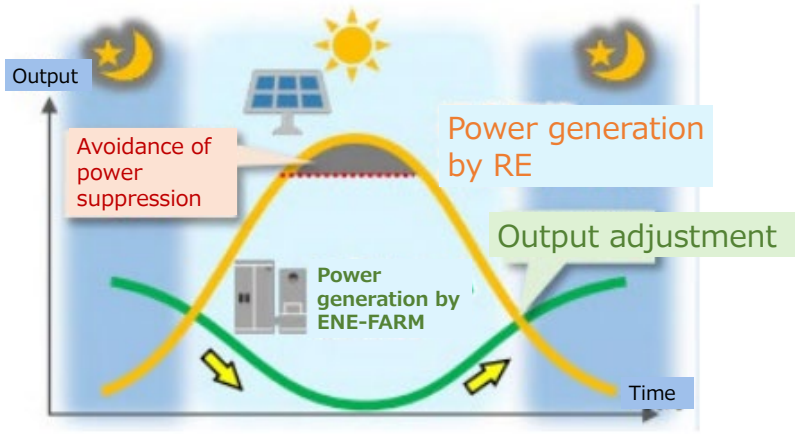


Figure 3-28 Schematic diagram of the output adjustment of ENE-FARM

Source: Material of Agency for Natural Resources and Energy of METI [24]

Technologies for applying hydrogen to transportation are under development around the world, but it has been pointed out that there are problems with costs for hydrogen stations, including hydrogen gas compression equipment for supplying fuel. In this situation, it may be possible to use "SimpleFuel™," which was jointly developed by IVYS Energy Solutions and PDC Machines in the U.S.

SimpleFuel™ was installed in the factories of Toyota Motor Corporation. It is a hydrogen station that produces hydrogen through the electrolysis of water by using the power generated by solar panels inside the premises of factories, compresses it, and refuels fuel cell (FC) forklifts.

The production volume of hydrogen is up to 99 Nm^3/day (about 8.8 kg/day). It can refuel seven or eight FC forklifts, and it can be set in a small space because of its compact size, so it is considered to be suited for refueling FC forklifts in factories.

Figure 3-29 Envisioned supply of hydrogen to transportation means with SimpleFuel™

Source: Produced by Hokusan Co., Ltd. based on reference material

[24] Agency for Natural Resources and Energy, METI: "Interim Summary of Challenges in Future Hydrogen Policies and Countermeasures (Provisional)," March 2021 (https://www.meti.go.jp/shingikai/energy_environment/suiso_nenryo/pdf/025_01_00.pdf)

It could be used for airport vehicles, public buses, boats, etc. whose operation ranges and energy consumption can be estimated easily. The adoption of EVs is being discussed for public buses operated by MTCC. Keeping in mind that fuel-cell vehicles are more economical when travel distance is longer, we will have discussions, including the comparison with hydrogen use.

d) Feasibility of using ammonia

As mentioned earlier, renewable energy sources are limited to solar power in the Maldives, and it has land-related constraints. Thus, to achieve carbon neutrality, it is highly likely that procuring hydrogen derived from renewable energy from overseas is an option to be considered.

Regarding the transportation and storage of hydrogen, they are interested in using ammonia (NH_3) along with liquefied hydrogen that is liquefied and compressed by cooling. Liquefied ammonia has a hydrogen density of about 1.5 times that of liquefied hydrogen and liquefies at 25°C and 10 atm. Moreover, compared to liquefied hydrogen, energy loss occurs in the process of conversion to ammonia. However, the energy required for its transportation is smaller. Thus, ammonia becomes a more beneficial option the longer the distance traveled[25].

Energy importing countries prefer selecting fuels with high transportation efficiency because it directly affects the costs. Therefore, as a decarbonized fuel, ammonia is an option to be considered. As shown in the figure below, when comparing the power generation costs, including the costs for the supply chain of hydrogen and ammonia, based on the case of Japan, which is an energy importing country, the power generation cost of ammonia is lower.

[25] Kojima, Ichikawa, Hydrogen Energy Systems Society in Japan, Vol.36, No.4, 34-41, 2011 (https://www.hess.jp/Search/data/36-04-034.pdf)

Table 3-8　Cost comparison of hydrogen and ammonia

	Hydrogen power generation cost (2020)	**Ammonia** power generation cost (2018)	
Production 製造	Overseas hydrogen production Natural gas + CO2 sales (for EOR) 11.5JPY /Nm3	Overseas hydrogen production Natural gas + CO2 sales (for EOR) 11.5JPY /Nm3（= 201USD/t）	
		Overseas ammonia production 4.3JPY 円/Nm3（= 76USD/t）	
Shipping 運送	Hydrogen import Raleigh transportation + liquefaction + cargo + sea transportation 162JPY ／Nm3*	Ammonia import cargo + sea transportation 2.3JPY 円/ Nm3（=40USD/t）	
Power generation 発電	Hydrogen generator 70,000 yen-90,000 JPY /kW**	Exclusive firing 460,000 yen /kW	Mixed firing 290,000 yen/kW
Total Cost	Exclusive firing 97.3JPY/**kWh***	Mixed firing 1 (e.g., calorific base 10%) 20.9JPY/**kWh***	Exclusive firing 23.5JPY/**kWh**	Mixed firing (e.g., calorific base 20%) 12.9JPY/**kWh**

Source: Produced by Hokusan Co., Ltd. based on reference material

In terms of utilization, Mitsubishi Power Co., Ltd. is developing an ammonia gas combustion turbine, and in 2021 it started to remodel a 40,000 kW class turbine. Also, IHI succeeded in realizing a natural gas and ammonia co-fired gas engine and aims to reach a 100% liquid ammonia-fueled firing in 2025. Regarding co-combustion with diesel, although it is used mainly in ships, JFE Engineering has succeeded in an ammonia and diesel co-combustion and plans to proceed with development to increase the ammonia ratio to 80% in the future[26].

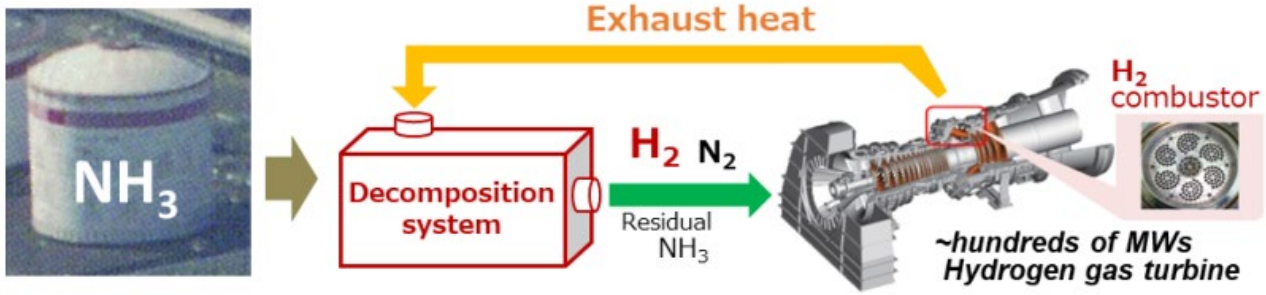
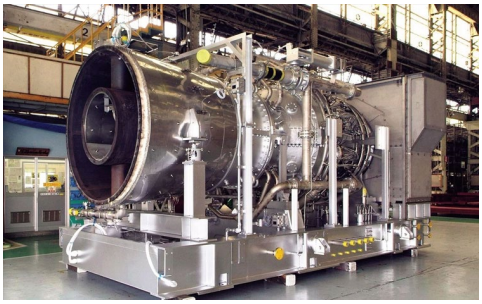
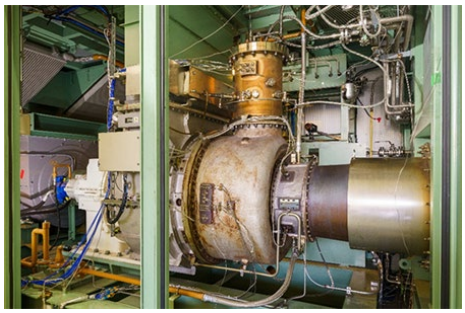


Figure 3-30　Example of the hydrogen technology

[26] Nippon Keidanren (Japan Business Federation) “Challenge Zero” Website Innovation Example “Ammonia Direct Combustion Technology ‘Application to Marine Diesel Engines’” (https://www.challenge-zero.jp/jp/casestudy/74)



Ammonia gas turbine(Dedicated burning)
Mitsubishi
In 2021, we started to remodel the existing 40,000 kW class gas turbine.



Ammonia gas turbine
IHI
Succeeded in co-firing natural gas and ammonia (70%). Aim for exclusive burning in 2025.

Figure 3-31 Case of ammonia gas turbine technology development

Source: Produced by Hokusan Co., Ltd. based on reference material

(2) Technical examination of natural gas supply feasibility

a) Overview of natural gas supply and power generation technology

Natural gas is a flammable gas used as the so-called city gas in Japan and refers to a naturally stored gas containing carbon compounds such as methane and ethane.

In island countries such as Japan, which import natural gas, liquefied natural gas is mainly imported by using tankers. Natural gas is liquefied by cooling it to -162°C at atmospheric pressure. By doing so, its volume is compressed to about 1/600, allowing more gas to be transported with a small volume. Thus, the transportation cost and portability are improved.

LNG needs to be regasified to be used as gas. Regasification is the process of raising the temperature of LNG and evaporating it to return natural gas to gas. Therefore, regasification equipment, LNG storage equipment, and land are required when using natural gas.

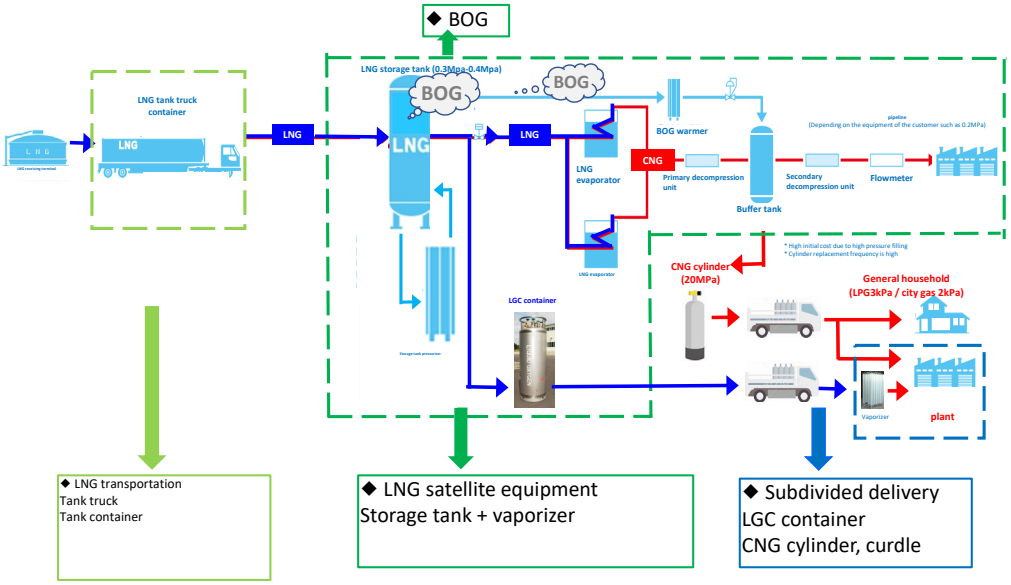


Figure 3-32 Process flow of delivery, storage, and vaporization of LNG

Source: Produced by Hokusan Co., Ltd. based on reference material

Compressed natural gas (CNG) has the same composition as liquefied natural gas (LNG). However, unlike the liquefied one, it does not require cooling, so transportation and storage facilities are much simpler. On the other hand, while LNG takes up 1/600 of the natural gas volume at atmospheric pressure, CNG is compressed to about 1/200 of the natural gas volume. Hence, the volume is large, so transportation costs are an issue.

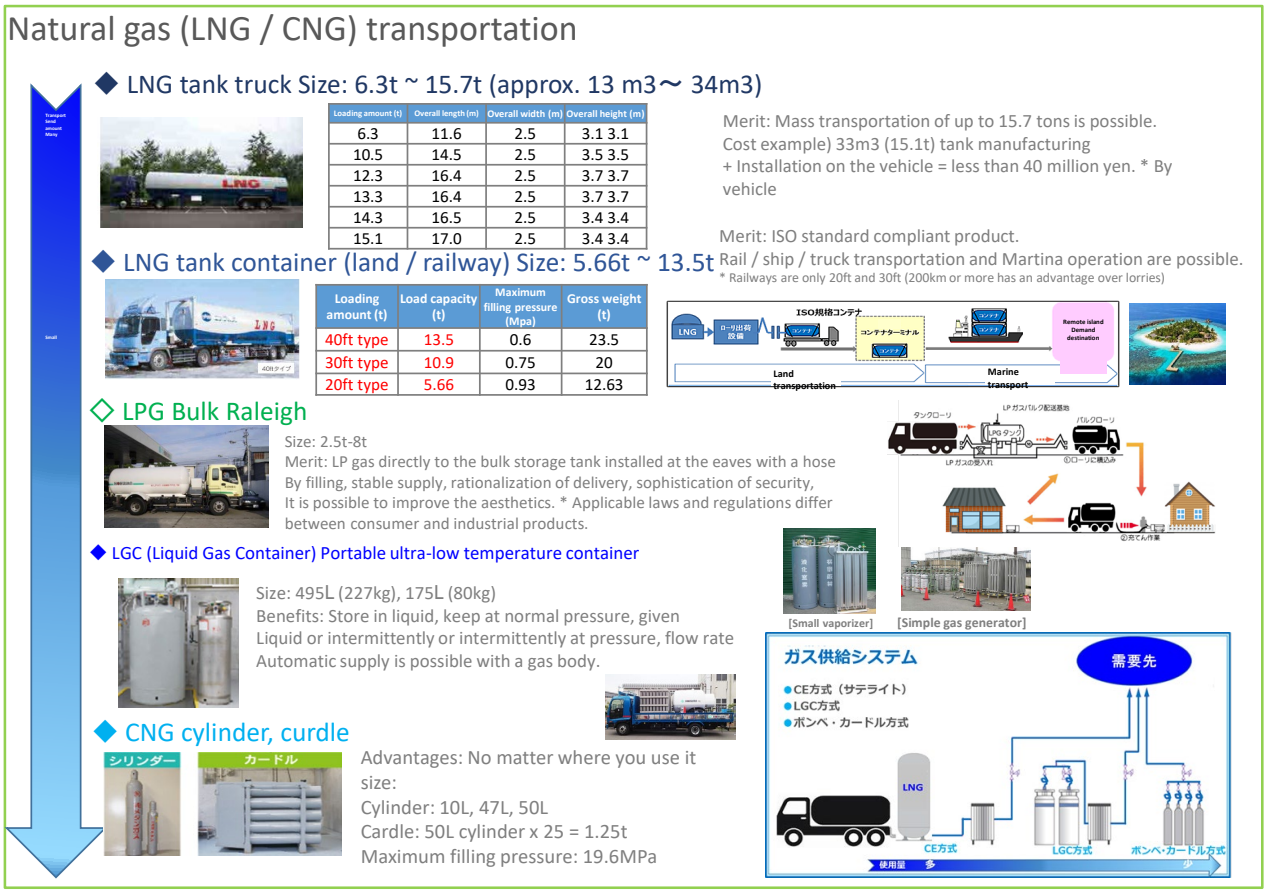


Figure 3-33　Comparison of LNG and CNG transport volumes

Source: Produced by Hokusan Co., Ltd. based on reference material

b)　LNG introduction plan in the Maldives and Malé region

In its 2019 annual report, STELCO, a state-owned electric power company responsible for providing electricity in the Malé metropolitan area, has announced investment plans for future power generation configurations, including LNG, solar power, battery technology, and hybrid systems[27].

The capacity of the LNG power generation facility is estimated to be 200 MW and would be constructed on the Thilafushi Island. Since the electricity demand in the Greater Malé region is estimated to exceed 260 MW, and the amount of electricity generated in the region is one-fourth of the Maldives as a whole, clean and low-priced LNG is preferable to diesel. Moreover, the existing

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

diesel power plant would continue to be used for load adjustment.

Figure 3-34 Power grid development plan for the Greater Malé area

This plan is also reflected in the biennial report (BUR: BIENNIAL UPDATE REPORT TO THE UNFCCC) submitted to UNFCCC by the Maldivian government. In it, you can find the plan to promote the use of LNG as one of the mitigation measures[28].

Che Energie, an Indian gas-related company, is discussing the fuel transportation issue. In its plan, the company is considering installing a hub consisting of floating gas storage and regasification units (FSRU) with a capacity of about 130,000-140,000 m^3 in the Gulhifalhu Island to send small LNG carriers to outer islands. This capacity would cover the energy consumption of the entire Maldives for about 40 days.

Like this, the supply chain for LNG utilization in the Maldives is being established. On the other hand, there is a problem with transmission lines in the plan to build an LNG thermal power plant on the Thilafushi Island. Regarding this point, a plan to construct a bridge connecting the Thilafushi Island and the Malé Island is currently underway, and India is moving to provide funding through ODA[29]. Specifically, in August 2020, India's Foreign Minister Subramaniyam Jaishankar promised a 100 million dollar subsidy for the construction of the bridge and a new 400 million dollar loan.

