



MINISTRY OF  
ENVIRONMENT, CLIMATE  
CHANGE & TECHNOLOGY  
REPUBLIC OF MALDIVES



WORLD BANK GROUP

# MALDIVES' INVESTMENT FRAMEWORK FOR NET-ZERO



## Notice for readers

This report has been prepared under the Accelerating Renewable Energy Integration and Sustainable Energy (ARISE) project of the World Bank Group to showcase a plausible investment framework that Maldives can adopt in its transition towards a net-zero economy. The intent of the study is to capture possible net-zero options across key sectors along with the associated investment requirements. The study is directional in nature and will require detailed feasibility and techno-economic analysis for different technologies specified in the report for the purpose of implementation. The study showcases the intent and ambition of the Republic of Maldives towards a net-zero future with investment estimates only for indicative purposes, to support detail techno-economic analysis on the select set of technologies going forward.

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# Abbreviations

<b>ACs</b>	Air Conditioners
<b>ADB</b>	Asian Development Bank
<b>ARISE</b>	Accelerating Renewable Energy Integration and Sustainable Energy
<b>BAU</b>	Business-as-usual
<b>BESS</b>	Battery Energy Storage Systems
<b>BUR</b>	Biennial Update Report
<b>CAGR</b>	Compound Annual Growth Rate
<b>CH<sub>4</sub></b>	Methane
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>CORSIA</b>	Carbon Offsetting and Reduction Scheme for International Aviation
<b>CUF</b>	Capacity Utilization Factor
<b>EE</b>	Energy Efficient
<b>EV</b>	Electric Vehicles
<b>FCEVs</b>	Fuel Cell Electric Vehicles
<b>GBIs</b>	Generation-based Incentives
<b>GDP</b>	Gross Domestic Product
<b>GEF</b>	Global Environment Facility
<b>GHG</b>	Greenhouse Gas
<b>GoM</b>	Government of Maldives
<b>GW</b>	Gigawatt
<b>HDV</b>	Heavy Duty Vehicle
<b>HRS</b>	Hydrogen Refueling Station
<b>ICAO</b>	International Civil Aviation Organization
<b>ICEs</b>	Internal Combustion Engines
<b>IEA</b>	International Energy Agency
<b>IPCC</b>	Intergovernmental Panel on Climate Change
<b>LCV</b>	Light Commercial Vehicle
<b>LPG</b>	Liquefied Petroleum Gas
<b>MEA</b>	Maldives Energy Authority
<b>MTCC</b>	Maldives Transport and Contracting Company

<b>MSW</b>	Municipal Solid Waste
<b>MW</b>	Megawatt
<b>NBS</b>	Nature-based Solutions
<b>NDC</b>	Nationally Determined Contribution
<b>OTEC</b>	Ocean Thermal Energy Conversion
<b>PES</b>	Payment for Ecosystem Services
<b>PPP</b>	Public-Private Partnership
<b>PV</b>	Photovoltaic
<b>RE</b>	Renewable Energy
<b>RECs</b>	Renewable Energy Certificates
<b>RNG</b>	Renewable Natural Gas
<b>SAF</b>	Sustainable Aviation Fuels
<b>SIDS</b>	Small Island Developing States
<b>SMEs</b>	Small and Medium Enterprises
<b>STO</b>	State Trading Organizations
<b>UNFCCC</b>	United Nations Framework Convention on Climate Change
<b>WBG</b>	World Bank Group
<b>WTE</b>	Waste-to-energy

# Table of Contents

1	Executive Summary	6
2	Introduction	13
3	GHG emissions portfolio and baseline trajectories till 2030	15
4	Maldives' investment framework for Net Zero	17
4.1	Electricity	18
4.1.1	Potential technology options	19
4.1.2	Net-zero investment framework	22
4.2	Transport	24
4.2.1	Potential technology options	24
4.2.2	Net-zero investment framework	28
4.3	Waste	30
4.3.1	Potential technology options	31
4.3.2	Net-zero investment framework	32
4.4	Others	33
4.4.1	Potential technology options (residential and tourism energy use)	33
4.4.2	Net-zero investment framework (residential and tourism energy use)	34
4.4.3	Potential technology options (fisheries energy use)	35
4.4.4	Net-zero investment framework (fisheries energy use)	35
5	Resource mobilization	36
6	Institutional Framework	38
7	Way Forward	40
8	Annexures	<b>Error! Bookmark not defined.</b>



# I Executive Summary

Globally, climate change continues to advance, with disproportionate impacts on the most vulnerable. The United Nations' Intergovernmental Panel on Climate Change (IPCC) Report 2022 states that the negative impacts of climate change are mounting much faster than scientists predicted less than a decade ago, with many such impacts being unavoidable and expected to hit the world's most vulnerable populations the hardest.

The Republic of Maldives is one of such highly vulnerable country to the impacts of climate change, even though the country's contribution in the overall global emission is minimum. Over 80% of the land area in Maldives is less than one meter above sea level. Its fragile ecological profile and low elevation, combined with its economic dependence on a limited number of blue economy sectors (fisheries and nature-based tourism) makes it highly and disproportionately vulnerable to extreme climate events<sup>1</sup>. A sea level rise of even a meter can lead to loss of almost entire land area of Maldives. Therefore, strengthening adaptation and developing resilience is a top priority for Maldives particularly for infrastructure resilience, food and water security, systematic observation and early warning etc. as identified in its Nationally Determined Contributions (NDC). While Maldives is continuously working to increase its climate resilience, it wants to reduce its own emissions that are largely caused by fossil fuels – imported for its power and transport sectors.

At present, the country is highly dependent on fossil fuels that contribute to ~99% of its energy mix. If Maldives continues to rely on fossil fuels going forward, its GHG emissions are likely to double by 2030 (~1,900 ktCO<sub>2</sub>e in 2020 to ~3,500 ktCO<sub>2</sub>e in 2030). Given that all fossil fuels used in the country are imported, it could have a significant impact on Maldives' economy and energy security as well. Therefore, mitigating the impacts of climate change is critical for the Maldives.

In recognition of these threats, the Government of Maldives (GoM) is actively driving policy agenda on climate change to ensure a safe, sustainable, resilient, and prosperous future for its citizens. At the United Nations Climate Ambition Summit in December 2020, Maldives made a commitment to strive towards achieving net-zero status by 2030 with extensive international support. Thereafter, the country's Nationally Determined Contribution (NDC) has been updated to reflect this commitment, with an aim to increase the share of renewable energy, reduce grid losses, establish efficient transport management system, establish, and integrate waste-to-energy plants, ensure climate proofing of critical infrastructure, among others.