However, considering the bridge's design, financial planning, and construction, it is expected to take about five to ten years to complete it.

However, as it is necessary to reduce emissions promptly, it is essential to take some mitigation measures against the dependence on the existing diesel power generation plants without waiting for

[28] MINISTRY OF ENVIRONMENT "MALDIVES FIRST BIENNIAL UPDATE REPORT TO THE UNFCCC",2019. (https://unfccc.int/sites/default/files/resource/First%20BUR%20of%20Maldives.pdf)
[29] 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

the completion of power plants and transmission lines.

The intercity collaboration project prioritizes using renewable energy. However, as the baseload diesel power facility must operate for load adjustment, using natural gas to minimize CO_2 emissions is reviewed as an option. Specifically, the method of converting existing diesel equipment into diesel and natural gas co-firing power generation can be used.

c) Natugral gas technology

As mentioned above, in this proposal, we do not consider the permanent usage of LNG in power generation, but consider it as a milestone toward low carbonization. Thus, we assume the adoption of co-firing technology in existing diesel power generation facilities.

This is called dual-fuel (DF) technology. It has been used in ships and large vehicles with diesel engines as well as power generation facilities. DF technology was also used in the 2018 JCM equipment subsidy project, "The introduction of CNG and diesel co-firing equipment to public transportation buses in Semarang City, Indonesia." Hokusan Co., Ltd., the co-operator of this project, is the representative company in the JCM project.

DF technology can be applied to all diesel engines, including those of vehicles, ships, and generators. By mixing the diesel fuel sprayed in the engine with natural gas, the amount of diesel used is reduced, which leads to less CO_2 emissions. Moreover, it can be cost-effective due to the difference in the number of thermal units. Furthermore, since it is only necessary to add devices such as a gas tank, piping, a supercharger, and a control system to the existing diesel generator, there are merits in terms of construction cost and construction period.

Natural gas conversion technology for diesel power generation equipment is found in Europe, China, India, etc., and Japanese heavy electric manufacturers and engineering companies also have the technology. For example, the dual-fuel engine gasification conversion technology developed by JFE Engineering Corporation has a track record of operating for 20,000 hours and a gas fuel ratio of 95%, making it a highly efficient facility globally. In developing countries, there is a tendency to prioritize lower prices over performance. However, it is highly possible that it will be used in the case of the JCM equipment subsidy project financing the project and ensuring price competitiveness.

JFE Engineering Corporation has already delivered nine facilities in Japan and overseas and has installed some in India, Indonesia, and other countries. Thus, it has a high market advantage in developing countries.

Installation in India (NEDO demonstration)

Installation in Indonesia

Figure 3-35 Example of JFE Engineering Corporation's DF technology

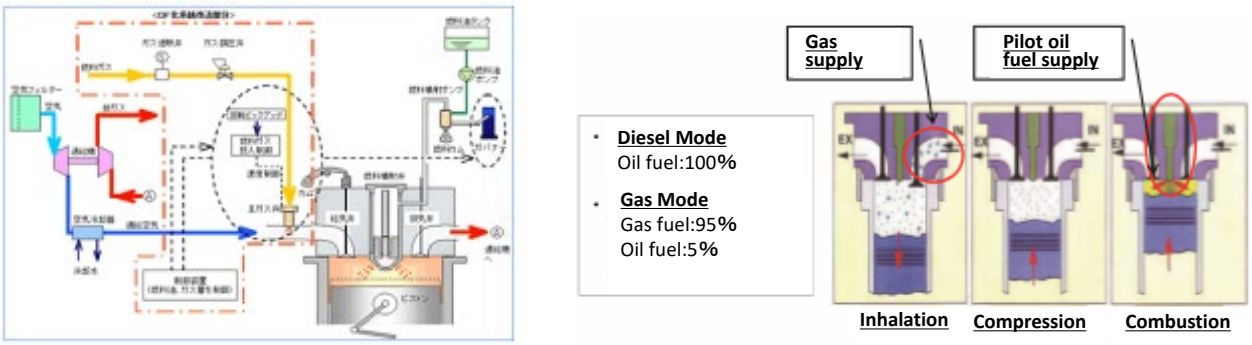


Figure 3-36 Combustion in a natural gas co-fired engine

Source: JFE Engineering Corporation 21[30]

Hitachi Zosen Corporation, which aims to install waste power generation and seawater desalination equipment in the Maldives, also has similar dual-fuel technology and has the advantage of partnering with the engine manufacturers used by many of Maldives' diesel power plants.

3.2.2. Discussion on the feasibility of commercialization with a JCM equipment subsidy

The potential of use of alternate fuels discussed in this section varies according to the governmental energy policy and infrastructure development. For natural gas utilization, land was secured and a policy for using LNG was formulated, but a final decision is still to be made. The establishment of natural gas infrastructure could reduce power generation costs, but it also could decrease the cost competitiveness of a system using hydrogen, etc.

Under these circumstances, we were not able to make a concrete deal for business utilizing hydrogen or LNG with a JCM equipment subsidy. While waiting for their decision to adopt LNG, we plan to ask related institutions to discuss the utilization of a JCM equipment subsidy at the good timing, while carrying out other projects.

In this field, the above-mentioned Japanese technologies excel as candidate technologies, so we will continue preparations for commercialization in cooperation with the companies in Toyama City.

3.2.3. Proposed implementation structure

a) Use of hydrogen

As mentioned above, we consider installing solar panels and water electrolysis systems for hydrogen production in each district and facility, as autonomous decentralized power sources. Possible components of this system include solar panels, seawater desalination equipment, water electrolysis systems for hydrogen production, ENE-FARM, and water electrolysis systems for hydrogen production and compression and dispensing equipment (for vehicles). We will discuss sites and facilities with high potential to use this system in the future. We assume that owners of green

[30] JFE Engineering Corporation: "Technology for gasification with a dual fuel engine," Jan. 2013, JFE Technological Journal No. 31, p.p. 89-90 (https://www.jfe-steel.co.jp/research/giho/031/pdf/031-22.pdf)

buildings, including HDC, which has multiple buildings in Hulhumalé, would become users of such systems. As for hydrogen supply to vehicles, MTCC Plc. is likely to use them as well.

As a hydrogen user, Hokushi Co., Ltd. would represent the JCM equipment subsidy program as a system design, security, and monitoring equipment provider. Nihonkucho Hokuriku Co., Ltd. is expected to be responsible for the design of the renewable energy system needed for hydrogen production.

All element technologies will be adopted in collaboration with Japanese manufacturers. Regarding the use of hydrogen derived from renewable energy, although the technology is in the dissemination stage, it has been pointed out that the high installation cost is a constraint on the dissemination even in Japan. Thus, it is still hard to install it from a financial point of view in a country like the Maldives, where electricity price is relatively high. Under such circumstances, even with the JCM equipment subsidy, there would remain problems in terms of economic efficiency, although this depends on the amount of demand and EPC costs. For this reason, we can understand the problems with installation through demonstration projects, such as JICA's SDGs business support project, and discuss the approach of establishing a model facilty for local promotion.

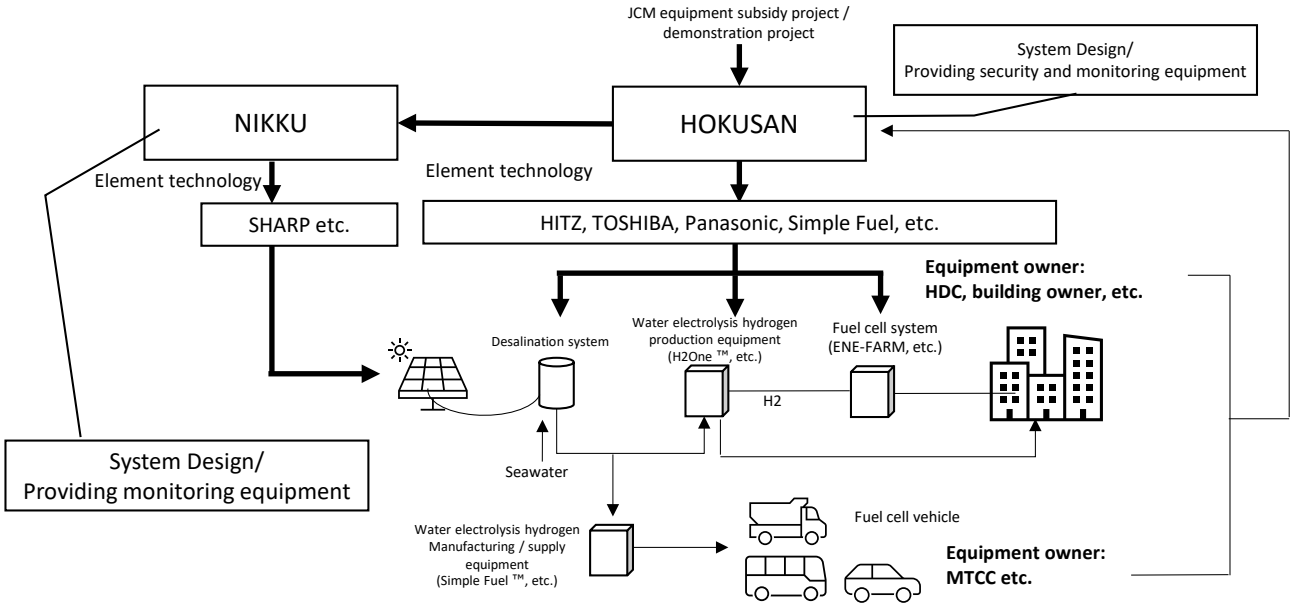


Figure 3-37 Schematic diagram of the structure for implementing the hydrogen distribution project

b) Use of natural gas

Regardin the use of natural gas, we will consider collaboration if the Maldivian government constructs the supply infrastructure as mentioned above. When establishing the LNG infrastructure, the government plans to build a new LNG thermal power plant. However, we were informed that the existing diesel power plant would continue to be used to cope with power load fluctuations. Therefore, we will consider adopting co-combustion technology through supplying natural gas to the existing diesel power plant from the storage facility via a pipeline and in the form of CNG and using DF and gas operation technologies.

This project will be implemented through an international consortium between Hokushi Co., Ltd., an energy company in Toyama City, as the representative company, and STELCO, a national electric power company that owns and operates a diesel power plant in the Malé metropolitan area, as a local company.

It is assumed that Indian companies will invest in the gas supply infrastructure. Since the key to establishing this project is the stable gas supply, we will also consider strengthening the project's foundation by inviting companies responsible for the gas supply chain to the international consortium as needed.

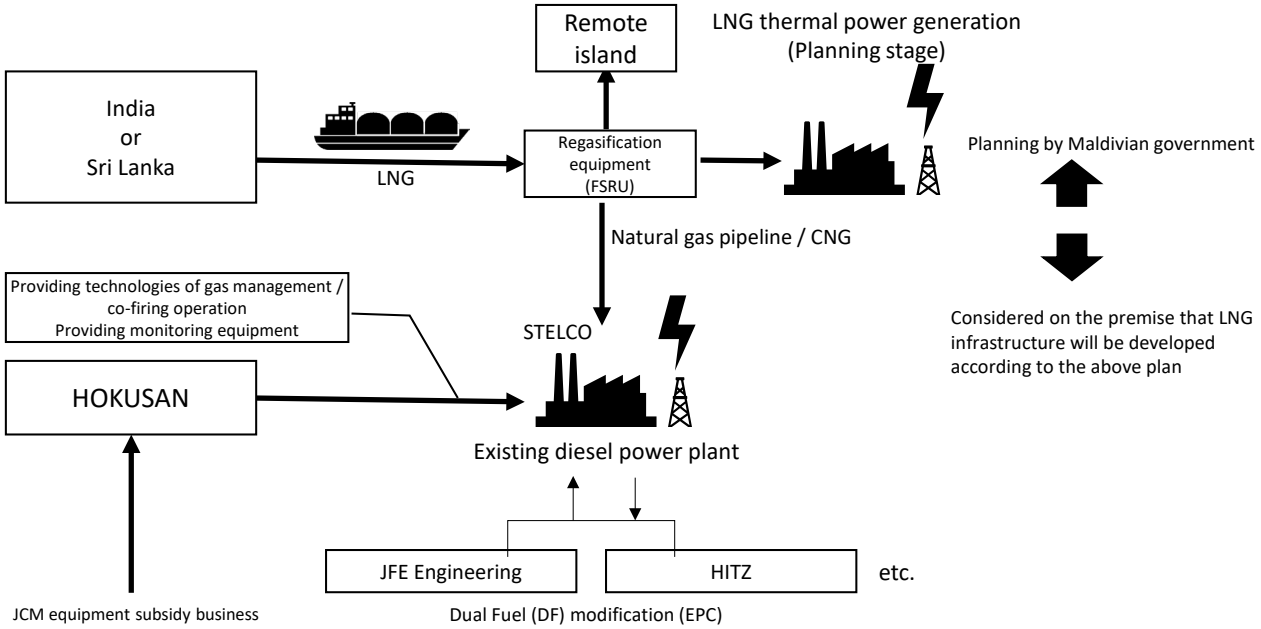


Figure 3-38 Schematic diagram of the system for implementing the natural gas project

3.3. Renewable energy popularization field

Regarding the feasibility of renewable energy in the Maldives, it has great potential for solar power generation due to its abundant amount of solar radiation. Thus, the utilization and popularization of solar power generation are already in progress. In particular, island resorts proactively use renewable energy, as they target environmentally conscious Western customers, and they are not only focusing on conserving marine life, which is a tourism resource, but also increasing their consideration of other environmental aspects such as waste and energy. In this survey, we aimed to receive business inquiries from multiple resort islands in the Malé metropolitan area for adopting solar power generation, and based on interviews with resort owners, we attempted to create a project.

3.3.1. BISON's Malé Atoll resort development

Regarding the launch of renewable energy business in the Maldives, renewable energy generation is already widespread in the Maldives, so we inferred that a certain number of businesses in Maldives are in charge of such industry. Thus, we assumed it would be easier to develop the project by cooperating with these businesses. Hence, we looked for renewable energy companies. As a result, we were able to get in touch with Renewable Energy Maldives, a company that has experience in executing international support projects. As a renewable energy developer, the company has established solar power generation projects throughout the Maldives.

After several online meetings, we reached an understanding and a cooperation agreement with the City-to-city Collaboration Program, and potential projects were introduced. One of them is a resort development project by BISON, a Maldivian construction company.

BISON plans to create a resort in the northwestern part of the Malé metropolitan area and manage it as part of its business. The company's vision is to supply most of the electric power with renewable energy, centering on the seawater desalination plants, which are facilities with a particularly high power load.

Hitachi Zosen Corporation, which strives to receive orders for waste power generation, etc., was considering distributing its seawater desalination facilities, one of its technologies, in the Maldives. Accordingly, BISON discussed the installation of an integrated system, a facility that supplies water using renewable energy, in cooperation with Hitachi Zosen Corporation.

Based on information such as the number of rooms and the resort area in BISON's resort development plan, a system with a seawater desalination volume of 1,000 m^3/day and required electric energy of 1,209 kWp was designed.

The RO system, which is part of the water production facilities, is distorted when power is lost and pressure is reduced, which adversely affects the system. Thus, it is necessary to install a diesel power generator as a backup power source or a battery that meets the power demand so that pressure is always applied.