Transitioning to renewable energy will help Maldives achieve the ambitious mitigation target in its revised NDC. In the 2020 update of the NDC, Maldives made ambitious plans to reduce emissions by 26% by 2030 through increased use of renewable energy sources<sup>2</sup>. Renewable sources of energy like solar PV not only provides an opportunity for decarbonizing the electricity sector, but also in achieving energy security on account of lower dependence on fuel imports.

The World Bank Group (WBG) has been a long-standing partner of the GoM in facilitating renewable energy projects and is committed to support the net zero transition. The World Bank and the GoM bring in extensive experience of implementing key projects across infrastructure development, clean energy, climate, and adaptation space. Building on the success of the partnership, the WBG and the GoM approved a new project titled Accelerating Renewable Energy Integration and Sustainable Energy (ARISE) in December 2020. The ARISE project has been developed taking into cognizance the country's

<sup>1</sup> World Bank. 2021. World Bank Climate Change Action Plan 2021-25. <https://openknowledge.worldbank.org/bitstream/handle/10986/36321/164599.pdf>.

<sup>2</sup> WWF. NDC Checklist for Maldives. [https://wwfint.awsassets.panda.org/downloads/ndcs\\_we\\_want\\_checklist\\_the\\_maldives.pdf](https://wwfint.awsassets.panda.org/downloads/ndcs_we_want_checklist_the_maldives.pdf)



commitments, policies and regulatory frameworks, investor requirements and the local financial landscape to support decarbonization across key sectors.

This investment framework has been prepared under the ARISE project of the WBG to showcase a plausible investment framework for the Maldives in its transition towards a net-zero economy, highlighting key sector level investments and associated emission reduction pathways. The investment framework aims to showcase potential private sector investors and international donors about specific technologies across key sectors and the scale of investment required in the form of international support and assistance for Maldives to achieve its ambition towards a net-zero economy.

The net zero ambition for Maldives is expected to deliver many benefits for the country and its citizens, from reduction in fuel import costs to reduced emissions and local air pollution, and its associated health benefits. For the world, it showcases the intent and ambition to lead the path towards a net zero future in collaboration and support of the international community.

For the net zero ambition, the focus sectors in the Maldives includes electricity generation, transportation, waste management and others.

With strategic interventions across key sectors, the combined investment estimate for achieving net-zero is expected to be in the range of **~USD 4.0 – 5.9 billion**, subject to detailed techno-commercial feasibility studies. Table below provides a summary of the indicative investment requirement.

Table ESI: Maldives' net-zero investment requirements by 2030

Sector		Indicative investment requirements (USD mn)
Electricity	Direct	3,000 – 4,000
	With decarbonization of transport and cooking (@10-20%)	300 – 800
Transport	Land	243 – 463
	Sea	116 – 234
	Aviation	189 – 200 <sup>3</sup>
Waste/		160 - 165
Others	Residential and tourism LPG use	10.5
	Fisheries	Included in sea transport
<b>Total (round-off)</b>		<b>4,000 – 5,900</b>

**Electricity generation** is a high emission intensive sector in the country, accounting for ~58% of the overall emissions in 2020. Decarbonization of the electricity sector can play the single largest role in reducing emissions and contribute to Maldives' 2030 net-zero target. Cost degression of renewables, battery storage and other clean technologies not only provide an option to decarbonize the sector, but also provide an opportunity to address crucial issues of energy security, affordability, employment generation etc. In the absence of any constraints, it might be possible to serve the energy demand using solar and battery storage systems in Greater Male, resorts, and other islands. An energy system designed on solar and battery storage besides bearing the maximum emission reduction impact also assures energy security and price certainty. Basis this, the investment required till 2030 for achieving net-zero in the electricity sector is expected to be in the range of **~USD 3.3 – 4.8 billion**, subject to detailed techno-commercial feasibility studies.

The **transport sector** accounts for 30% of the country's total GHG emissions, with marine transport being the major contributor, responsible for ~52% of transport emissions. Road transport and aviation account for ~21% and ~27% of the transport sector's emissions respectively. Accordingly, the investment

<sup>3</sup> For aviation segment, investment required is ~USD 68 million and annual operating expense required is ~USD 120 – 130 million



required for achieving net-zero in transport sector is expected to be ~**USD 430 - 760 million** along with an annual operating expense of ~**USD 120 – 130 million** for the aviation sector.

About 54% emission reduction may be achieved if 100% **waste** generated is treated by 2030. Residual emissions may still exist even with 100% treatment of waste generated by 2030, primarily due to the waste dumped at the landfill before 2030 that will continue to undergo anaerobic decomposition emitting methane (CH<sub>4</sub>) for another 10-20 years. Accordingly, the investment required for emission reduction from waste is expected to be ~**USD 160 - 165 million**.

Apart from fuel consumption in electricity and transport sectors, **energy use in residential and tourism sectors** include liquified petroleum gas (LPG) consumption for cooking and heating purposes. Most of the LPG imported by the country is used in cooking. Emissions from LPG consumption contribute to about 2% of the total GHG emissions in the Maldives.

Thus, the investment required for emission reduction through other interventions combined is expected to be ~**USD 22 - 42 million**. Table below showcases Maldives' sector-wise investment framework for net-zero from 2020 to 2030.

Table ES2: Maldives' sector-wise investment framework for Net-Zero, 2020-2030

Sector	Contribution to emissions (2030)	Abatement potential	Ease of implementation	Technology options			Investment requirement (USD mn)
				Immediate term	Medium term	Long term	
<b>Electricity Sector</b>							
Electricity Sector (Residential & Commercial Industrial & Resorts)	~56%	High	High	Solar + Battery Wind	Solar + Battery Wind	Solar + Battery Wind Hydrogen fuel cell	3,300 – 4,800
<b>Transport Sector</b>							
Land Transport	Passenger & Light Commercial	High	Moderate	Electric Vehicles	Electric Vehicles	FCEVs	234 – 463
	Heavy Duty						
Marine Transport	Tourism & Passenger	High	Low		Solar + Battery	Solar + Battery Other clean technologies	116 – 234
	Cargo					High	
Aviation		Moderate	Low		Electric SAF	Electric SAF NBS/Offsets	189 – 200 <sup>4</sup>

<sup>4</sup> For aviation segment, investment required is ~USD 68 million and annual operating expense required is ~USD 120 – 130 million



Sector	Contribution to emissions (2030)	Abatement potential	Ease of implementation	Technology options			Investment requirement (USD mn)
				Immediate term	Medium term	Long term	
<b>Waste</b>							
Waste	~8%	Moderate	Moderate	Waste Reduction Composting	Composting WTE (bio-methanation & incineration)	Composting WTE (bio-methanation & incineration) NBS/Offsets	160 – 165
<b>Others</b>							
Others	~4%	Moderate	Moderate	Cookstove Efficiency Standards Electric Cookstoves	RNG (Biogas) + Electric Cookstoves Solar fishing vessels	LPG Blending/ Replacing with Green Hydrogen Electric cookstoves	10.5

The success stories from the country's initial solar PV projects are testimony to the efforts and commitment of the GoM to meet its net-zero vision. Solar PV installation in the Maldives has grown at an annual rate of 45%-55% since 2016 and there are several more solar PV projects in the pipeline, in addition to other projects on battery storage, grid upgrades, etc. Maldives is also actively driving other initiatives such as the energy efficiency and waste-to-energy to reinforce the overall net-zero strategy. The WBG and GoM have been strong partners in facilitating such solar PV and clean energy projects.

The WB funded Accelerating Sustainable Private Investments in Renewable Energy (ASPIRE) project approved in May 2014, has been instrumental in kick-starting private sector investments in large-scale solar projects in the Maldives. Activities undertaken in Maldives were under the Solar Risk Mitigation Initiative (SRMI) that extends guarantees and technical assistance (TA) to deal with critical challenges such as grid integration, off-taker risk, and weak procurement and planning capacity. The SRMI framework for projects in Maldives facilitated (i) guarantees for Power Purchase Agreement termination risk, (ii) escrow account for payment security against payment delays, and (iii) tariff buy down to decrease upfront capital cost. With these risk mitigation instruments built in, the project realized one of the record lowest tariffs in the country.

In the recent auctions for solar PV projects, the prices for per unit of electricity have been discovered as USD 0.098/ kWh (fixed price for 15 years), down from the earlier discovered price of USD 0.21/ kWh. The prices discovered for solar capacities are significantly lower than the costs of generation from diesel which range between USD 0.23/kWh and USD 0.33/kWh in the most efficient case and go up to USD 0.70/ kWh for some of the smaller inhabited islands. With further advances in solar technology, the per unit electricity prices for solar generation are expected to go down further. As such **solar installations not only provide an opportunity for decarbonizing the electricity sector, but they also provide an opportunity to achieve energy security on account of lower dependence on imports and extend a price assurance for a significantly longer time.**

Currently, Maldives has installed capacity of over 20 MW of renewables<sup>5</sup>, with additional on-going pipeline of projects totaling more than 45 MW. Going forward, the total electricity demand for Maldives is expected to increase from ~1600 GWh in 2020 to ~2700 GWh by 2030. This demand, when discounted by energy

<sup>5</sup> A Brighter Future for Maldives Powered by Renewables, Roadmap for the energy sector 2020-2030



efficiency of 15-20%, and grossed up with a loss estimate of ~25% (technical loss @ 20%, and distribution loss @ 5%) would translate into a requirement of ~2,900 GWh of electricity. At ~18% Capacity Utilization Factor (CUF), this translates into a solar PV installation of ~ 1.6-2.0 GW and assuming ~60% of the demand to be met by battery storage, this translates to a storage requirement of ~4-5 GWh. The table below highlights the electricity sector's indicative capacity and investment requirements by 2030.

Table ES3: Electricity sector's indicative capacity and investment requirements by 2030

Solar installations in MW <sup>6</sup>	Battery storage requirement in MWh	Solar Investments (USD Mn)	Storage Investments (USD Mn)	Total Investments (USD Mn)
~1,600-2,000	~4,000-5,000	~1,800 – 2,000	~1,200 – 2,000	~3,000-4,000

The decarbonization measures in other sectors such as electrification of road transport and cooking might result in a slightly increased demand by ~10-20% and it is recommended that the incremental electricity demand be served using environmentally benign sources. Accordingly, the investment layouts may also increase by ~10-20% to **~USD 3,300 – 4,800 million**. Other technologies such as wind energy, ocean energy, wave, and tidal energy, etc., are also covered in the report, which may be considered over medium to long term when economic feasibility and/or commercialization is achieved.

In the transportation sector, land transport presents higher potential for decarbonization on account of the presence of relatively mature technologies such as electric vehicles. In the marine and aviation segment, there are emerging initiatives and technologies such as sustainable aviation fuel, solar boats, and planes, etc. which are awaited to reach commercial scale. The transport sector's indicative investment requirement by 2030 is showcased below.

Table ES4: Transport sector's indicative investment requirements by 2030<sup>7</sup>

Particulars	Vehicle Stock Estimates (2030)	Indicative investment (USD mn)
<b>Land Transport</b>		<b>243 - 463</b>
Electric Vehicles	<ul style="list-style-type: none"> <li>2-Wheelers – 96,399</li> <li>Passenger Cars – 8,105</li> <li>Light Commercial Vehicles – 3,502</li> <li>Heavy Duty Vehicles – 909</li> <li>Buses – 2,552</li> </ul>	160 - 306
Fuel Cell Electric Vehicles	<ul style="list-style-type: none"> <li>Light Commercial Vehicles – 1,501</li> <li>Heavy Duty Vehicles – 2,120</li> </ul>	83 - 157
<b>Sea Transport</b>		
Electric	<ul style="list-style-type: none"> <li>Solar Boats - 4,860</li> </ul>	116 - 234
<b>Aviation</b>		<b>189 – 200*</b>
Fuel	<ul style="list-style-type: none"> <li>SAF</li> </ul>	114
Electric	<ul style="list-style-type: none"> <li>Sea Planes (Passenger and Cargo combined)</li> </ul>	68
<b>Total Transport (CAPEX)</b>		<b>424 - 757</b>
<b>Total Transport (OPEX)</b>		<b>124 - 139</b>

<sup>6</sup> The solar capacity indicated here is the estimated solar installation required to meet the net zero goal, considering electricity demand and growth scenario. As indicated in other parts of the report, this is a high-level estimate, which needs to be followed by detailed techno-commercial studies to validate these estimates, and assess the real potential in Maldives considering availability of land, lagoons, and shallow waters for floating solar, grid infrastructure, etc.