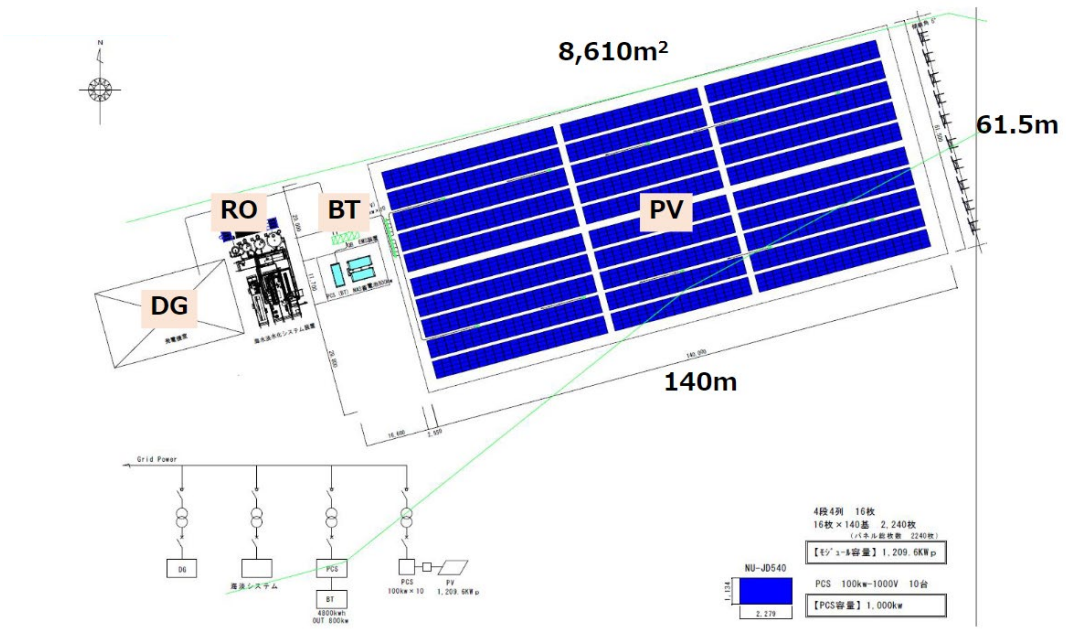


Figure 3-39 Layout of solar power generation equipment for resorts for BISON

Source: Nihon Kucho Hokuriku

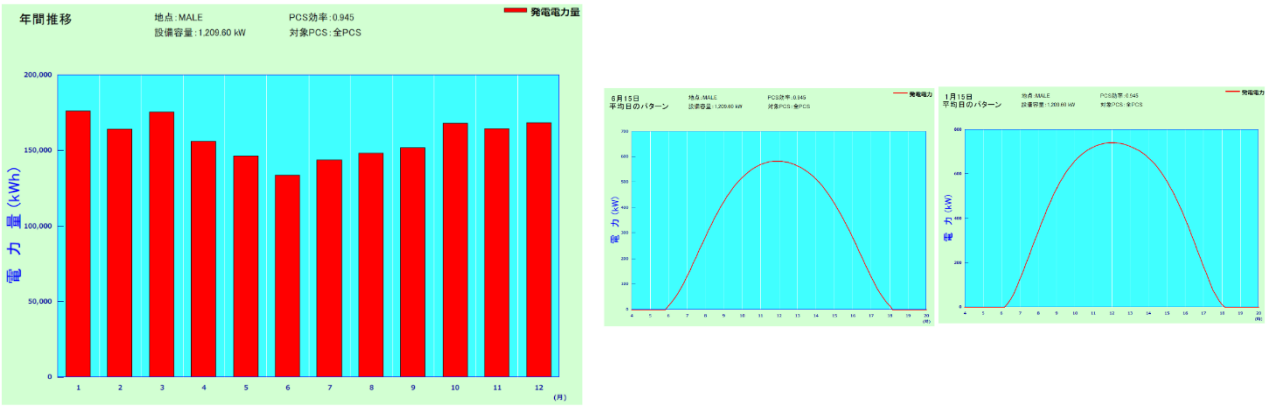


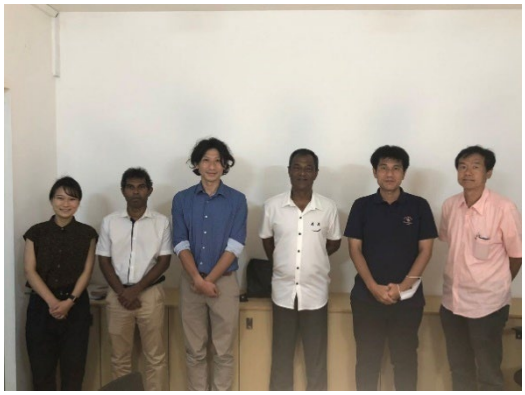
Figure 3-40 Estimated variation in power output in the resort

Source: Nihon Kucho Hokuriku

Based on the results of these basic investigations, we have exchanged information to discuss the details of the business policy.

We found out that BISON had difficulty raising funds due to the deterioration of loan conditions at the Central Bank of Sri Lanka, which was their financer, due to the spread of the novel coronavirus. BISON reported that they were in the process of considering other financers, such as the Bank of Singapore, and that they would reconsider the matter as soon as they establish some prospects regarding the financing issue.

As of February 2023, they still cannot see any progress in fund raising. Considering the loan situation, we will start discussions.



Office of BISON　　Photo of the staff

Figure 3-41　Scene of exchange of opinions with BISON

Based on the BISON case, you can calculate the simple CO_2 emission reduction amount and cost-effectiveness as below.

The amount of solar power generation with an installed capacity of 1,209 kWp is estimated to be about 1,695,000 kWh based on the fact that the power generation efficiency was about 16% according to the power generation estimate calculated in Malé in the previous fiscal year.

Assuming that diesel power generation is used and referring to Malé's grid factor, which is 0.533 t-CO_2/MWh, the following formula obtaines the reference emissions of about 900 t-CO_2/year.

Power generated (year) x Grid emission factor = CO_2 emissions
1,695,000 kWh/year x 0.533 t-CO_2/MWh/1000 (unit adjustment) = 900 t-CO_2/year

The CO_2 emission reduction means that the solar power generation would make up for 900 t-CO_2/year of the diesel power generation equipment's emissions. Regarding the useful life of the equipment, based on the Ministerial Ordinance concerning the Useful Life, etc. of Depreciable Assets (Finance Ministry Ordinance No.15 in 1965), as the solar power generation facility would solely be used to produce energy for the seawater desalination plant, it falls under the category of water supply and drainage, sanitary equipment and gas equipment that is considered affiliated buildings. Thus, the useful life of the solar power generation facility is estimated to be 15 years.

Therefore, the amount of CO_2 emission reduction during the project period will be 13,500 t-CO_2.

Since this is the second solar power generation facility in the Maldives, a subsidy of 40% of the total project cost or cost-effectiveness at 4,000 yen/t-CO_2, whichever is lower, will be applied.

Since the project cost is an issue to be discussed, we will examine the subsidy impact based on cost-effectiveness. Multiplying the previously mentioned reduction effect of 13,500 t-CO_2 by 4,000 yen will result in 54 million yen. If this amount is 40% or less of the project cost, it will be the subsidy's upper limit.

When the cost of only solar panels is considered, the installation cost of the 1,145 kW solar system, which was investigated for the roof-mounted solar power system in Malé in the previous fiscal year's

survey, is of a similar scale and can be used as a reference. The installation cost was about 1.3 million US dollars (about 150 million yen) in that survey. Thus, it is expected that the BISON business will have a sufficient subsidy if the equipment cost is close.

3.3.2. Crossroads Island Resort

The Crossroads Island is a resort located 8 km south of the Malé Island and is developed and managed by Thailand's Singha Group. The resort has a Hard Rock hotel (198 rooms) and a Hilton hotel (174 rooms) and plans to expand to the surrounding three islands.

The resort uses diesel power generation equipment to generate electric power. However, considering the market needs, the group is considering transforming the resort into an eco-resort in the future. The resort also plans to use renewable energy, and they were attracted to the idea of using it combined with the seawater desalination facilities to supply water.

Currently, the resort's demand for water supply is 500 m^3/day. Although there are some issues regarding the location of the solar power and storage batteries, we agreed to pursue further discussions and exchange information on the matter.

Seawater desalination equipment (RO)

Intake

Figure 3-42 Equipment in the Crossroads Island

3.3.3. Solar power generation at a seafood processing factory

We had an opportunity to have a meeting with Ensis Fisheries, which processes seafood in Hulhumalé, and stirred their interest in adopting solar power generation.

Ensis Fisheries consumes energy for pumps, lighting, air-conditioning, etc. when processing tuna and other seafood. The consumption in 2022 was 11,667MWh.

Figure 3-43 Inside and appearance of the factory of Ensis Fisheries

Figure 3-44 Location of Ensis Fisheries

Ensis Fisheries is planning to adopt more inexpensive and low-carbon power sources, and got interested in the project of solar power generation utilizing the JCM equipment subsidy.

We were able to obtain data on energy consumption from that company. Based on the data, we discussed power output and economical performance.

The area of land where solar panels can be installed is about 6,630 m^2. Considering the surveys and discussions in the past fiscal years, about 1,700 solar panels (440 W) can be installed. Their capacity would be 684 kW.

The following shows the results of simulation using the amount of solar radiation, air temperature, etc. in Malé.

Table 3-9　Estimated annual output

月	日積算日射量 [KWh/㎡/日]	気温	Kpt	発電量 日発電量 [kwh/日]	月当たり日数 [日/月]	月発電量 [kwh/月]
1月	6.3	27.7	0.907	3322.2	31	102,988
2月	6.7	28	0.907	3533.1	28	98,927
3月	6.5	28.5	0.907	3427.6	31	106,257
4月	6	29	0.908	3167.5	30	95,024
5月	5.3	28.7	0.908	2797.9	31	86,736
6月	5	28.2	0.912	2651.2	30	79,536
7月	5.2	28.1	0.913	2760.3	31	85,568
8月	5.4	27.9	0.913	2866.4	31	88,859
9月	5.7	27.7	0.913	3025.7	30	90,770
10月	6.1	27.8	0.907	3216.7	31	99,718
11月	6.1	27.7	0.907	3216.7	30	96,501
12月	5.9	27.6	0.907	3111.2	31	96,449
平均	5.85	28.1	合計		365	1,127,332
年間発電量		1,127,332				kWh/年

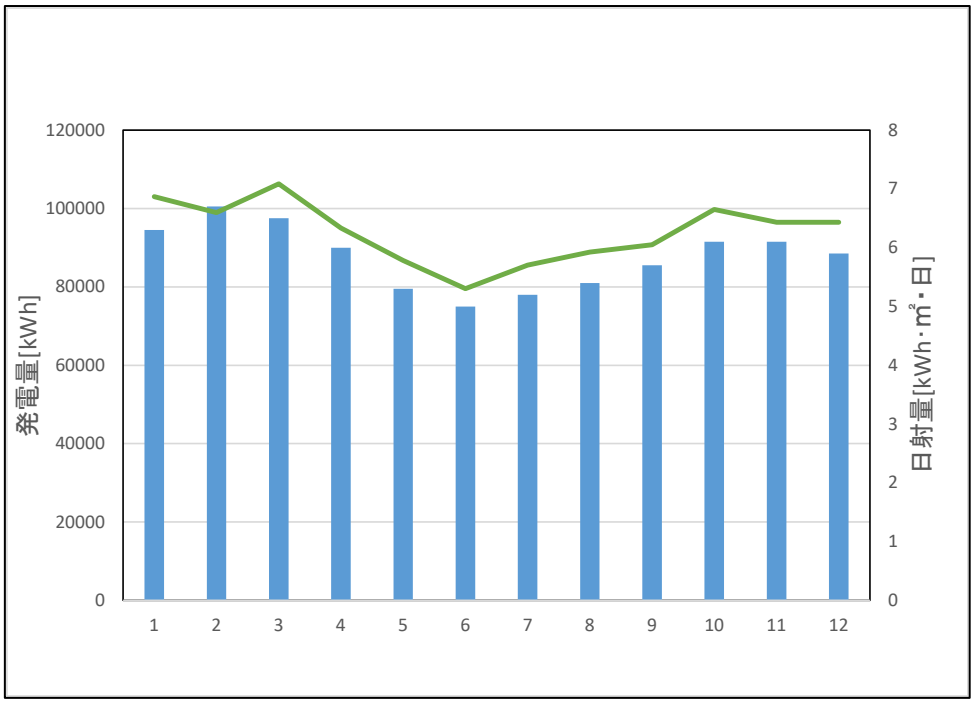


Figure 3-45　Variation in output

The grid emission factor in the Maldives is 0.533 t-CO_2/MWh, so the reference emissions obtained with the following formula is about 600 t-CO_2/year.

Power generated (year) × Grid emission factor = CO_2 emissions
1,127,332 kWh/year × 0.533 t-CO_2/MWh/1000 (unit adjustment) = 600.868 t-CO_2/year

Regarding the useful life of the equipment, it falls under solar power generation equipment, according to the Ministerial Ordinance concerning the Useful Life, etc. of Depreciable Assets (Finance Ministry Ordinance No.15 in 1965), so its useful life is 17 years.

Accordingly, the reduction amount of CO_2 emissions during the project period is 10,214.76 t-CO_2.

Since this is the second or later solar power generation facility in the Maldives, a subsidy of 40% of the total project cost or cost-effectiveness at 4,000 yen/t-CO_2, whichever is lower, will be applied.

Since the project cost is an issue to be discussed, we will examine the subsidy impact based on cost-effectiveness. Multiplying the previously mentioned reduction effect of 10,214.76 t-CO_2 by 4,000 yen will result in about 40 million yen. If this amount is 40% or less of the project cost, it will be the subsidy's upper limit.

For Ensis Fisheries, we will consider giving a proposal for energy saving at factory equipment that would stir up their interest in the JCM program.

3.3.4. Possibility of introducing solar energy generation to the local islands in the Malé metropolitan area

The seawater desalination plants at resort islands have a significant power load. Thus, as mentioned above, we have been considering the adoption of solar power generation at resorts in collaboration with Hitachi Zosen Corporation, which has RO water production equipment and technology. On the other hand, there are cases where local islands primarily use seawater desalination equipment as their water source. Hence, we assumed that these islands would have similar needs.

In addition, as the Maldives has a one-island-one-resort policy, tourists could not visit or stay in the local islands in principle. However, easing regulations has made it possible to accept tourists in the local islands in recent years, and the development of guest houses is in progress.

In the Thulusdhoo Island, which is located in the suburbs of the Malé metropolitan area, residents are aggressively constructing guest houses and developing resorts. The island is also famous as a surfing spot, and a factory of Coca-Cola Company is located there. It is a 30-minute speedboat ride from Malé and is home to 250 households, and has a population of 1,750. The guesthouses have 200 rooms and can accommodate up to 400 tourists, and they are expected to expand further.

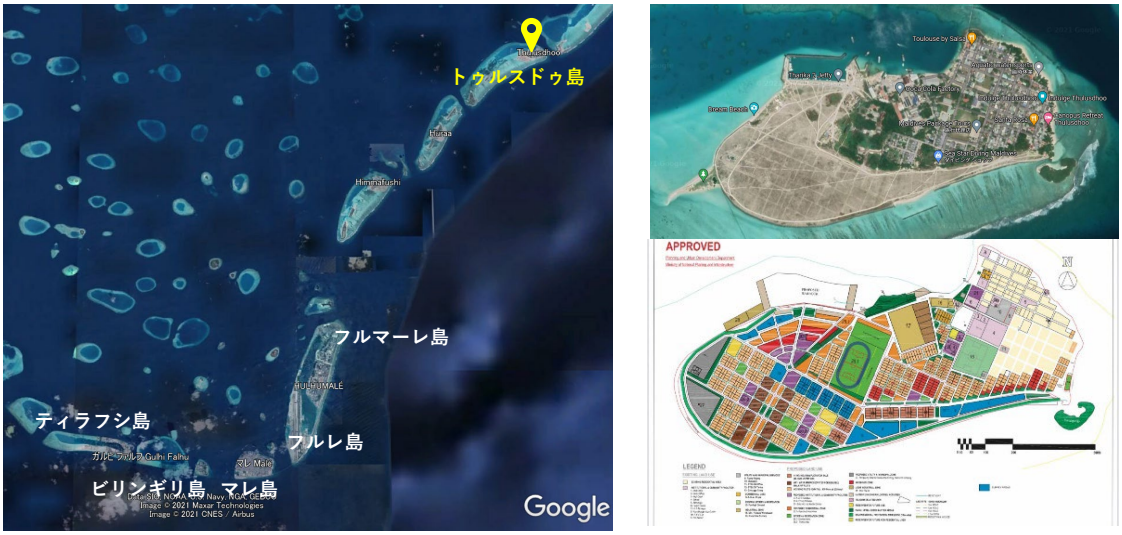


Figure 3-46　Location of the Thulusdhoo Island

In addition to the severe coastal erosion and the progress of land reclamation, the island council (the island's government) is considering a land-use plan that includes the use of the reclaimed land.

The water demand in the Thulusdhoo Island is estimated to be up to 100 m^3/day based on the information of the island council that the guest houses have 200 rooms (two beds per room) and water consumption per tourist is 250 L/day. In addition, there are 250 households with about seven people per household and water consumption per person is 150 L/day. Therefore, their demand is about 260 m^3/day, which makes the adequate amount of water to be produced about 500 m^3/day.

Currently, the island does not have a water production facility, and the only way to acquire water is to purchase bottled water from Malé or Coca-Cola, but the cost is high. The island council owns the facilities and considers supplying water to the residents and guest houses. Since we had the opportunity to propose using solar power generation along with these facilities, we decided to investigate the matter while taking into account the local situation and the land use plan.

On the other hand, the island was damaged by the tsunami caused by the 2004 Sumatra earthquake, and ADB and others provided reconstruction assistance, and seawater desalination facilities and sewage treatment facilities were constructed. However, these are not currently in operation because maintenance and parts replacement were not performed properly. Thus, we believe it is necessary to consider operation and management systems for solar power generation or operate them by the PPA method.

Sewage treatment plant provided through reconstruction assistance	Seawater desalination facility provided through reconstruction assistance

Figure 3-47 Equipment in the Thulusdhoo Island

3.3.5. Project implementation system and estimation of CO_2 emissions reduction

As a result of examining the implementation system for each candidate project based on the project inquired about by BISON, we expect that Nihonkucho Hokuriku would procure the panels and collaborate with Renewable Energy Maldives, a local solar system construction company we are cooperating with, to introduce a solar power generation system. In addition, Hitachi Zosen Corporation would be responsible for installing the seawater desalination equipment that would use the power generated by the solar power generation system, and BISON, the resort owner, would be the off-taker.