<sup>7</sup> Please note that the increase in electricity demand because of electrification of the transport sector is covered in the section covering electricity. This includes the investment required to cater to the increase in electricity demand in the form of electricity capacity augmentation, system strengthening, transmission infrastructure, etc.



**Note:** Investment requirements are high level indicative numbers estimated using secondary research and need to be validated through detailed techno-commercial studies. \*Including 7-18 mn considered under offsets

In the waste sector, the suitable options for decarbonization includes recycling and reuse, composting, waste to energy and waste to hydrogen. The table below highlights the waste sector's indicative capacity and investment requirements by 2030

Table ES5: Waste sector's indicative capacities and investment requirements by 2030

Technology	Capacity (TPD)	Indicative investment requirement till 2030 <sup>a</sup> (USD mn)
Waste Minimization	-	0
Material recovery for recycling/reuse	62	0
Composting	244	~ 1.3
Bio-methanation	111	~ 2.3
WTE	640	~155
Offset	-	3 – 6
<b>Total</b>	-	<b>160 - 165</b>

Other areas that have been covered in this investment framework to support the net zero journey includes (i) efficiency in energy use in residential and tourism sectors for cooking purposes, such as adopting cookstove efficiency standards, promoting electric stoves over LPG stoves, green hydrogen blending with LPG, etc.; and (ii) efficiency in fisheries sector through solar powered fishing vessels, as well as use of electric induction stoves in fishing vessels for cooking purposes. The investment estimates for these are included within the electricity and transport sectors respectively.

To deliver the net zero agenda by implementing various net-zero strategies as highlighted above, a high-level institutional framework has been proposed. The key stakeholders have been categorized under the following:

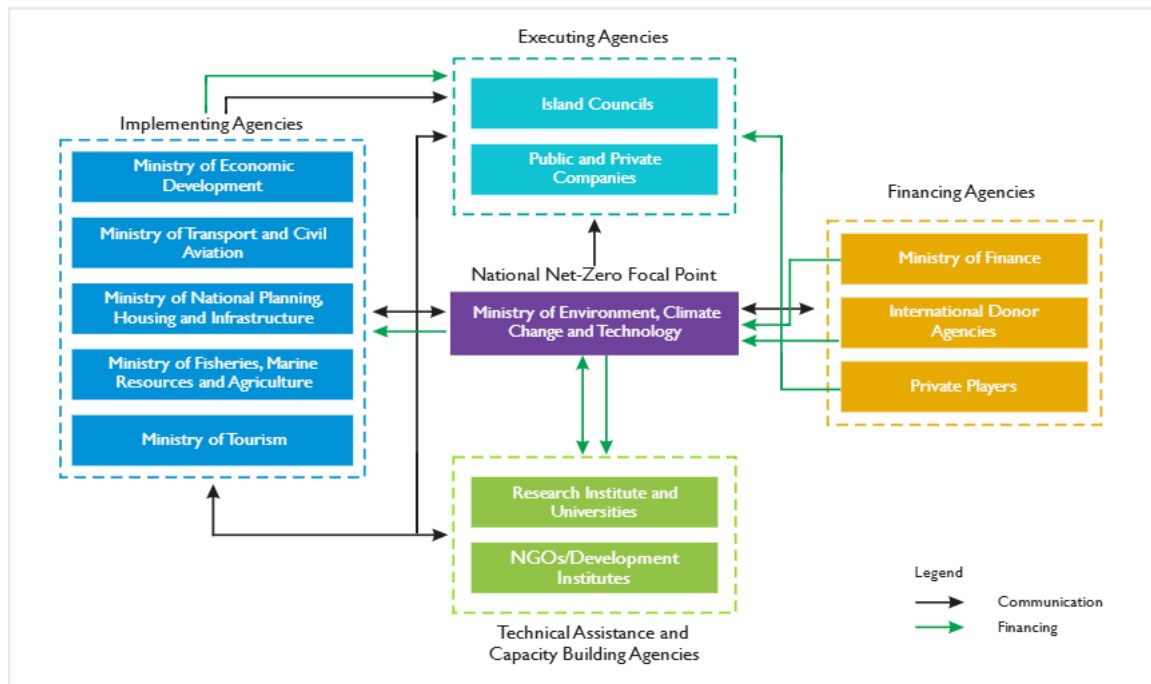
- **National net-zero focal point** responsible for implementing/overseeing the implementation of the proposed net-zero strategies.
- **Implementing agencies** responsible for designing and planning specific projects and strategies for implementation.
- **Executing agencies** responsible for implementing, regular monitoring of the progress of projects and reporting to respective implementing agencies.
- **Technical assistance and capacity building agencies** that can provide necessary technical assistance. **Financing agencies** that can support in financing/mobilizing financing for net-zero strategies.

Figure below shows potential institutional framework for Maldives' net-zero mission.

<sup>a</sup> Investment requirements are high level indicative numbers estimated using secondary research and need to be validated through detailed techno-commercial studies.



Figure ES1: Potential institutional framework for Maldives' net-zero mission



To sum up, this report is a joint effort by the Maldives government and the World Bank that puts forth an investment roadmap under the ARISE project that Maldives can leverage to begin its decarbonization journey with the aim of achieving net-zero status by 2030.

The ASPIRE project within the SRMI has supported the GoM in implementing solar projects to the tune of 17.5 megawatts. This is further being accelerated to scale up by an additional 25 MW of solar PV under ARISE project. Implementation of SRMI has led to an enabling environment for mobilizing private sector investments and improving project bankability. The lessons from Maldives' can also be integrated into the SRMI framework for the benefit of other small island developing states (SIDS).

For the Government of Maldives, the combined investment estimate for achieving net-zero is expected to be in the range of **~USD 4.0 – 5.9 billion**, subject to detailed techno-commercial feasibility studies<sup>9</sup>. Collaboration with various international donors and multilateral organizations will be critical in gaining access to requisite finance and undertake technical assistance for assessments as well as implementation. Additionally, successful implementation of this roadmap significantly hinges on the degree to which the private sector aligns its investments towards adopting technologies and commercialization of new and emerging clean technologies.

<sup>9</sup> The cost estimate is based on current prices, estimated sizing and penetration level, with an objective to bring down emissions to zero.

## 2 Introduction

Maldives is an island archipelago comprising of 1,192 coral islands grouped into 26 atolls, spread across roughly 115,300 square kilometers of Indian Ocean. Standing at an average elevation of 1.8 m above sea level, it is one of the lowest-lying countries, significantly vulnerable to the impacts of climate change.

Maldives is already facing an existential threat due to climate change with over 90% of its islands reporting annual flooding, 97% reporting shoreline erosion and 64% severe erosion<sup>10</sup>. This indicates that the situation in Maldives is alarming and needs immediate action. Further as per Intergovernmental Panel on Climate Change's (IPCC) sixth assessment report, global temperatures will rise by more than 2 degrees Celsius by 2100, unless rapid and deep reductions in GHG emissions occur in the coming decade, further exacerbating the impacts of climate change on the country<sup>11</sup>.



The Government Maldives (GoM) recognizes threats such as monsoon flooding, storms, coastal erosion, salt-water intrusion, and sea level rise. Coastal erosion from sea level rise and storms has increased over the recent decades. More than 80% of the islands face erosion issues, with about 30 islands currently identified as critically eroded. As a result, the GoM is actively driving international action to check climate change to ensure a safe, sustainable, resilient, and prosperous future for its citizens. At the United Nations Climate Ambition Summit in December 2020, Maldives committed to achieve net-zero status by 2030, with extensive international support.

The success stories from the country's initial solar projects are testimony to the efforts and commitment of the GoM to meet its net-zero vision. Solar PV installation in Maldives has grown at an annual rate of

<sup>10</sup> There is no higher ground for us! Maldives' environment minister says country risks disappearing, Sustainable Future, in news channel CNBC, 2021

<sup>11</sup> Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC, 2021



45%-55% since 2016<sup>12</sup> and there are several more solar PV projects in the pipeline, in addition to other projects on battery storage, grid upgrades, etc. Maldives is also actively driving other initiatives such as the energy efficiency and waste-to-energy to reinforce the overall net-zero strategy.

The World Bank Group (WBG) has been a long-standing partner of the GoM in facilitating clean energy projects and is committed to support Maldives' net-zero transition. The WBG and the GoM bring in extensive experience of implementing key projects across infrastructure development, clean energy, climate, and adaptation space. Building on the success of the partnership, the WBG and the GoM approved a new project titled Accelerating Renewable Energy Integration and Sustainable Energy (ARISE) in December 2020. The ARISE project is about building resilience to climate change, natural hazards, and other intermittency caused by increasing electricity generation from renewable energy and to improve climate resilience by diversifying the energy mix and strengthening fiscal sustainability.

In this context, this investment framework has been prepared under the ARISE project of the WBG to showcase a plausible investment framework for the Maldives in its transition towards a net-zero economy, highlighting key sector level investments and associated emission reduction pathways. The investment framework aims to showcase potential private sector investors and international donors about specific technologies across key sectors and the scale of investment required in the form of international support and assistance for Maldives to achieve its ambition towards a net-zero economy.



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<sup>12</sup> Island Electricity Databook 2019

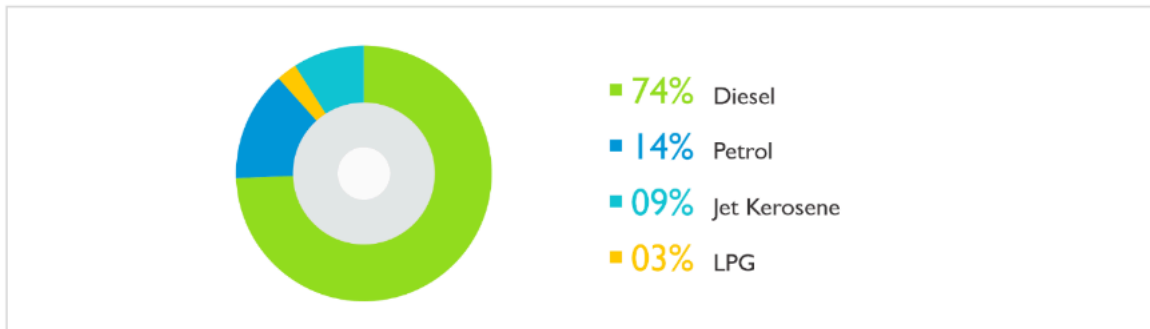


### 3 GHG emissions portfolio and baseline trajectories till 2030

Maldives is a highly fossil fuel dependent economy with fossil fuels contributing to ~99% of its energy mix. With fuel combustion being the main source of emissions in Maldives, diesel is the most prominent fuel used, followed by petrol, aviation fuel and LPG. Given that all fuels are imported into the country, fossil fuel use has a significant impact on the country's economy and energy security.

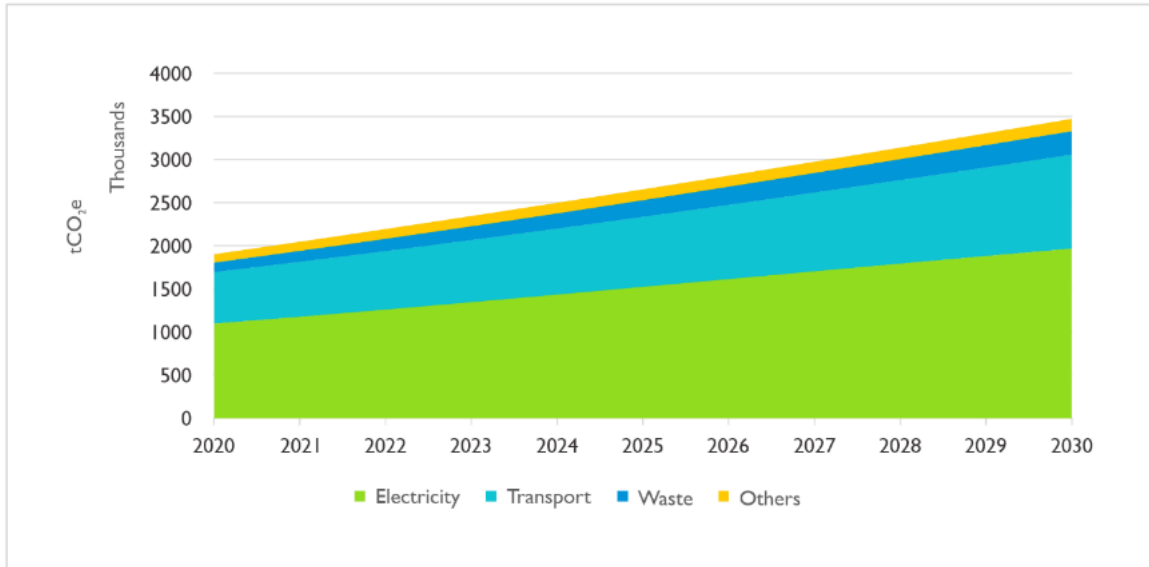
In 2020, GHG emissions in Maldives were ~1,900 ktCO<sub>2</sub>e, out of which ~95% was from energy consumption while the remaining 5% came from waste disposal. Within the energy sector, electricity production (58%) and fuel combustion in the transport sector (32%) are responsible for majority of the emissions. The remainder 5% is made up of emissions from other sectors such as residential and commercial LPG use, fisheries etc. Figure 1 showcases the graphical representation of breakdown of fuel use in Maldives in 2020.