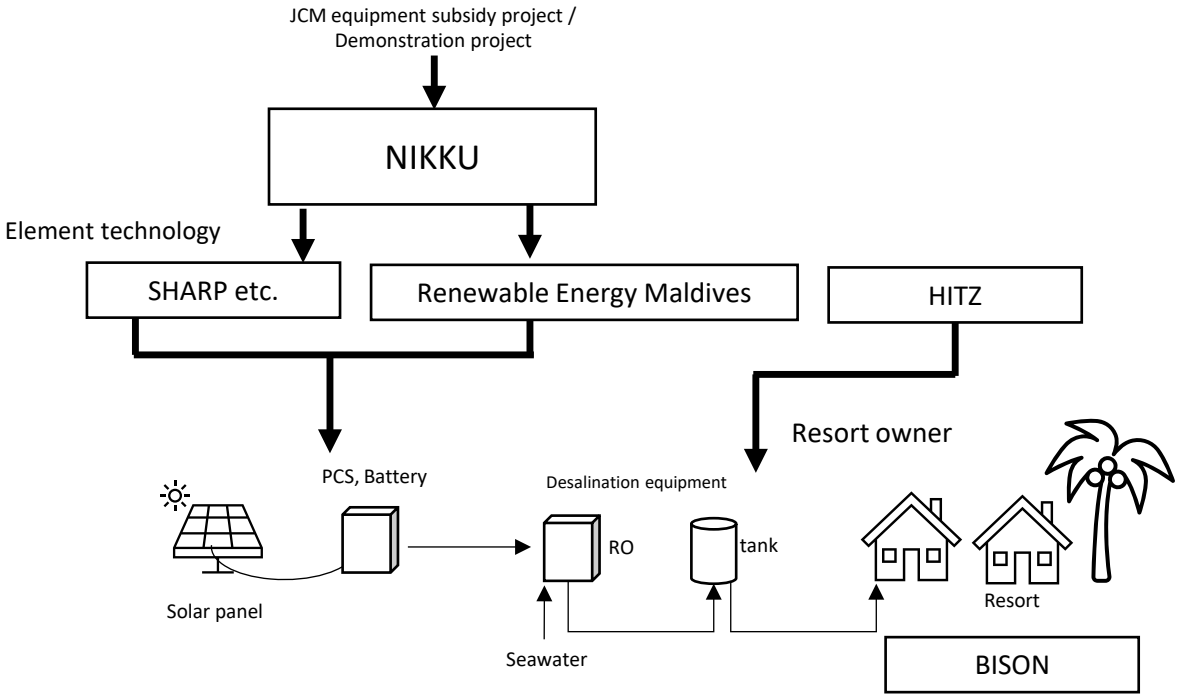


Figure 3-48 Envisioned project for installing a solar power generation system for resorts

Regarding the project type, it may be necessary to consider a PPA mentioned above or the like. From the viewpoint of monitoring, which is required when considering applying for the JCM (Joint Crediting Mechanism) equipment subsidy project, a business that includes equipment operation and management is suitable. Thus, we will consider establishing the operation and management system while comprehensively examining and evaluating the risks in overseas business.

3.4. Field of recycling of organic waste

Waste is a major environmental issue in the Maldives and the Malé metropolitan area. Since it is an island country, the dumpsites are limited, and waste is not disposed of properly. Therefore, there are concerns regarding the capacity of the dumpsites as well as the impact of the pollution resulting from harmful substances and plastics on the ocean.

Organic waste in the Malé metropolitan area is finally disposed of unsorted with other waste on the nearby waste dumpsite in the Thilafushi Island. Although there is a plan to install a waste-to-energy plant at the dumpsite, organic waste has high water content and may adversely affect the efficiency of power generation from waste. Thus, it is excluded, and its disposal method is undecided.

These organic wastes are resources that can be used for energy and composting using the methane fermentation process. Hence, recycling can contribute to solving the waste problems and achieving a low-carbon society. In the previous fiscal year's project, we examined the feasibility of the methane fermentation process and considered the current compost's import value. Our survey has shown that the methane fermentation process would be cost-effective even with the cost of the installation of the fermentation equipment. On the other hand, since methane fermentation equipment requires specialized knowledge to guarantee its stable operation, the Maldives faces some issues regarding operating as it has few engineers. In addition, we received some information that when the former Ambassador of Japan to the Maldives, Mr. Yanai, exchanged opinions with the Maldivian Minister of the Environment, Mr. Aminath Shauna, he expressed high interest in composting organic waste and that he wants to "adopt automatic composting machines that are not labor-intensive." Therefore, this year, we focused on the composting of organic waste and examined the possibility of adopting it.

3.4.1. Gathering of information on waste management in Malé City

(1) Waste management situation

The Master Plan for Handling Waste in the Malé Metropolitan Area divided the Maldives into waste management zones, and the Malé Metropolitan Area is classified as Zone 3. Zone 3 consists of 32 inhabited islands and 86 tourist resort islands (population: 295,000, accounting for 53% of the Maldives' total population). Zone 3 covers Kaafu Atoll, including the Greater Malé region, Vaavu Atoll to its south, and Alif Alif Atoll and Alif Dhaal Atoll in the west. Generally, each island stores unsorted waste at the waste collection point on the island and then ships to the Thilafushi Island. However, since there are no established shipping and storage systems or rules, it has become the norm in many local islands to dump the waste into the ocean and on the island or burn it in open fields to reduce its volume. Resorts are primarily obliged to dispose of waste properly on the islands. Nonetheless, there are cases where they are dependent on shipping them to the Thilafushi Island due to problems with disposal equipment and processing costs.

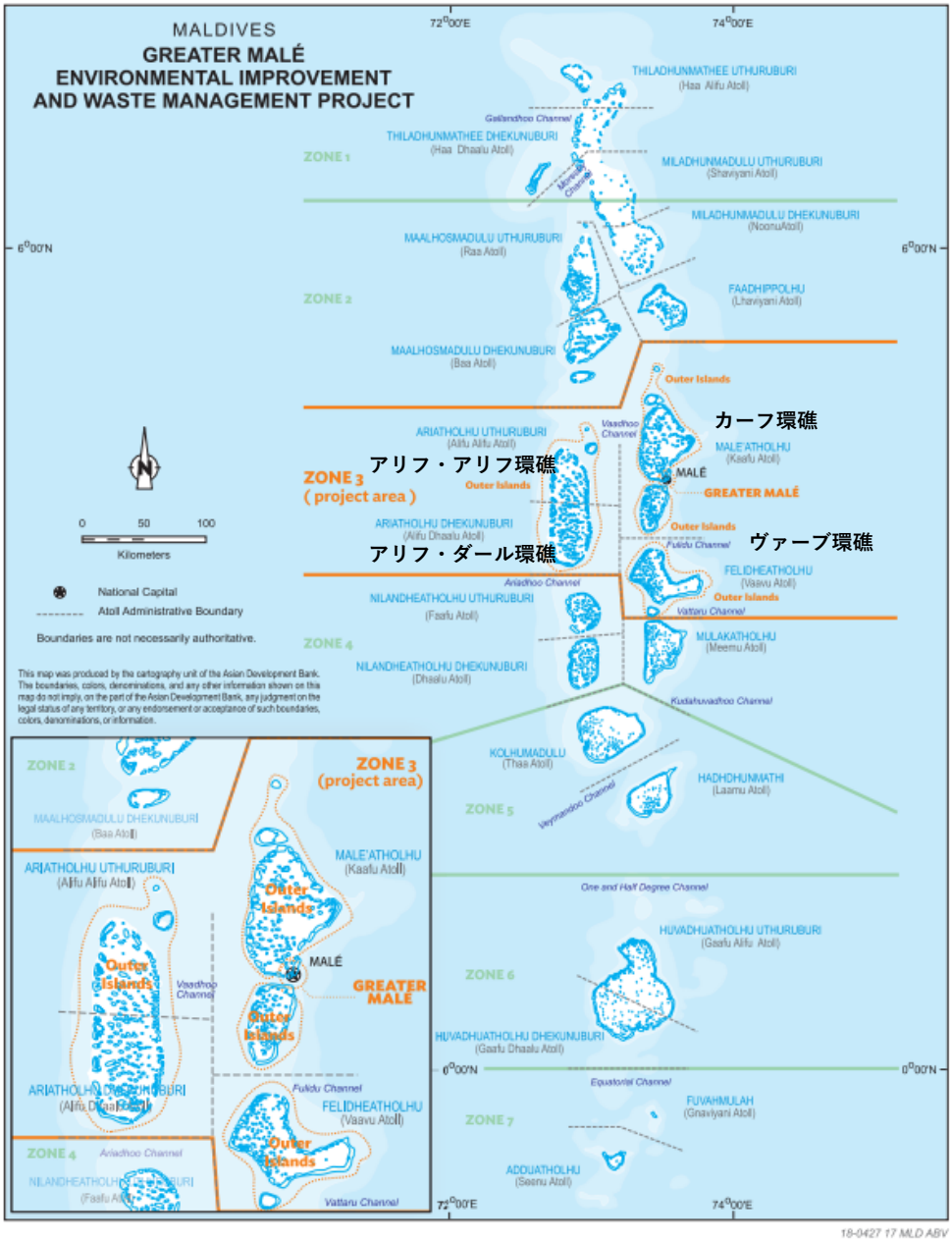


Figure 3-49　The Maldives and Waste Management Zone 3[31]

(2) Examples of waste management

When we conducted the field study from October 26th to November 9th, 2021, we investigated the waste management conditions of each island. The study results are as follows.

a) Malé Island (urban area)

The Malé Island is the most populous and has the largest amount of household waste in the entire

[31] Asian development Bank "Proposed Grant and Technical Assistance Grant and Administration of Grant Republic of Maldives: Greater Malé Environmental Improvement and Waste Management Project," Project Number: 51077-002 June 2018.
https://www.adb.org/sites/default/files/project-documents/51077/51077-002-rrp-en.pdf

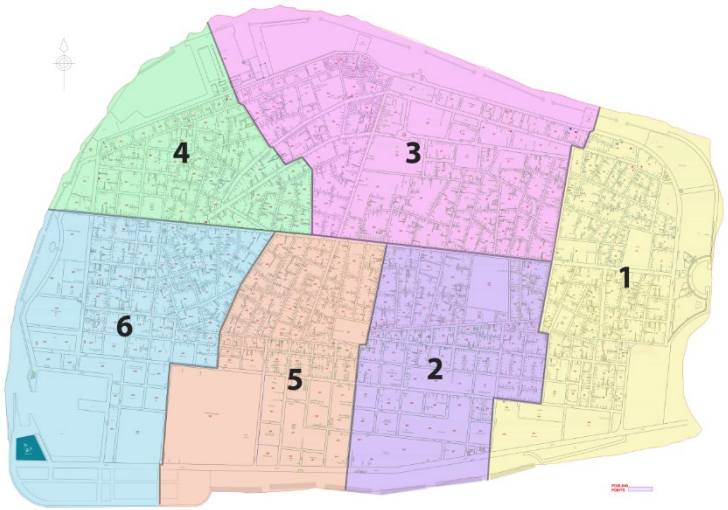
Maldives. Furthermore, as the population has grown, enlargements, renovations, etc. of buildings have increased, leading to construction waste being left scattered. Thus, this island is one of the Maldives islands that should urgently take waste management measures.

Based on the World Bank's estimate (amount of waste generated: 1.8 kg/person/day in the urban area) and the Malé population estimate (as of 2014), it is estimated that approximately 229 t/day of waste is generated. This figure accounts for nearly 40% of the total amount of waste generated in the Maldives.

The Waste Management Corporation (WAMCO) was established in the Maldives in 2009 to handle waste management properly. Since 2016, WAMCO has been in charge of collecting waste from households on the Malé Island, the Hulhumalé Island, and the Villingili Island. Initially, the company collected garbage from each household. However, due to the spread of the novel coronavirus, they switched to collecting garbage from collection points outside as an infection control measure. They plan to set up a garbage station in each district in the future, and they are considering sorting garbage into dry and wet ones from June 2022.

Garbage piled up

Scene of garbage collection



Map of garbage collection points in Malé

Figure 3-50 Situation in the Malé Island

b) Hulhumalé Island (urban area)

As mentioned above, the Hulhumalé Island was artificially created to meet the housing needs that arose due to the population growth and the overcrowding of the Malé Island and prepare for the land's disappearance due to coastal erosion as a result of climate change. Currently, it has the second-largest population after the Malé Island, and it is expected that 240,000 people will migrate to there in the future due to the promotion of further migration from Malé.

The development of the Hulhumalé Island consists of Phase 1 and Phase 2. As of 2021, Phase 1 has been completed and it is now home to approximately 60,000 to 65,000 people. Condominiums have been completed in Phase 2 as well, and migration is in progress.

Based on the World Bank's estimate (amount of waste generated: 1.8 kg/person/day in the urban area) and the population estimate as of 2014, it is estimated that 28 t/day of waste is generated. If 240,000 people migrate to the island as planned, the amount of waste generated will be 432 t/day. Since it is expected that the amount of waste will increase in direct proportion to the population, it is necessary to put in mind the future population when considering waste collection, transportation, and storage systems and infrastructure.

Garbage piled up

Scene of garbage collection

Phase 1 Phase 2

Figure 3-51 Situation in the Hulhumalé Island

c) Thulusdhoo Island (local island)

As described in Chapter 3.3.4, the Thulusdhoo Island, located about 30 minutes by speedboat from the Malé Island, is a local island with a population of 1,750 people and 250 households. It has guesthouses, being a tourist island. The 200-room guesthouses can accommodate up to 400 tourists and have problems with securing water for daily use and disposing of waste.

Based on the World Bank's estimates (amount of waste generated: 0.8 kg/person/day in local islands), it is estimated that the residents generate 1.4 t/day of waste. Furthermore, assuming that the amount of waste generated from the guesthouses is equivalent to the amount of waste generated on the resort island estimated by the World Bank (3.5 kg/person/day), 1.4 t/day of waste will be generated if the guesthouses accommodate 400 tourists.

According to an interview with the island councilors, waste is sorted into wet and dry waste. Previously, a composting facility was installed to treat organic waste, but the project was canceled, and now the waste is dumped into the ocean after collection. The composting equipment will be installed again in the near future to improve the situation. Regarding the dry waste, there is no waste collection system, and the island residents themselves collect and dump it at the collection point which results in the waste piling up there. After being brought in, it is burned in an open field when it reaches a certain height to reduce its bulk.

Satellite image
(Source: Google Map)

Land use plan

Dumping site

Central area

Figure 3-52 Situation in the Thulusdhoo Island

d) Resort Islands (Crossroads Island and Reethi Faru Island)

The Maldives succeeded with its one-island-one-resort concept, and tourism has become a major industry along with fishing. Tourism accounts for 26% of GDP directly and 70% indirectly[32].

Currently, there are 145 tourist resorts in the Maldives, and their waste management is under the jurisdiction of the Ministry of Tourism. "Regulations on Environmental Protection and Conservation in the Tourism Industry" require all resort islands to dispose of waste in a way that has the least impact on the environment. However, in reality, due to the inadequate infrastructure and the lack of monitoring, waste is not properly handled in many cases.

To understand the actual situation, we investigated the situation of waste treatment in the Crossroads Island, which was mentioned as one of the potential sites for solar power generation in Chapter 3.3.2. According to the interview with the resort owner, the resort installed a small incinerator and composting equipment to achieve zero waste. However, it broke down and had not been operating properly as of October 2021. As shown in the lower-left figure, most of the garbage piled up unsorted due to the measures against the novel coronavirus and the malfunction of the small incinerator. The waste is not treated on the island and is transported to the Thilafushi Island.

Situation of waste disposal　　View of the resort

Figure 3-53　Situation in the Crossroads Island

In addition, we investigated the actual situation of waste treatment at Reethi Faru Resort, located in the northern Raa Atoll, which was introduced as an environmentally friendly resort in Chapter 3.3.3. As described in Chapter 3.3.3., this resort is an eco-friendly resort with the theme of bio-luxury. We were able to conduct our study through the introduction of former Ambassador Yanai of the Japanese Embassy in the Maldives.

During our visit to the resort, we have noticed some eco-friendly measures such as providing drinking water in glass bottles and eliminating disposable plastics as much as possible at guest rooms. Regarding organic waste, it is treated in a methane fermentation facility, and the generated methane

[32] Government of Maldives and UNDP Sign 'Re-imagining Tourism' Project | UNDP in Maldives

gas is used directly for cooking. Regarding the fermentation residue, it is used as liquid fertilizer. On the other hand, waste (plastic, etc.) that cannot be treated on the island is transported to the Thilafushi Island, which is about 155 km away. Therefore, the resort faces a problem with disposing of packaging materials such as styrofoam, which is indispensable for transporting food.

Segregation in kitchen (Segregaed into food waste, paper and plastic, metal and glass)

Methane fermentation facility

Solar panel

Disposable plastic-free amenities

Figure 3-54 Situation in Reethi Faru

As mentioned above, some resort governments are working on waste treatment and resources recycling on resort islands, by using methane fermentation equipment and composting equipment for organic waste, but there are still problems with waste treatment. In addition, such resorts are only a few. The reality is that most of the resort governments dispose of waste by transporting and dumping it at waste islands such as the Thilafushi Island or into the ocean.

(3) Waste Management Plan

a) Legal system related to waste

The law governing environmental protection in the Maldives is the Environmental Protection and Preservation Act (EPPA) enforced in 1993 (Act No. 4/93), which sets out principles for maintaining and expanding the environmental benefits of the Maldives, including waste management. The law authorizes the Ministry of the Environment to develop regulations and policies for environmental protection and conservation. Section 7 of the Act provides regulations for waste disposal and management of petroleum and toxic substances, while Section 8 provides regulations for the management of hazardous/toxic or nuclear waste and sets out waste management policies.

The National Solid Waste Management Policy was formulated in 2008 by the Environmental Research Centre of the then Ministry of Environment and Energy (now EPA) with the support of the

United Nations Development Programme (UNDP) and was subsequently revised in 2015. The policy begins with an analysis of the current state of waste management, which clarified the lack of a national approach to waste management in the Maldives and inequities in governance and resources, both in terms of capacity and infrastructure. The lack of leadership on waste management is also a challenge, as there is no clear role or responsibility for waste management not only at the national level, but also at the regional, atoll and island levels. In addition to a lack of awareness of the waste problem, there are no provisions on incentives or punitive measures to encourage active waste management.

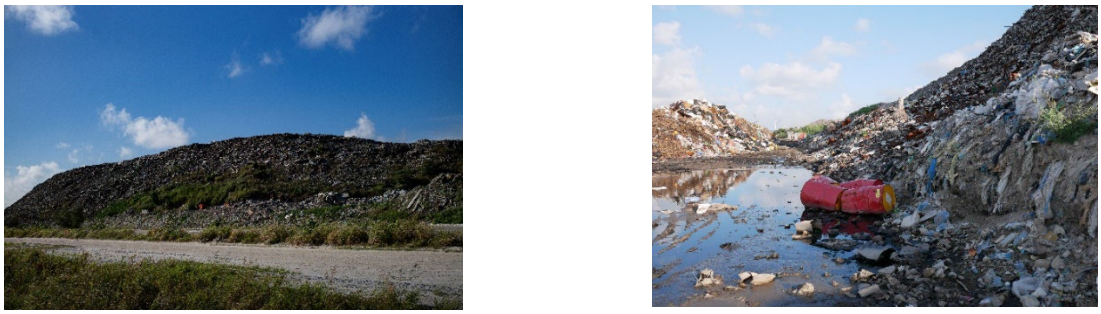
In addition, the Strategy Action Plan states that the goals for waste to be achieved by 2023 include "selection of cost-effective technologies to generate profit from waste which are appropriate for the situation in the Maldives" and "evaluation of the mechanism by which waste-derived fuel is generated." Specifically, the following policies, strategies, and actions have been presented.

Policy 1: To promote the use of waste as a valuable source of revenue generation

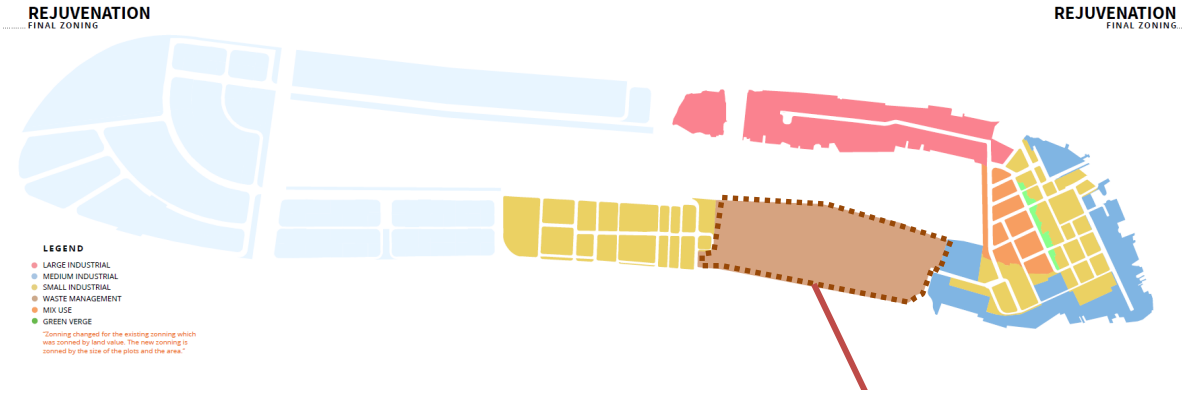
- Strategy 1.3: To establish a mechanism for the collection, storage and management of waste at the island level
  - ✧ Action 1.3f: To provide guidance to the Island Council to integrate waste collection as part of the government's integrated utility service offering
- Strategy 1.4: To strengthen waste collection and management in the Greater Malé region
  - ✧ Action 1.4a: To develop a scheme for separating household waste
- Strategy 1.5: To strengthen waste management through evidence-based policies
  - ✧ Action 1.5a: To conduct comprehensive waste assessment on all islands to identify the volume of various waste flows and set reduction targets
- Strategy 1.7: To expand and implement the conversion of waste into energy and expand efforts in local communities to convert waste into resources
  - ✧ Action 1.7a: To conduct research to identify cost-effective technologies to generate profit from waste which are appropriate for the situation in the Maldives.

b) Future Waste Management Plan

The construction of the final disposal site on the Thilafushi Island began in 1992, but it has been in a state of open dumping as no pollution control measures have been implemented since the beginning, leading to serious public health and environmental impacts. Smoke from spontaneous combustion causes air pollution, and uncontrolled waste leachate may lead to marine environmental pollution.



Final disposal site on the Thilafushi Island



Waste management area

Master plan of development of the Thilafushi Island
Source: Reference material provided by the HDC

Figure 3-55 Situation in the Thilafushi Island

In light of this situation, in order to optimize the disposal of 836 t/day of waste generated in Zone 3 and to promote energy use as well as waste disposal, the ADB agreed with the Maldivian government in August 2020 regarding waste disposal optimization and infrastructure development, to conduct the stepwise development of waste power generation infrastructure by combining it with the following four initiatives.[33]

(i) Improvement in the venous chain for solid waste, including collection and waste container transportation
(ii) Implementation of temporary measures, such as the storage of urban solid waste, as an interim solution to stop the illegal dumping and incineration in the Thilafushi Island until a modern solid waste treatment and disposal facility becomes operational
(iii) Collection and treatment of construction and demolition waste
(iv) Strengthening institutional capacity and public awareness to provide sustainable SWM services

The project has been approved as the "Greater Malé Waste-to-Energy Project" utilizing the Japan

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

Fund for the Joint Crediting Mechanism of the Asian Development Bank. The target is a waste power plant with a capacity of 500 t/day, and the expected emission reduction is about 40,417 t CO_2/year.

In this project, based on the above-mentioned waste power generation project, the target will be the organic waste in the Hulhumalé district. Due to the high water content of organic waste, the treatment of organic waste in the "Greater Malé Waste-to-Energy Project" planned for the Thilafushi Island may lead to a decrease in heat generated, resulting in a decrease in power generation efficiency or a resultant increase in fuel consumption.

At present, in the Malé metropolitan area, waste is not segregated at the source, and unsorted waste is being collected for household waste, business waste, commercial waste, etc. Waste segregation at the source is being planned in preparation for the start of operation of the waste power plant. The 5th amendment to the Waste Management Act was announced in August 2021, under which the sorting of waste into dry waste and wet waste, is scheduled to start. According to an interview with the Waste Management Corporation Limited (WAMCO), wet waste will mean organic waste such as food waste, and dry waste will mean all other types of waste. Sorting is scheduled to begin in June 2022, and full-scale waste management will begin when the waste power generation facility starts operation around 2025. In addition, in an interview with the Ministry of the Environment of the Maldives, we heard that waste generated after December 2021 would be disposed of at the waste power generation facility, and that it would be stored under a veil until the completion of the facility.

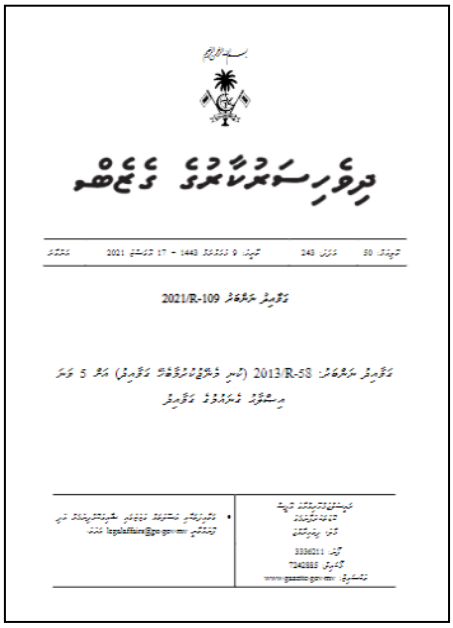


Figure 3-56　5th Amendment to the Waste Management Act (Cover)[34]

Under the current plan, only dry waste will be transported to the Thilafushi Island to be used as fuel for waste-to-energy generation. Dry garbage collected on the Thilafushi Island is sorted into

[34] 5th Amendment to Waste Management Regulation
https://www.environment.gov.mv/v2/en/download/12347

end-of-life vehicles (ELVs), construction waste, etc. by using sorting equipment installed on the island. As for plastic waste, PARLEY, which is an international NGO that aims to reduce marine waste worldwide, is discussing the collection and recycling of plastic waste. The company is working with Adidas and other companies to reduce plastic waste. In the Maldives, plastic bottle compression facilities have been installed on the Malé Island and the Thilafushi Island. In the future, the Maldives intend to install additional resource recovery bags at the sorting and collection site on the Thilafushi Island to promote the recovery of resources other than plastic bottles, and is also considering the construction of a new resource selection facility on the Thilafushi Island.

Wet waste, on the other hand, will not be transported to the Thilafushi Island, but will remain on the source island. There is no current plan for the treatment of wet waste or organic waste, and if no method of utilization is found, there is a concern that it may be dumped in the ocean and cause marine pollution with the plastics included in the waste.

There are also plans for sorting dry waste, but the movement toward recycling after sorting has not been integrated in the Maldives, and a domestic resource recycling model has yet to be drawn up.

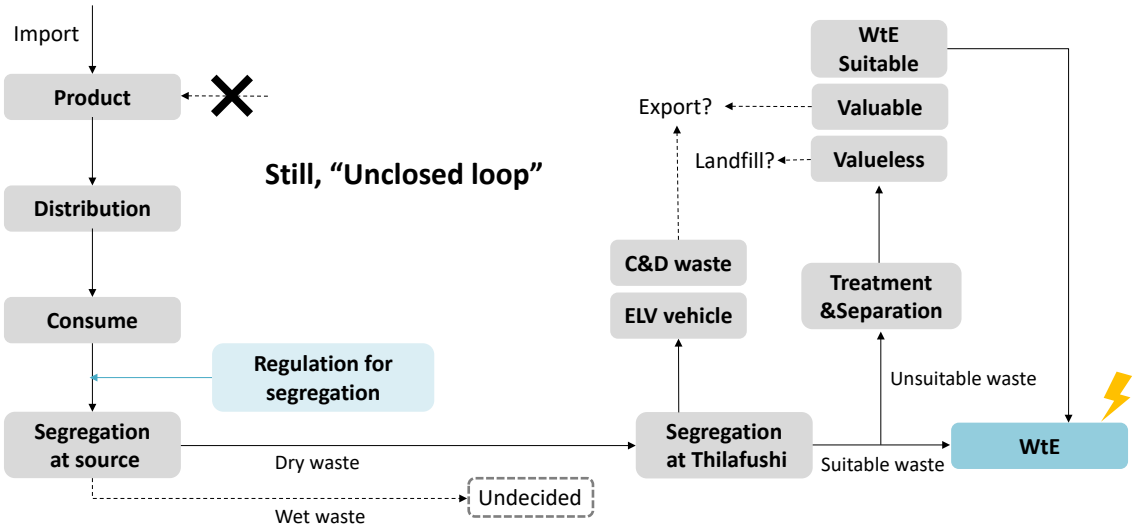


Figure 3-57 Planned waste flow

Source: Prepared by JAPAN NUS CO., LTD. with reference to a report of the Ministry of the Environment of the Maldives[36]

In recent years, the concept of "Circular Economy" has been proposed mainly in Europe. The circular economy is an approach that aims for sustainable economic growth by considering waste as a resource and making the most effective use of it. In Japan, the "Circular Economy Vision 2020[35]" includes a list of policies for a circular economy. In particular, in the Maldives, where almost all resources are imported from overseas, it is desirable to realize a circular economy that makes the most effective use of resources in the region. In the Maldives, a model can be devised in which waste

[35] METI: “Recycling Economy Vision 2020” 2020 (https://www.meti.go.jp/press/2020/05/20200522004/20200522004.html)

is collected on the Thilafushi Island, where a waste power plant is located, and resources are allocated to a waste power plant or a recycling facility after sorting.

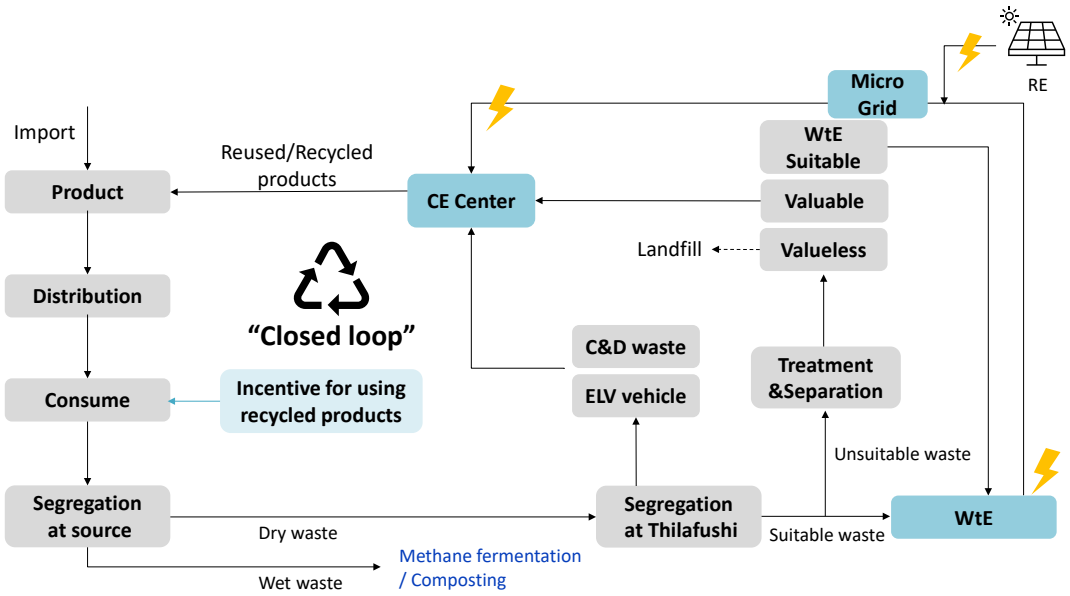
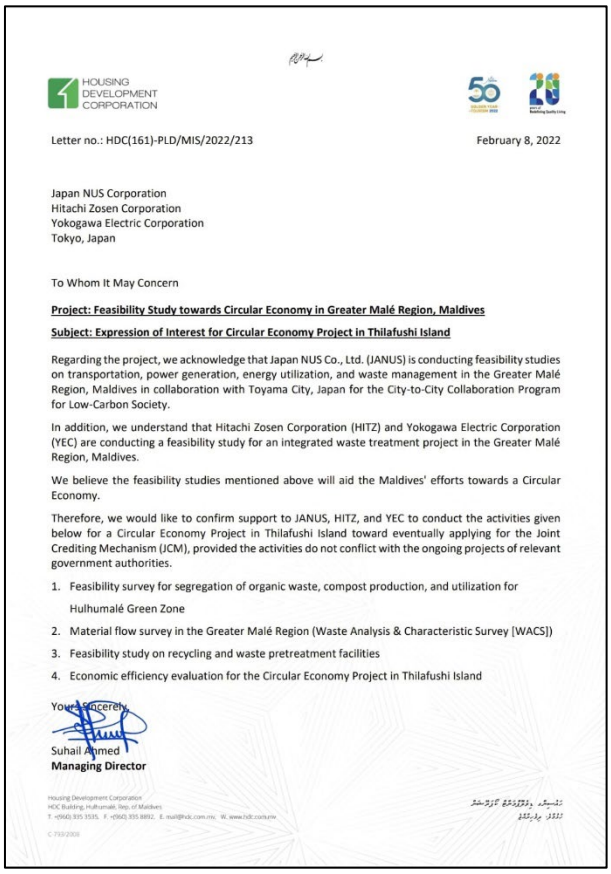


Figure 3-58 Waste flow for a circular economy

In this way, we proposed the concept of achieving a circular economy starting from the waste power plant on the Thilafushi Island to the HDC. Then, they showed great interest, and we received a letter from them expressing their interest in a feasibility study.

The recycling of organic waste under consideration in this project can be regarded as part of this circular economy concept. The Hulhumalé district needs compost to maintain roadside trees, parks and green space, and currently imports about $500,000 worth of compost annually from overseas. Imported compost could be replaced by the compost produced from domestic waste. The consideration of the material balance and economy is key to the feasibility study. The results of these studies are presented in the next section.



HOUSING DEVELOPMENT CORPORATION

Letter no.: HDC(161)-PLD/MIS/2022/213 February 8, 2022

Japan NUS Corporation
Hitachi Zosen Corporation
Yokogawa Electric Corporation
Tokyo, Japan

To Whom It May Concern

Project: Feasibility Study towards Circular Economy in Greater Malé Region, Maldives

Subject: Expression of Interest for Circular Economy Project in Thilafushi Island

Regarding the project, we acknowledge that Japan NUS Co., Ltd. (JANUS) is conducting feasibility studies on transportation, power generation, energy utilization, and waste management in the Greater Malé Region, Maldives in collaboration with Toyama City, Japan for the City-to-City Collaboration Program for Low-Carbon Society.