Figure 1: Breakdown of fuel use in Maldives in 2020



Maldives' emissions are expected to increase to ~3,500 ktCO<sub>2</sub>e by 2030, if it continues to operate in its current fossil fuel rich “business-as-usual” (BAU) mode and does not begin transitioning to a path of low carbon development. In this regard, the chart in Figure 2 illustrates Maldives' likely GHG emissions trajectory from 2020 to 2030 under its current BAU scenario, broken down sector wise.

Figure 2: Sector-wise GHG emissions trajectory under BAU scenario, 2020-2030



- Electricity production:** Approximately half of the fuel imports (diesel) are used for electricity generation. With an estimated demand of 1,591 GWh in 2020, electricity demand is expected to increase to 2,666 GWh by 2030. Correspondingly, diesel consumption for electricity production is expected to increase from 377,000 tons to 677,000 tons, resulting in ~2,000 ktCO<sub>2</sub>e in 2030.
- Transport sector:** More than 40% of the fuel imports in Maldives are utilized in the transport sector. Diesel and petrol are the two prominent fuels used in the sector. This sector is expected to see an increase in emissions from ~600 ktCO<sub>2</sub>e in 2020 to ~1,100 ktCO<sub>2</sub>e in 2030.
- Waste:** With unabated open burning and disposal of municipal and tourist related waste, emissions are likely to see an increase from ~100 ktCO<sub>2</sub>e in 2020 to ~300 ktCO<sub>2</sub>e in 2030.
- Others:** Emissions also occur from the use of LPG for cooking in domestic households and commercial resorts, from consumption of diesel, LPG, and kerosene in Maldives' fishing industry. These emissions can see an increase from ~100 ktCO<sub>2</sub>e in 2020 to ~150 ktCO<sub>2</sub>e by 2030.



## 4 Maldives' investment framework for Net Zero

A net zero investment framework has been suggested for Maldives that provides an indicative view of the investment requirements for reaching net zero emission across the different sectors considered as part of this study. Based on the projected BAU emission trajectories and an assessment of current and potential decarbonization technologies available in the market, the following net-zero investment framework has been proposed for the Maldives. Table 1 below summarizes the sector wise investment requirements, abatement potential, and proposed technology options.

Table 1: Maldives' sector-wise investment framework for Net-Zero, 2020-2030

Sector	Contribution to emissions (2030)	Abatement potential	Ease of implementation	Technology options			Investment requirement (USD mn)
				Immediate term	Medium term	Long term	
<b>Electricity Sector</b>							
Electricity Sector (Residential & Commercial Industrial & Resorts)	~56%	High	High	Solar + Battery Wind	Solar + Battery Wind	Solar + Battery Wind Hydrogen fuel cell	3,300 – 4,800
<b>Transport Sector</b>							
Land Transport	Passenger & Light Commercial	High	Moderate	Electric Vehicles	Electric Vehicles	FCEVs	234 – 463
	Heavy Duty			Electric Vehicles	FCEVs		
Marine Transport	Tourism & Passenger	High	Low	Clean technology	Solar + Battery	Solar + Battery Other clean technologies	116 – 234
	Cargo				Clean technology NBS/Offsets		
Aviation		Moderate	Low	Electric SAF	Electric SAF	NBS/Offsets	189 – 200 <sup>13</sup>

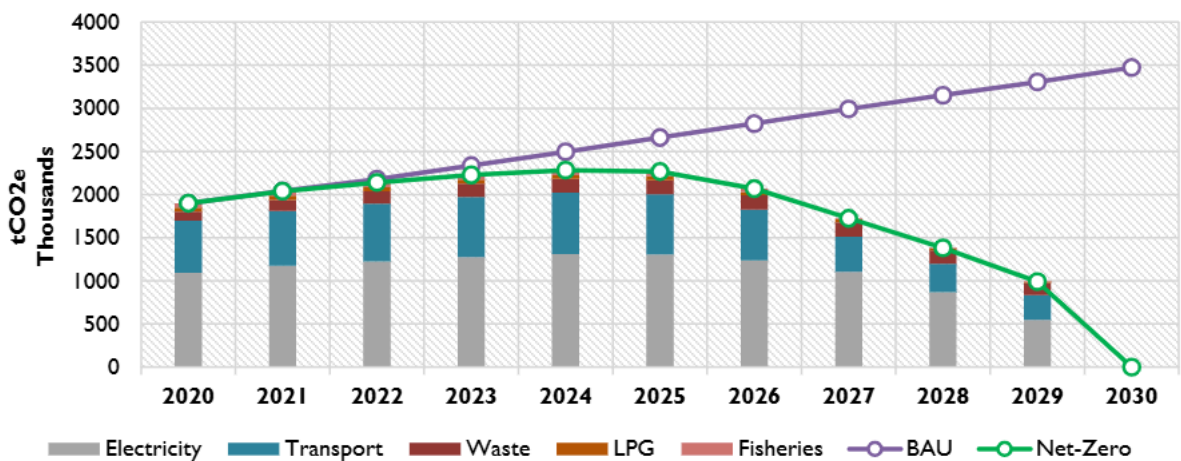
<sup>13</sup> For aviation segment, investment required is ~USD 68 million and annual operating expense required is ~USD 120 – 130 million



Sector	Contribution to emissions (2030)	Abatement potential	Ease of implementation	Technology options			Investment requirement (USD mn)
				Immediate term	Medium term	Long term	
<b>Waste</b>							
Waste	~8%	Moderate	Moderate	Waste Reduction Composting	Composting WTE (bio-methanation & incineration)	Composting WTE (bio-methanation & incineration) NBS/Offsets	160 – 165
<b>Others</b>							
Others	~4%	Moderate	Moderate	Cookstove Efficiency Standards Electric Cookstoves	RNG (Biogas) + Electric Cookstoves Solar fishing vessels	LPG Blending/ Replacing with Green Hydrogen Electric cookstoves	10.5

Through these investments and associated interventions, Maldives could potentially achieve net-zero status by 2030 as illustrated in figure 3 below:

Figure 3: Maldives' net-zero GHG emissions trajectory, 2020-2030



Details of sector level investment frameworks and potential GHG emission trajectories have been provided in the subsequent sections.