In addition, we understand that Hitachi Zosen Corporation (HITZ) and Yokogawa Electric Corporation (YEC) are conducting a feasibility study for an integrated waste treatment project in the Greater Malé Region, Maldives.

We believe the feasibility studies mentioned above will aid the Maldives' efforts towards a Circular Economy.

Therefore, we would like to confirm support to JANUS, HITZ, and YEC to conduct the activities given below for a Circular Economy Project in Thilafushi Island toward eventually applying for the Joint Crediting Mechanism (JCM), provided the activities do not conflict with the ongoing projects of relevant government authorities.

1. Feasibility survey for segregation of organic waste, compost production, and utilization for Hulhumalé Green Zone
2. Material flow survey in the Greater Malé Region (Waste Analysis & Characteristic Survey [WACS])
3. Feasibility study on recycling and waste pretreatment facilities
4. Economic efficiency evaluation for the Circular Economy Project in Thilafushi Island

Yours sincerely,

Suhail Ahmed
Managing Director

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C-793/2008

Figure 3-59 Letter from the HDC expressing their interest in a feasibility study for the Circular Economy Project in the Thilafushi Island

(4) Amount and composition of waste produced

According to HDC, the survey conducted last fiscal year showed that the amounts of waste generated in Hulhumalé were 1,643 t/year of sewage sludge, 1,825 t/year of organic waste (garden waste) such as plants, and 405 t/year of kitchen waste, which amounted to 3,873 t/year in total. Regarding the composition of the waste, we have obtained the results of the survey performed in 2016 from the report published in 2017 by the Ministry of Environment and Energy of the Republic of Maldives[36].

[36] Ministry of Environment and Energy, "Consultancy Services for Feasibility Study for an Integrated Solid Waste Management System for Zone III (including Greater Male') and Preparation of Engineering Design of the Regional Waste Management Facility at Thilafushi FEASIBILITY REPORT", 2017

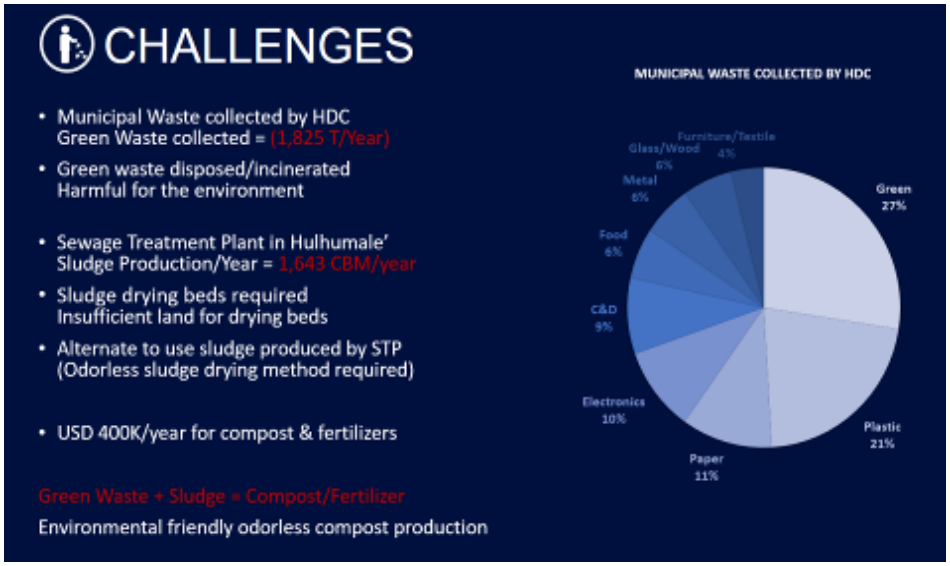

Figure 3-60 Amount and proportion of organic waste produced in Hulhumalé

Source: Material provided by HDC

Table 3-10 Composition of household waste

Waste composition	%	Trend
Organics	60%	constant
Garden waste	*10%*	
Kitchen waste	*40%*	
other organics	*10%*	
Paper & cardboard	10%	constant
Glass	3%	decrease by 1%
Plastics	10%	increase in the next years probably by 1-2 %
Metals	4%	constant
Hazardous wastes (including clinical)	3%	constant
Other (inert & dust)/mixed waste	10%	decrease
Total	100%	

Source: Ministry of Environment and Energy[36]

Although we strived to collect more detailed information on these data this fiscal year, we found out that there are no official monitoring data, except for the results of the survey carried out last fiscal year. Our interviews with the Ministry of National Planning, Housing and Infrastructure, and Malé Water and Sewerage Company (MWSC) have revealed that nether Malé nor Hulhumalé has any sewage treatment plants, and no sewage sludge has been produced currently. According to the

interview with MWSC, a sewage treatment plant would be built in Hulhumalé through the Maldives Urban Development and Resilience Project[37] by the World Bank, the project was at a bidding stage at the time, and construction would start in February 2021. MWSC will be in charge of the operation for three years and the Ministry of National Planning, Housing and Infrastructure will be responsible for the project as a whole, and information on the amount and quality of sewage sludge will become available through inquiries to the relevant organizations as they have made some progress with the project.

In this survey, therefore, we have estimated the amount of waste created based on the population using the estimates given by the World Bank (the amount of waste produced: 1.8 kg/person/day in the urban areas, 0.8 kg/person/day in the residential islands). With regard to the composition of waste, we enlisted the cooperation of Hitachi Zosen Corporation that participates in this project and referred to part of the results of the survey on waste composition that Hitachi Zosen conducted in the Integrated Waste Management Business in Greater Malé Capital Region, Maldives under the program to support carbon dioxide emissions reduction through strategic international expansion of Japan's circulation industries in 2021. We will amass information on the amount of sewage sludge generated as progress has been made with the project.

To begin with, the population and the amount of waste (estimate) are as shown in the table below for the residential islands in Zone 3 that includes the Greater Malé Capital Region. The values have been estimated based on the population (the statistics in 2014) using the estimates provided by the World Bank (the amount of waste produced: 1.8 kg/person/day in the urban area and 0.8 kg/person/day in the residential islands) as described earlier, with the estimated amount standing at 28 t/day in Hulhumalé and 228 t/day in Malé.

Table 3-11 Population and amount of waste (estimate) of each island in Zone 3

Island name/category			Population (2014)	Waste gereration (estimated amount, kg/day)
Kaafu Atoll	Dhihffushi	Residential land	1,053	842
	Gaafaru	Residential land	1,066	853
	Himmafushi	Residential land	1,725	1,380
	Hulhumalé	City	15,769	28,384
	Huraa	Residential land	1,300	1,040

[37] Project ID: P163957, "Maldives Urban Development and Resilience Project"
The details of the project are as follows:
(1) Resilient infrastructure and strengthening of emergency response systems, (2) sustainable urban planning, development, and management, and (3) project implementation, management, and reporting. (https://projects.worldbank.org/en/projects-operations/project-detail/P163957)

	Kaashidhoo	Residential land	1,865	1,492
	Male'	City	127,079	228,742
	Thulusdhoo	Residential land	1,408	1,126
	Vilin'gili	Residential land	7,790	6,232
	Gulhi	Residential land	912	730
	Guraidhoo	Residential land	1,738	1,390
	Maafushi	Residential land	3,025	2,420
Kaafu Atoll			164,730	274,632
Vaavu Atoll	Felidhoo	Residential land	506	405
	Fulidhoo	Residential land	372	298
	Keyodhoo	Residential land	675	540
	Rakeedhoo	Residential land	106	85
	Thinadhoo	Residential land	152	122
Vaavu Atoll			1,811	1,449
Alifu Dhaalu Atoll	Dhan'gethi	Residential land	824	659
	Dhigurah	Residential land	610	488
	Dhihdhoo	Residential land	153	122
	Fenfushi	Residential land	837	670
	Hangnaameedhoo	Residential land	517	414
	Kun'burudhoo	Residential land	462	370
	Maamigili	Residential land	2,359	1,887
	Mahibadhoo	Residential land	2,074	1,659
	Mandhoo	Residential land	367	294
	Omadhoo	Residential land	883	706
Alifu Dhaalu Atoll			9,086	7,269
Alifu Alifu Atoll	Bodufolhudhoo	Residential land	608	486
	Feridhoo	Residential land	441	353
	Himandhoo	Residential land	724	579
	Maalhos	Residential land	434	347
	Mathiveri	Residential land	662	530
	Rasdhoo	Residential land	1,067	854
	Thoddoo	Residential land	1,534	1,227

	Ukulhas	Residential land	1,005	804
Alifu Alifu Atoll			6,475	5,180
Zone III			182,102	288,530

*The estimates have been made with Male' and Hulhumalé being considered as urban areas and others as residential islands based on the estimates given by the World Bank (the amount of waste produced: 1.8 kg/person/day in the urban areas and 0.8 kg/person/day in the residential islands).

As shown in the table above, most of waste is generated in Malé and Hulhumalé, and the total volume of waste in the two islands accounts for nearly 90% of the waste created in Zone 3. The Maldives Bureau of Statistics published demographic statistics only up to 2014, thus we had to make estimates as given above; however, the population has been growing since 2014 and the amount of waste produced is considered to have increased accordingly. The population of Hulhumalé has already reached 65,000 in Phase I and 30,000 people will reportedly move into Hulhumalé soon in Phase II. Assuming that the population stands at 100,000 as of 2022, the amount of waste produced in Hulhumalé is 180 t/day.

Then, concerning the composition of waste, we referred to part of the results of the waste composition survey by Hitachi Zosen Corporation as mentioned earlier. The types and sources of waste carried into the Thilafushi Island are as follows, and the waste composition survey was performed targeting the waste collected in Malé:

【Classification (sources) of waste carried into the Thilafushi Island】
- From Malé (twice a day)
- From Hulhumalé (once a day)
- From Villingili Island (once a week)
- From Resort Island (via small boats (Dhonis))

【Classification (types) of waste dumped in the Thilafushi Island】
- Household waste (collected by WAMCO or other authorized companies)
- Commercial waste (such as waste generated in shops, restaurants, and other commercial facilities)
- Construction waste (waste collected mainly by private operators and carried into the shipping bases of WAMCO)
- Medical waste produced in hospitals in Male' (collected by WAMCO or other authorized companies)

According to the table below, kitchen waste accounts for 21% and garden waste makes up 5%.

Table 3-12 Results of the waste composition survey

Type of waste	Percent
Inseparable mixed waste	27.05

Kitchen waste	21.13
Packaging Plastics	11.86
Paper and cardboard	10.14
Garden waste	4.96
Rags &Textiles	4.30
PET bottles	4.23
Diapers and sanitary pads	4.07
Glass	3.23
Industrial Plastics	3.09
Metals	2.71
Rubbers, Leathers	0.99
Others	0.96
Other organics	0.71
Hazardous waste	0.57
Incombustibles (Inert, dust, etc.)	0.00

Based on these pieces of information, the volume of waste generated in Hulhumalé is estimated at 180 t/day given that the population is 100,000. Out of the waste, kitchen waste and garden waste that can be raw material for farmyard compost will amount to 38 t/day (21%) and 9 t/day (5%), respectively, according to the results of the waste composition survey, and it is expected that a total of 47 t/day will be created as raw material for compost production.

3.4.2. Discussion about the possibility to adopt organic waste-based compost and a survey on sales networks

The Maldives relies on imports for most of resources, and compost is no exception. HDC imports compost from Singapore for the greening of the Hulhumale Island, which costs about 40 million yen per year. In this project, with an eye to the composting of organic waste (food and green wastes), the properties and prices of compost currently available in the Maldives were surveyed on the Internet. A survey of online stores for the Maldives revealed that compost is imported from a wide range of countries, such as USA, UAE, UK, and India. The table below shows the information on compost made from food and green wastes, which is similar to the content of this project, although the raw materials of compost include food, green wastes such as branches and leaves, and livestock manure (chicken manure and cow manure).

Table 3-13 Compost available in Maldives[38]

Product name	Importer	Price	Amount	Unit price	Raw materials
Blue Ribbon Organics OMRI Certified Natural	USA	2649 MVR	820L	3.2 MVR/L	Food waste, Green waste

[38] https://maldives.desertcart.com/brand/compost

Premium Organic Compost for Plants					
Shalimar Vegetarian Bio Organic Compost	UAE	1,269 MVR	50L	25 MVR/L	Tea leaves
Green Rich Bio Organic Compost	UAE	1,179 MVR	50L	24 MVR/L	Green waste
Plant Based Powder Form Fertilizer Compost	UAE	1,999 MVR	25 kg	80 MVR/kg	Green waste
Coir Brick 650g x 4 | Compressed Soil for Gardening	UK	1,199 MVR	9L	133 MVR/L	Coconut shell

As mentioned above, the compost made from food and green wastes is available in the Maldives and may be purchased by citizens for gardening. In the organic waste composting business, the issue is that the demand for compost is generally low and sufficient sales revenue cannot be earned. On the other hand, in the Maldives, most of the land is sandy soil, and compost is necessary for greening. In addition to large-scale urban greening, demand from citizens is also expected. In site survey, we saw plastic containers placed under the eaves of houses to grow plants, and guesthouse owners laying soil on their premises to create green areas. When considering specific candidate technologies to be introduced, the properties of the compost and its applicability to the Maldives will be investigated in more detail.

In addition, since the selling price of compost varies as shown in the table above, we will consider setting a competitive price by referring to the price range of these imported products.

Figure 3-61 Scene of greening in the capital area of Malé

(Left: Cultivation of green plants in Villingili [a residential island],
Right: Proposed green zone of a guesthouse in the Thulusdhoo Island)

3.4.3. Discussion about an operational plan, business feasibility assessment, and a business structure

(1) How to utilize organic waste and candidate equipment

Organic waste provides methane as energy through a methane fermentation treatment process and residue of the fermentation process as farmyard compost, and these recycling efforts would

contribute to settling waste-related issues and decarbonizing society.

Ishibashi Co., Ltd. in Toyama City possesses knowledge of composting business. It handles RA-X, a screw-type composting plant. RA-X can realize aerobic high-temperature fermentation for 100 tons/day or more, which was difficult with conventional technologies. It is low-cost and can be maintained easily, and does not require manpower for stirring thanks to the screw unit. Accordingly, this equipment is suitable for the Maldives. Ishibashi Co., Ltd. also has the experience of installing it in Sri Lanka and the plan to install in Bali, so it possesses significant knowledge of commercialization in developing countries.

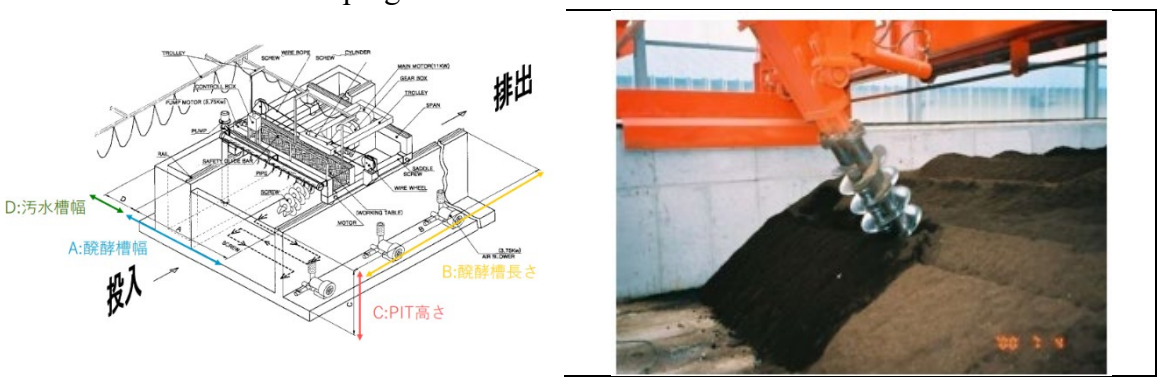

Figure 3-62 Screw-type composting plant RA-X

Source: Website of Ishibashi Co., Ltd. (http://www.ishibashi.ne.jp/rax.html)

In addition, considering the current cost of importing farmyard compost, an economical potential has been demonstrated even though it costs money to adopt methane fermentation equipment. The following figure shows an operational plan in Hulhumalé when both methane fermentation equipment and composting equipment are installed:

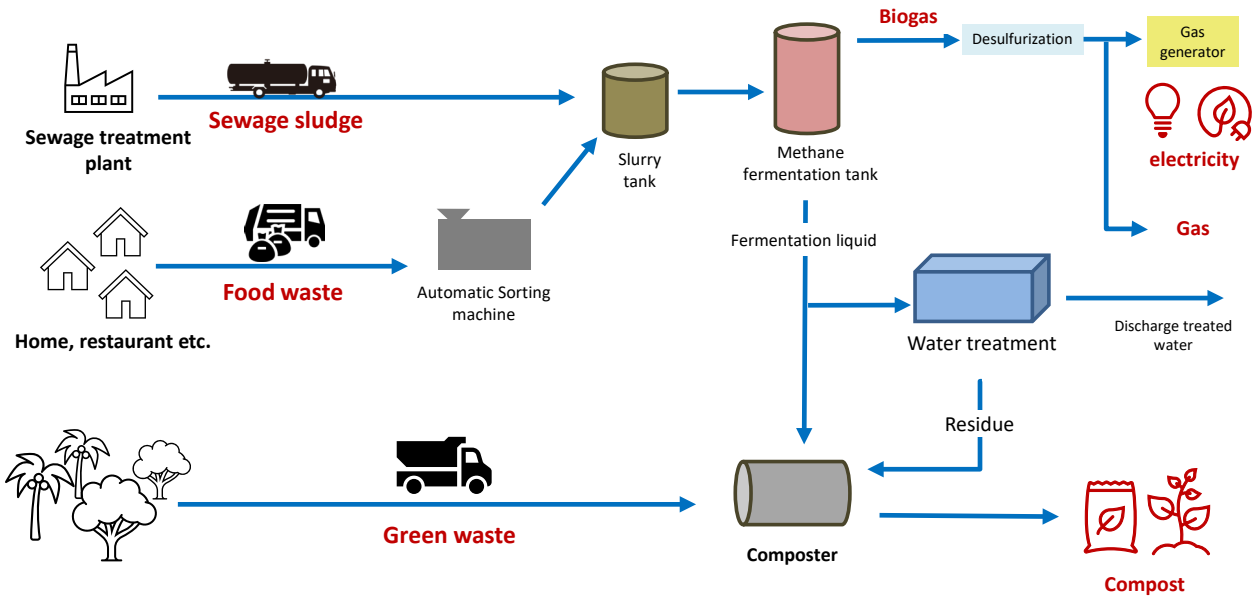

Figure 3-63 A proposed system that combines methane fermentation equipment with composting equipment

While the above-mentioned system that combines methane fermentation with composting is an ideal system that generates energy and compost and enables maximum utilization of organic waste as resources, it is difficult for a small number of engineers in the Maldives to operate methane fermentation equipment because it requires expertise for stable operation. In addition, the former ambassador Keiko Yanai of the Embassy of Japan in the Maldives told us that the minister Aminath Shauna of the Ministry of Environment and Energy expressed great interest in recycling organic waste as compost and said that they wanted to adopt not labor-intensive, but automatic composting equipment during their opinion exchange.

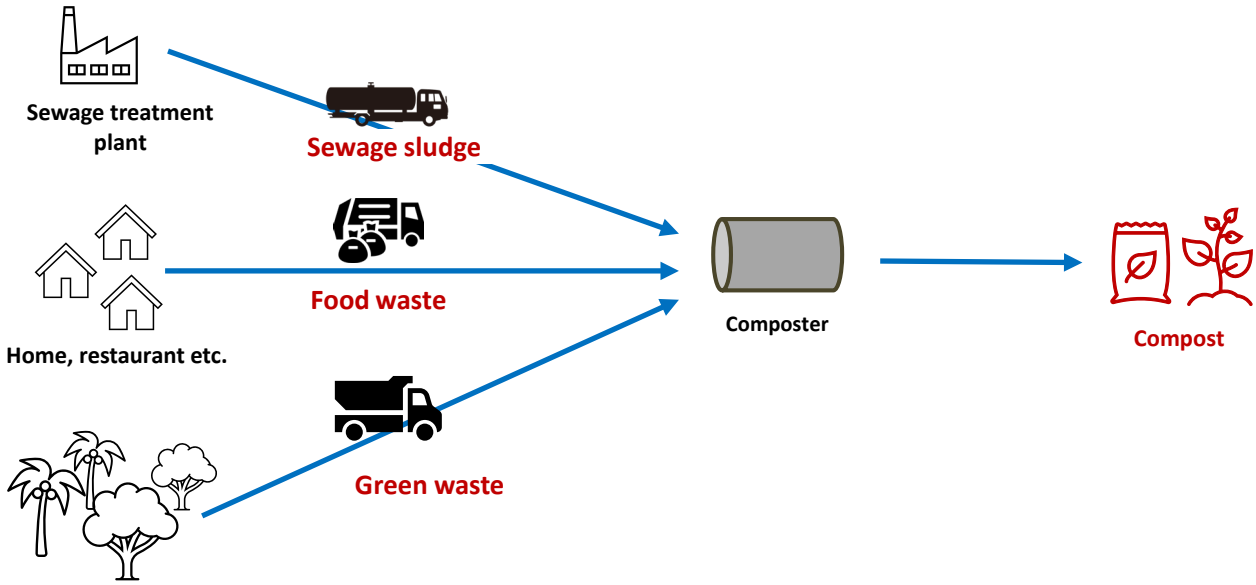

Figure 3-64 A proposed system with only composting equipment

Conventionally, the composting process is divided into two phases. The first is primary fermentation during which easily degradable organic matters are mainly decomposed, and the second is secondary fermentation during which decomposition and humification of degradable organic matters progress together. Compost must be moved for the secondary fermentation process after primary fermentation. Furthermore, technology associated with composting is essential in addition to labor power, for manufacturing quality compost because it is required to appropriately record and manage such factors as air flow rate, temperature, frequency of stirring and turning compost, fermentation period, and moisture.

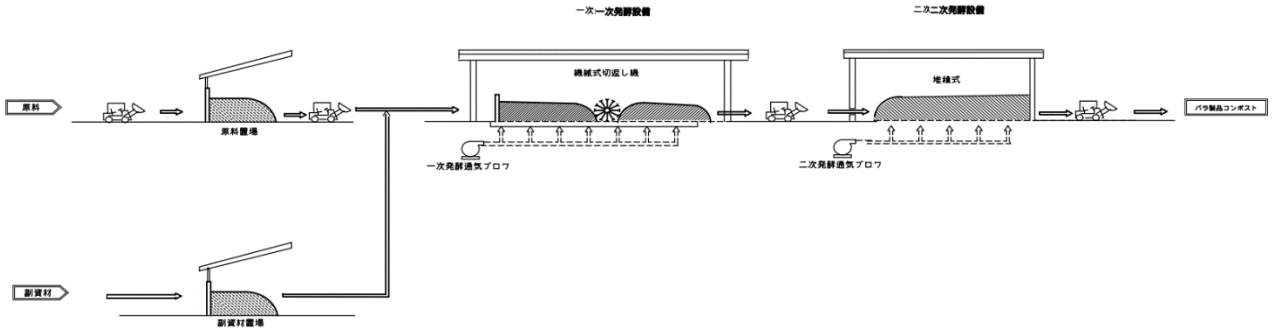

Figure 3-65 Flow chart of the conventional compost production process

Source: Material given by Minamiboso City.[39]

Equipment that can be maintained relatively easily and operated without specialized knowledge is desirable to realize stable compost production in the Maldives.

After RA-X of Ishibashi Co., Ltd. was adopted in the neighboring country Sri Lanka while enlisting support from JICA, it turned out to be effective, so it received additional orders. This indicates that its technology is suitable for the on-site conditions, and it can be said that the feasibility of distribution in the Maldives is high.

(2) Business feasibility assessment

As mentioned above, the volume of waste generated in Hulhumalé would be 180 t/day with the population assumed to be 100,000. Of the waste, based on the results of the waste composition survey, kitchen waste that serves as a raw material for compost is 38 t/day (21%) and garden waste is 9 t/day (5%), resulting in a raw material for compost production of 47 t/day in total. That is, a total of 17,155 t/year of the raw material would be produced.

An example of business feasibility assessment is that for Eco☆West, a facility for reducing the volume of raw waste operated by Kumagaya Cleaning Company, although the scale of the facility is a little small. With the waste treatment capacity being 20 t/day, the facility treated 7,458 t of raw waste (from May 2014 when the company began operation of the facility to February 2016) and produced 373 t of compost. The initial cost was 296,877,500 yen according to the table blow.

Table 3-14 Initial cost of Eco☆West (composting equipment)

Facility summary	Site area		2,907.76 m^2
	Building area		1,703.36 m^2
	Capacity		20t/day
Initial cost	Building		220,000,000 yen
	Facility	Self-propelled agitator	20,000,000yen

[39] Compost production method by Minamicboso City (49fab7d9005.pdf (city.minamiboso.chiba.jp))

		Crushing and separating machine	5,000,000 yen
		Wheel loader	4,000,000 yen
		Sieving machine	3,000,000 yen
		Deodorizer	20,000,000 yen
		Truck scale (30t)	2,500,000
		Aeration facility	5,000,000 yen
		Bacterial cell	15,600,000 yen
	Total		296,877,500 yen

Source: Report on verification through demonstration tests for a raw waste volume reduction (HDM system) and composting project by Kuki-Miyashiro Eisei Kumiai (2017).[40]

Assuming that a similar type of equipment is adopted, produced compost could be used for roadside trees and gardens in Hulhumalé, and according to a simple calculation, the initial investment could be recouped in the seventh year after the adoption with the expenditure of 400,000 US dollars (about 40 million yen) currently used for importing compost considered to be revenue.

The estimated amount of compost produced is 10,220 t per year, based on the data indicating that the decomposition rate of raw waste through composting treatment is 70% and that of pruned branches is 20%.[41]. These amounts are larger than the volume of compost used in Hulhumalé, and revenue can possibly be yielded by selling compost to other islands in the Greater Malé Capital Region.

This analysis, however, does not include such matters as the interest on financing related to equipment installation, cost of land acquisition, inflation rate, and operational cost. It is necessary to identify stakeholders and discuss economic potential including these costs, while obtaining estimates of waste volumes and detailed information on the composition and amount of waste and forging ahead with in-detail design with the local situation taken into consideration.

3.4.4. Estimation of the CO_2 emissions reduction effect of composting equipment

Composting equipment exerts its decarbonization effect by preventing methane from being emitted from anaerobic fermentation at organic waste treatment plants. Meanwhile, the composting processes release greenhouse gas.

Organic waste is generally transformed into compost under aerobic conditions, which produces

[40] Report on verification through verification tests for a raw material volume reduction (HDM system) and compost production project by Kuki-Miyashiro Eisei Kumiai, 2017 (http://www.crt-kuki.miyashiro.saitama.jp/pdf/hdmhoukokusyo.pdf)

[41] Research and analysis on compost production and methane fermentation equipment targeting various types of organic waste by Laboratory of Solid Waste Disposal Engineering, Graduate School of Engineering, Hokkaido University, 2011 (https://www.eng.hokudai.ac.jp/labo/waste/wp-content/uploads/2014/03/report3.pdf)

almost no methane; however, methane will be generated when the volume of oxygen supplied is not adequate because the insufficiency of oxygen will induce anaerobic reactions. The methane so produced will be oxidized and become carbon dioxide under an aerobic environment, but part of the methane will be released into the air as it is. The amount of dinitrogen monoxide produced depends on the percentage of nitrogen contained in the organic waste that will be transformed into compost[42].

To begin with, we used the IPCC Waste Model[43], which is the guidelines offered by the IPCC in 2006, for calculating a reference emission amount, the amount of methane emission avoidance through anaerobic fermentation at organic waste treatment plants. Candidate legal useful lives of composting equipment are seven years for agricultural equipment and ten years for equipment for manufacturing beverages, cigarettes, or feed based on the list of the useful lives of depreciable assets, and we decided to employ ten years for equipment for manufacturing beverages, cigarettes, or feed, because we consider this project to be a compost manufacturing project. The methane emission avoidance volume through anaerobic fermentation of waste generated in Hulhumalé with an estimated population of 100,000 (with kitchen waste standing at 13,882 t/year and garden waste amounting to 3,259 t/year) (reference emissions) will be 2,120 t-CH_4 in total, which will be 44,512 t-CO_2 when converted into an amount of CO_2 using 21 that is the global warming potential of methane.

Table 3-15 Reference emissions (methane emissions through anaerobic fermentation of organic waste)

Avoided methane emissions in each year

Year	Food waste[Gg]	Green waste[Gg]
1	0.000	0.000
2	0.073	0.018
3	0.122	0.034
4	0.155	0.047
5	0.177	0.058
6	0.192	0.067
7	0.202	0.075
8	0.209	0.082
9	0.213	0.087
10	0.216	0.092

[42] Website of the Ministry of the Environment "5. Field of Waste | Detailed information on how to calculate the amount of greenhouse gas emitted and absorbed, 5.B.1 Composting" (https://www.env.go.jp/earth/ondanka/ghg-mrv/methodology/material/methodology_5B1_2020.pdf)

[43] 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)

	Food waste	Green waste
Methane emission (t-CH_4)	1,560	560
Methane emission (t-CO_2)	32,755	11,756

Reference emission (t-CO_2)	44,512

Then, we calculate an amount of greenhouse gas released through compost production, which is a project emission amount. We calculated the volumes of CH_4 and N_2O emitted from the process of transforming organic waste into compost using the method described in Chapter 4: Biological Treatment of Solid Waste in the IPCC guidelines published in 2006.

CH_4 emissions from biological treatment

$$CH_4\ Emissions = \sum \left(M_i \bullet EF_i\right) \bullet 10^{-3} - R$$

CH_4 Emissions: Total CH_4 emissions ($GgCH_4$)
M_i: Amount of input of "organic waste (i) "(Gg)
EF: Emission factor(gCH_4/kg waste treated)

N_2O emissions from biological treatment

$$N_2O\ Emissions = \sum_i \left(M_i \bullet EF_i\right) \bullet 10^{-3}$$

N_2O Emissions: Total N_2O emission (GgN_2O)
M_i: Amount of input of "organic waste (i)" (Gg)
EF: Emission Factor (gN_2O/kg waste treated)

For EF, the default values based on wet weight of IPCC guidelines (CH_4: 4 gCH_4/kg waste treated, N_2O: 0.24 gN_2O/kg waste treated) were used.

Figure 3-66 Equations for calculating the amounts of CH_4 and N_2O emitted from biological treatment

Source: IPCC Guidelines published in 2006, Volume 5 Waste, Chapter 4 Biological Treatment of Solid Waste

Consequently, the volume of greenhouse gas emitted from the process of transforming organic waste into compost was 27,152 t-CO_2. Although electricity consumed and fuel used for composting equipment must actually be included as the project emission amount, the volumes are unclear at the moment and we consider 27,152 t-CO_2 so calculated as the project emission amount.

Table 3-16 Project emission amount (volumes of CH_4 and N_2O released from the composting process

[when converted into an amount of CO_2])

	CH_4 emissions	N_2O emissions
Food waste (t-CO_2/year)	1,166	1,033
Green waste (t-CO_2/year)	274	242
Annual emissions (t-CO_2/year)	2,715	
Project emissions (t-CO_2)	27,152	

The reduction amount is calculated by subtracting the project emission amount from the reference emission amount, and it is 17,360 t-CO_2.

As mentioned above, the JCM equipment subsidy program covers 50% of the cost for equipment that contributes to the reduction of CO_2 emissions or 4,000 yen/t-CO_2, a rough indication of an emission reduction cost, whichever is less, for the first project in a relevant country. The upper limit of a subsidy (when the subsidy rate is 50% or lower) will be 69.44 million yen if it is calculated backwards using the rough indication of an emission reduction cost of 4,000 yen/t-CO_2. If this is discounted at a subsidy rate of 50%, it will be possible to introduce facilities worth 138.88 million yen.

No composting project has been registered for either the Clean Development Mechanism (CDM) or the JCM at the moment, and a Measurement, Reporting, and Verification (MRV) methodology must be developed from scratch for setting up business. For instance, if composting equipment is installed in Hulhumalé, the reduction amount of the vessel fuel conventionally required for carrying waste into the Thilafushi Island may be added to the reference emission amount. Meanwhile, the amount used for bringing organic waste to composting equipment may be added to the project emission amount.

As the segregation and collection of organic waste have just started, they are still conducted roughly, so the infrastructure for efficiently collecting organic waste cannot be said to be sufficient. In this light, it is indispensable to strengthen systems for sorting, collecting, and transporting waste.

3.4.5. Implementation structure

Regarding the implementation structure, we discuss a plan to form an international consortium with HDC and Waste Management Corporation Ltd. (WAMCO) with a company based in Toyama City, which takes interest in the composting project, serving as the representative operator. When installing composting equipment, we need to confirm whether there is demand that is commensurate with the volume of compost generated, but stable operation of the equipment will be possible with HDC playing the roles of both the equipment owner and the off-taker of compost. Furthermore, although it is expected that securing land for building composting equipment will face difficulties due to territorial limitations in the Greater Male' Capital Region, HDC has an authority over the use of land in the region and we expect smooth coordination, including securing land for construction. In addition, greening activities in other places than Hulhumalé are expected to contribute to compost use. If WAMCO, which operates the entire waste business, operates equipment, it will be possible to

conduct efficient operation while integrating activities other than composting, such as the formation of plans for transporting waste. For WAMCO, too, proper sorting and collection of organic waste can result in not only production of high-quality compost, but increased revenue, and this can give WAMCO incentives to manage waste.

When the utilization of sewage sludge becomes possible, we plan to cooperate with Male Water and Sewage Company (MWSC) in carrying sewage sludge. We will also discuss how to effectively collect organic waste not only from household garbage, but from such places as restaurants, food processing plants, and markets and potential of using them because the properties of such waste are considered to be uniform to a certain extent.

We will amass more information on various matters, including plans to collect wet garbage and progress in other waste-related projects, and move ahead with in-detail discussion about places to install composting equipment, selection of equipment to install, and other relevant matters. Regarding places for equipment isntallation, we are currently considering the Thilafushi Island and Hulhumalé as candidate sites together with HDC, and profound discussion with the local parties concerned needs to be continued because the impact on the local waste flow is significant. Since there are a concept and project of recycling waste centering on construction of a waste-based power plant in the Thilafushi Island, integrating venous industries in the Thilafushi Island could result in effective waste management. This is an item to be discussed.