## 4.1 Electricity

The electricity sector is the largest contributor of emissions in Maldives accounting for 58% of the country's total emissions in 2020. Given the dominant share of electricity in the country's GHG emissions profile and its cascading impact on emissions from sectors such as transport (transportation of fuel across the islands), it is imperative that the sector is decarbonized to the maximum possible extent. This need is further accentuated



by the fact that options for decarbonization in the electricity sector are currently available with demonstrated cost economics, whereas abatement options for other sectors like marine transport, heavy duty land transport, aviation etc. are currently limited and may take considerably longer to evolve and become viable.

Decarbonization of the electricity sector is expected to play the single largest role in reducing emissions and contributing to Maldives' 2030 net-zero target. Falling cost of renewables, battery storage and other clean technologies such as green hydrogen not only provides an option to decarbonize the sector, but also provides an opportunity to address crucial issues of energy security, affordability, employment generation etc. Besides amendment of the production functions to replace fossil fuel-based sources with cleaner sources of energy, energy efficiency measures are also expected to be an integral part of the decarbonization equation.

#### 4.1.1 Potential technology options

The range of options that can be considered for the electricity sector, includes a mix of mature and emerging cutting-edge technologies to help mitigate emissions, which have been listed below in table 2:

Table 2: Potential technology options - Electricity Sector

Technology	Potential	Usage	Current Deployment Status	Considerations / Challenges	Implementation Timeframe
Solar	Solar radiation of 1,200 Kwh/m <sup>2</sup> /year	PV panels installed on roofs, power plants, desalination plants, sewage plants and public buildings	High	Land unavailability, potential effects of salinity over solar panels, lack of economies of scale	Immediate term
Wind	Wind speed recorded – 5.69 m/s in Naifaru and 5.73 m/s in Gulhifalu	Small wind turbines for power generation	Low	Offshore wind projects not economically viable as wind resources are not equally distributed across country	Long Term
Ocean Energy	In selected channels, currents having a speed of 1.5-2.6 m/s have been observed	Specific to resort islands mainly catering to cooling demands, laundry, desalination plants.	Low	Expensive and emerging technology, yet to achieve commercial viability	Long Term
Wave and Tidal Energy	Wave and Tidal Energy is picking up globally and is a promising technology for a long-term solution		Low		Long Term



Technology	Potential	Usage	Current Deployment Status	Considerations / Challenges	Implementation Timeframe
Battery Energy Storage	Surplus RE can be stored and utilized during non-RE hours	For energy shifting applications	Low	Battery energy systems are currently expensive and are expected to become cheaper by the decade	Medium term
Green hydrogen fuel	Surplus RE can be used to make hydrogen using electrolysis	Hydrogen as a fuel for vehicles, ammonia production etc.	Low	Production of green hydrogen is a capital-intensive process	Long Term
Energy Efficiency (EE)	Energy demand in residential and tourism segment can be significantly reduced	Electric appliances	Low	Most studies indicate significant emission reduction potential; EE measures typically require lower investments	Immediate Term

- Solar Photovoltaic:** Solar energy appears to be the most abundant source of renewable energy in Maldives. The solar radiation in Maldives is of the order of 1,200 kWh/sq m/year. In recent auctions, the prices for energy generation from solar have been discovered as USD 0.109/ kWh (fixed price for 15 years), down from the earlier discovered price of USD 0.21/ kWh. The prices discovered for solar capacities are significantly lower than the costs of generation from diesel which range between USD 0.23/kWh and USD 0.33/kWh in the most efficient case and go upto USD 0.70/ kWh for some of the smaller inhabited islands<sup>14</sup>. With further advances in solar technology, the costs are expected to go down further. As such **solar installations not only provide an opportunity for decarbonizing the electricity sector, but they also provide an opportunity to achieve energy security on account of lower dependence on imports and extend a price assurance for a significantly longer time.** The World Bank's ASPIRE projects have given the sector the right momentum with total of projects of ~ 18.5 MW solar PV awarded, and now, ARISE project coming up with an immediate pipeline of 25 MWs of solar PV.

As indicated above, while there is adequate solar irradiance potential in the country, the economic potential or the potential for solar capacity is not well established, considering aspects such as availability of space, grid infrastructure and others. Similarly, the theoretical potential for deployment of floating solar PV appears abundant, however its economic potential is unknown.

<sup>14</sup> Road Map for the Energy Sector 2020-2030, ADB

\* CUF means the ratio of the actual output from a solar plant over the year (kWh) to the maximum possible output from it for a year (kWh) under ideal conditions.  $CUF = \text{Actual Plant Output in kWh over the year} / (\text{Installed Plant Capacity in kWp} \times 365 \times 24)$ .



The total electricity demand for Maldives is expected to reach ~2700 GWh by 2030 from ~1600 GWh in 2020. This demand, when discounted by energy efficiency of 15-20%, and grossed up with a loss estimate of ~25% (technical loss @ 20%, and distribution loss @ 5%) would translate into a requirement of ~2,900 GWh of electricity. At ~18% Capacity Utilization Factor (CUF), this translates into a solar PV installation requirement of ~2,000 MW. With land requirement for 1 MW ground mounted solar installations at around 10,000 sq m, the total solar installations would amount to ~6-7% of the land area (assuming total land area of ~298 sq km) in Maldives. Hence to achieve this ambition and scale, it is important to scale up floating solar PV deployments.