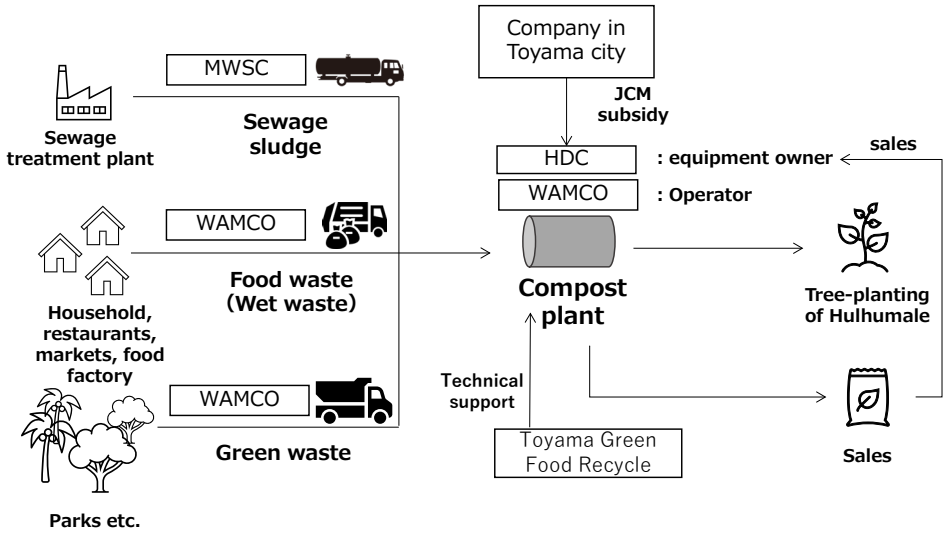

Figure 3-67 Proposed implementation structure for using organic waste as compost

4. Intercity collaboration to realize a low-carbon society (invitation of local stakeholders and workshops)

4.1. Overview of intercity collaboration activities

As the impact of the COVID-19 pandemic has subsided, this fiscal year, we were able to conduct an on-site survey for this intercity collaboration project, while utilizing information obtained through

the online exchange of opinions held till last fiscal year. As remarkable outcomes, the officials of Toyama City were able to visit the islands, obtain survey results, win the understanding of local staff, exchange opinions with our counterparts: HDC, the Ministry of Environment of the Maldives, and potential business operators, and give proposals to them. Our major activities in this fiscal year are as follows.

Table 4-1 Major activities and participating institutions

Date	Activities	Participating institutions
Jun. 7, 2022	Pre-KoM of the Ministry of Environment	MoE, JANUS
Jun. 14, 2022	Exchange of opinions with Nihonkucho Hokuriku aand ReM	Nihonkucho Hokuriku, ReM, JANUS
Jun. 28, 2022	Exchange of opinions with Ishibashi Co., Ltd.	Ishibashi, JANUS
Jun. 29, 2022	Discussion with Nippon Engineering Consultants about SATREPS	Nippon Engineering Consultants, JANUS
Jul. 12, 2022	Exchange of opinions with Hitachi Zosen	Hitachi Zosen, JANUS
Jul. 15, 2022	Exchange of opinions with Nihonkucho Hokuriku and Ishibashi	Nihonkucho Hokuriku, Ishibashi, JANUS
Aug. 31, 2022	Exchange of opinions for proposals based on SATREPS	JICA Maldives, Nippon Engineering Consultants, JANUS
Sep. 2, 2022	Discussion on the policy for proposals based on SATREPS	Nippon Engineering Consultants, JANUS
Sep. 7, 2022	Discussion with HDC	HDC, Toyama City, JANUS
Sep. 13, 2022	Discussion with MTCC	MTCC, HDC, JANUS
Sep. 22, 2022	Discussion on the policy for proposals based on SATREPS	MNU, HDC, Nippon Engineering Consultants, the University of Toyama, Nagoya University, JANUS
Oct. 1-2, 2022	On-site survey	JANUS, Toyama City, HDC, STELCO, ReM, MTCC, Ensis, MNU, MECCT, the Embassy, etc.
Jan. 17, 2023	Discussion on solar power generation projects subsidized by JCM	Ensis Fisheries, JANUS

4.2. On-site survey

This fiscal year, we tried to visit and stay there from October 1 to 12. Our destinations and schedule are as follows.

Date		Meetings/Site visiting	Note
1st Oct.	Sat	Arrive at Maldives	
2nd Oct.	Sun	10:30-12:00 HDC	
3rd Oct.	Mon	10:30-11:30 REM Tourism day in the Maldives	

4th Oct.	Tue	9:30 JANUS arrive at HDC 10:00-12:00 Ministry of Transport and Civil Aviation, MTCC 15:00-16:00 JICA Maldives 16:40-18:00 Geotech Maldives	
5th Oct.	Wed	10:00-12:00 WAMCO Lunch _ HDC and JANUS 13:00-15:00 STELCO	
6th Oct.	Thu	11:30-12:30 Prime Maldives 13:00-14:30 MNU	
7th Oct.	Fri	Dhigurah 10:00 Male to Dhigurah	
8th Oct.	Sat	Dhigurah 13:30 Dhigurah to Male	
9th Oct.	Sun	9:00-9:30 Meeting with HDC and Toyama City officials 10:00-12:00 MECCT 13:00-14:00 Ensis Fisheries 15:45-16:00 Hulhumale tour 16:00-18:00 Gulhifalhu, Tilafushi (site visiting)	Accompanied by the officials of Toyama City
10th Oct.	Mon	11:30-12:30 Embassy of Japan 17:30-19:30 Dinner at ambassador's residence	Accompanied by the officials of Toyama City
11th Oct.	Tue	13:00- Lunch meeting with HDC	
12th Oct.	Wed	Arrive at Japan	

Figure 4-1 Itinerary and destinations in this on-site survey

The details of individual discussions and surveys are as mentioned in relevant sections of this report, but we will introduce the details of the discussions with HDC and the exchange of opinions with the Japanese Embasy regarding this task.

(1) Discussion with Hulhumalé Housing Development Cooperation (HDC) and the Ministry of Environment, Climate Change and Technology (MECCT)

We visited there together with the staff of HDC and Toyama City, which are the counterparts in this intercity collaboration project, introduced the international collaboration projects and decarbonization measures Toyama City has conducted so far, and explained the importance and effects of discussing decarbonization measures as a municipality.

From HDC, Mr. Ahmed Shahud Zuhair Senior, who is a senior urban designer/planner, and Mr. Ibrahim Naushad Ali, who is an assistant urban designer/planner, participated.

From MTCCT, Mr. Ahmed Murthaza, who is the director general, Mr. Ibrahim Zameel, who is the project manager, Mr. Mauman Abdul Rasheed, who is the assistant director of Climate Change Department, and others participated.

HDC expressed their gratitude for the cooperation and provision of information in the intercity collaboration project, and confirmed the schedule and policy for discussing items to be put into practice with us.

Regarding the utilization of natural gas, we are still at the stage of discussing the plan, but it is considered that needs for natural gas for transportation will emerge after infrastructure is developed. MECCT gave us a similar comment regarding this matter. If they decide to develop infrastructure for natural gas, natural gas may be used for other purposes than power generation.

MECCT informed us that they are considering the adoption of solar power for stations for refueling electric buses and setting solar panels on the large bridge of Malé as plans related to solar power generation.

Regarding the composting of waste, there are also needs for the compost as soil. Accordingly, they got keenly interested in the effective use of the compost. We reached an agreement on the policy of continuing discussions with an eye to another support scheme.

Figure 4-2　Scenes of meetings with HDC and MECCT

(2) Exchange of opinions with the Japanese Embassy

We had a meeting with the ambassador Takeuchi, the counselor Asano, and the secretary Fukuoka of the Japanese Embassy in the Maldives, to report the intercity collaboration project and discuss future policies.

Regarding the transportation field, we received information about MTCC's plans to introduce compact buses in residential islands and ferries for residential islands, which are related to the project for installing solar power generation equipment linked with the plan for adopting electric buses. As decentralization, community-based tourism, and regional vitalization are demanded, we heard that they are planning such projects actively.

In addition, regarding the waste business, we were informed that the plan to install intermediate processing equipment (bottle compressors and glass crushers) in the Thilafushi Island and the Addu Atoll based on gratuitous financial aid will be officially approved in December.

As the embassy, they keenly feel the difficulty in doing business in the Maldives, but expressed their gratitude for Toyama City's consistent survey, and requested us to continue steady cooperation.

Figure 4-3 Scene of the meeting with the Japanese Embassy in the Maldives

5. Summary

5.1. Outcomes in this fiscal year

This fiscal year, we were able to conduct an on-site survey involving Toyama City, because COVID-19 has subsided. Then, we proceeded with each project item and cemented our relationships with local staff in the third year of this project. Projects that would cost time to develop infrastructure, systems, and economic viability will be discussed in the future through SATREPS or the like. Meanwhile, feasible projects will be discussed for realizing projects subsidized by JCM as an outcome of this intercity collaboration project. The outcomes are summarized below.

Table 5-1 Summary of outcomes

Candidate projects	Outcomes
Public transportation	・As a long-term measure, we reached an agreement about the use of SATREPS, and started preparations. ・As a short-term measure, we proposed a plan of adopting electric buses in the GEF business and the solar power generation business that would help the adoption of electric public buses by MTCC. ・We estimated the reduction volume of CO_2 emissions in the JCM project and effects of the JCM equipment subsidy. ・We confirmed the policy for detailed discussions and system development.
Field of low-carbon power generation after changing fuel for diesel power generation equipment	・We confirmed the situation of discussions on policies and plans.
Renewable energy	・Continued proposing concrete projects for resorts. ・Discussed the collaboration with Hitachi Zosen Corporation for using seawater desalination equipment. ・Proposed the adoption of solar power generation to a seafood processing factory.
Recycling of organic waste	・Grasped the situation of waste management and problems in the urban area, residential lands, and resorts. ・Reached an agreement for having discussions to realize a circular economy starting with waste-based power plants. ・Discussed a project for contributing to the training, etc. at waste-handling organizations.
Intercity collaboration activities	・Proposed political measures (introducing Toyama City's experiences and activities for public transportation, use of hydrogen, ecotowns, etc.) ・Introduced and explained Toyama City's declaration of decarbonization, and expressed our expectations toward the domino effect in the capital area of Malé.

We will continue discussions on waste while considering the linkage with other F/S, etc. Japanese

enterprises engage in. In detail, the venous industry, including the segregation and recyclding of waste, in the Maldives is weak, so it is impossible to solve the entire waste problem just by combusting waste for power generation. Accordingly, Hitachi Zosen Corporation is considering support for waste-conscious administration and empowerment and training of business operators.

The composting of organic waste, which is being discussed in this intercity collaboration project, would become an effective recycling model, but there remain problems with collection and segregation of waste as mentioned above. Its feasibility is determined by the establishment of paths and systems for utilizing other waste than organic ones, too, and the provision of technologies.

With reference to the ecotown project Toyama City has engaged in since 2002, we proposed measures for sorting and utilizing waste through integration, etc. in the recycling industry to HDC, WAMCO, and the Ministry of Environment of the Maldives.

The waste-based power generation project that is being discussed by ADB and the government of the Maldives is one-way from the viewpoint of recycling of resources, so we proposed the application of the concept of a circular economy, the strengthening of the recycling industry with recycling technologies, and decarbonization through the adoption of renewable energy for the industry, in order to achieve sustainable recycling of resources.

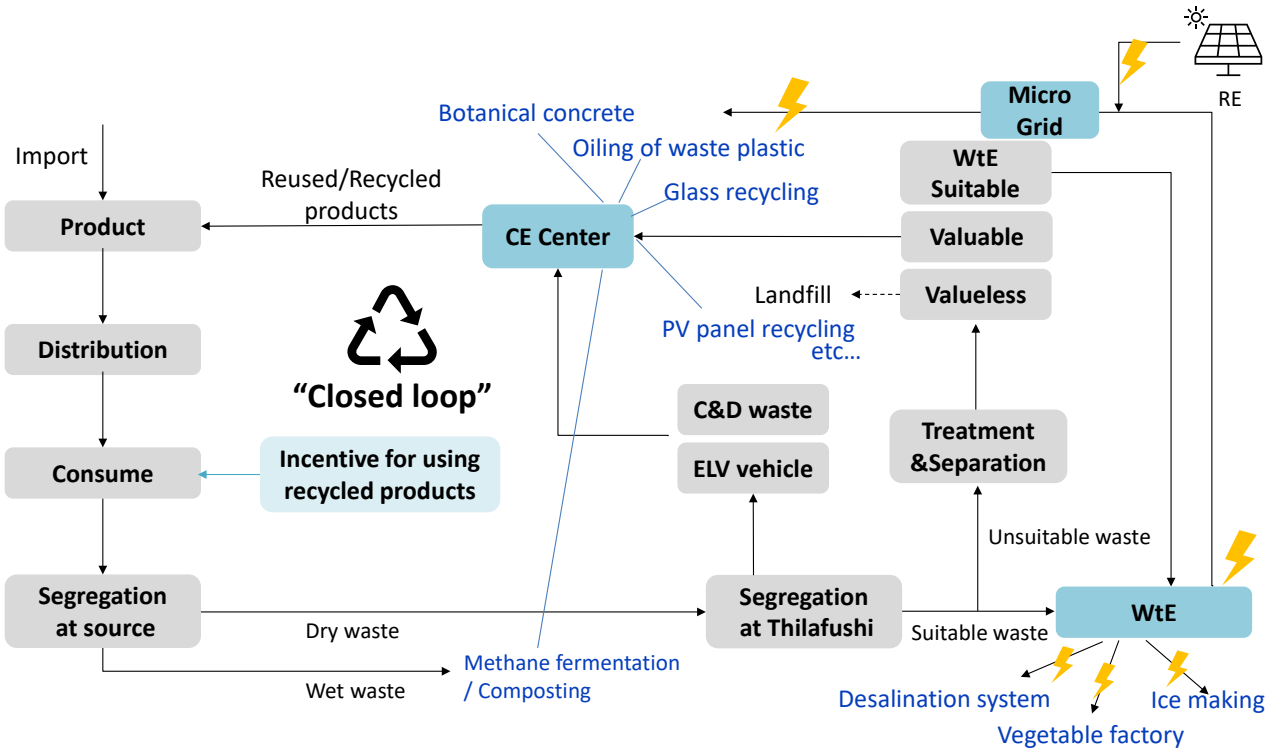

Figure 5-1 System proposed to the Ministry of Environment, HDC, WAMCO, and STELCO

Related institutions expressed their interest in this proposal, so we decided to discuss more details with Hitachi Zosen Corporation.

5.2. Candidate projects subsidized by JCM and problems to be solved

In this survey, we studied (1) public transportation, (2) change of fuel for diesel power generation, (3) distribution of renewable energy, and (4) recycling of organic waste for projects subsidized by JCM.

As mentioned above, we have finished discussions on respective projects this fiscal year, which is the final fisal year of this program. From now on, we will actualize feasible projects.

The following summarizes the results of discussions on respective themes.

Table 5-2 Candidate projects subsidized by JCM, problems, and measures for solving them

Theme	Candidate projects subsidized by JCM	Discussion results	Policy
(1) Public transportation	・Electric buses	・The scale of the GEF project is too small to achieve sufficient cost-effectiveness for JCM. ・The MTCC project will not be fully covered. A project for solar power generation equipment for electric buses is realistic.	・Solar power generation facilities would be managed by STELCO. When STELCO adopts solar power generation facilities, we will propose the utilization of the JCM equipment subsidy.
(2) Change of fuel for diesel power generation	・Autonomous decentralized hydrogen use ・Replacement of gas with CNG, etc.	・Due to the stagnation of diesel replacement measures of STELCO and the government of the Maldives, the base for actualizing the use of natural gas and hydrogen is insufficient.	・To consider giving proposals while taking into account the situation of decisions on political measures, etc. while executing other projects
(3) Renewable energy	・Facilities with seawater desalination equipment in resorts ・Adoption of solar power for seafood processing factories	・Due to economic circumstances, resort owners are reluctant to make a decision. ・They are interested in utilizing the JCM equipment subsidy for installing them. We received information for concrete discussions.	・To check the decision-making situation while executing other projects ・To give proposals utilizing the JCM equipment subsidy and facilitate decision-making
(4) Recycling of	・Composting	・The sorting and collection	・To discuss the

organic waste	equipment	of organic waste are insufficient. ・It is necessary to support the entire waste-conscious administration.	training, etc. of officials and staff in waste-related projects

5.3. Future action plans

Through this intercity collaboration project, we were able to grasp the problems with decarbonization in Malé and the Maldives to a sufficient degree.

We provided the local governments with information on possible governmental measures proposed by Toyama City to close the gap between policies and execution. However, it would take time to put them into practice due to political and social circumstances.

Accordingly, we will keep in touch with them while prioritizing the execution of feasible projects, in order to maintain the momentum of decarbonization.

In addition, by utilizing SATREPS and waste-related budgets, we would like to work on the support for infrastructure based on information and research on decarbonization, and establish the groundwork for adopting decarbonization technologies smoothly.