Therefore, avenues for large scale deployment of floating solar PV need to be explored in conjunction with opportunities for deployment of ground mounted solar and rooftop solar, considering all constraints. In this regard, a number of floating solar projects, with cumulative capacity exceeding 20 MW (including 10 MW in the islands of Addu-Mainland and Addu-Hulhumeedhoo under ARISE project) are under discussion and/or advance stage of procurement. It may be noted that the capital expenditure for floating solar is seen to be more than that of ground mounted solar in most cases, when all other conditions are same. However, detailed studies need to be done to compare the ground mounted and floating solar plants in Maldives in granularity, including cost comparison on a per unit basis.

Policies incentivizing solar rooftop like net metering are in place and can contribute towards meeting net-zero targets. The Strategic Action Plan (2019-2023) postulates a target of 10 MW solar PV to be installed under net metering by 2023, which can be scaled up further till 2030, facilitated by net metering regulations.

- **Wind Energy:** The deployment of large-scale onshore wind energy may be limited in Maldives primarily on account of less than desirable wind speeds, space constraints and small grid sizes. Studies indicate that wind projects with 2 MW turbines may be deployed for the industrial islands in the Greater Male' region with an estimated potential of ~80 MW<sup>15</sup>. As per Asian Development Bank (ADB) reports, current offshore wind technologies do not appear to be economically feasible for Maldives. The Greater Male' Region is the only possible demand center with sufficient electricity demand to absorb power from offshore wind projects, however, the seawaters in the Greater Male' Region are very deep, and the atolls exhibit sharp slopes causing challenges for the foundations of the turbines. In case technical feasibility is established, it might be prudent to explore opportunities to scale up offshore and onshore wind projects in the Greater Male Region, along with evaluation of financing mechanisms such as capital subsidies to offset initial investment costs, low-cost financing, etc. to overcome commercial barriers.
- **Ocean Energy:** Ocean energy could be one of the possible alternative sources of energy for Maldives. Ocean energy sources, in contrast to wind and solar technologies which are characterized by variability, are expected to deliver continuous output. As such deployment of technologies to harness ocean energy may obviate battery storage requirements. The potential for Ocean Thermal Energy Conversion (OTEC) which uses the difference in surface and deep-water temperature of the ocean to produce electricity may also be explored, though there might be challenges on account of adverse environmental conditions increasing the stress on OTEC platforms. Potential assessments for most ocean energy sources are at very nascent stages and most of these technologies are yet to reach commercialization. This technology is currently at a nascent stage and can be explored over the next decade as a potential option for decarbonization considering its huge potential. In the interim, pilot projects may be considered to establish use cases and enable scale-up.
- **Wave and Tidal Energy:** The potential for tidal energy may also be explored in Maldives, utilizing access to ocean tides and currents. The global wave and tidal energy market is an emerging area and is projected to grow significantly over the next decade. In 2021, 1.38 MW of wave energy came online,

<sup>15</sup> Road Map for the Energy Sector 2020-2030, ADB



while 3.12 MW of tidal stream capacity was installed. According to Globe Newswire<sup>16</sup>, the global wave and tidal energy market is projected to grow from \$0.47 billion in 2021 to \$4.41 billion by 2028. This technology can be explored over the next decade, while for now, pilot projects may be taken up to establish use cases and test technologies.

- **Battery Storage:** Over the past few years, Battery Energy Storage Systems (BESS) have experienced a rapid decline in costs, mirroring the learning curves seen in renewable technologies like wind and solar PV. With further decline in costs, battery energy storage systems may offer significant opportunities to serve demand throughout the day using renewables. The increasing penetration of renewable energy to meet net-zero targets and focus on electrification of mobility may further accelerate BESS cost declines, with expectations of ~50% drop from current levels. With falling costs of battery and solar PV, it might be possible to design energy systems which can serve a large fraction of electricity demand at competitive prices.
- **Green Hydrogen Fuel:** Electricity generation from hydrogen is largely driven by the costs of green hydrogen, hydrogen transportation and fuel cells. The cost of electrolysis has seen a steep decline since 2010, falling by about 60% which has resulted in a decline in green hydrogen prices from USD 10 - 15/kg to as low as USD 4/kg and is expected to fall significantly going forward. The costs of hydrogen tankers and fuel cells are also expected to drop by ~70% by the end of the decade. Hence, green hydrogen and fuel cells-based electricity can be sought out as a possible solution towards the latter half of the decade. This solution can be deployed along with solar + battery to provide a techno-commercially optimized solution, especially for the islands.
- **Energy Efficiency:** Energy Efficiency is expected to be a crucial element in the journey to achieve net-zero targets without hindering progress or lifestyles, at significantly lower costs compared to creation of physical infrastructure for meeting energy demands. The electricity demand in Maldives originates primarily from residential and tourism sectors, which can contribute significant savings through adoption of energy efficiency measures like building energy efficiency codes, use of energy efficient appliances, etc. Digital solutions like smart metering, automation of distribution systems, etc. can help in reduction of distribution losses and aid in accommodating growing shares of renewables. For example, using energy efficient ACs, refrigerators and lighting, Maldives can save anywhere between 666 GWh to 918 GWh<sup>17</sup> by 2030.

#### 4.1.2 Net-zero investment framework

In the absence of any constraints, it might be possible to serve the energy demand using solar and battery storage systems in Greater Malé, resorts and other islands. An energy system designed on solar and battery storage besides bearing the maximum emission reduction impact also assures energy security and price certainty. Solar, being the dominant source of renewable energy in Maldives, can be chosen as the primary source and other sources of renewable energy such as wind, ocean and biomass energy could continue to contribute at the margins, scaling up as and when technical viability is established through studies.

Though a system designed on solar and battery storage is desirable, there might be challenges in deployment of solar PV at the required scale. The lack of resource potential studies for Maldives in public domain makes feasibility assessment of configurations of such systems a challenging task. However, general indications point towards possible physical limitations with Greater Malé Region facing greater technical and economic hurdles compared to the other islands. Limitations in space availability may necessitate evaluation of deployment of floating solar PV at scale. While the theoretical potential for floating solar PV is huge, its techno-commercial feasibility needs to be assessed. Since the Greater Malé region has an estimated wind potential of ~80 MW,

<sup>16</sup> Globe Newswire is one of the world's largest newswire distribution networks, specializing in the delivery of corporate press releases, financial disclosures and multimedia content to media, investors, and consumers worldwide.

<sup>17</sup> Calculated from Maldives first Biennial Update Report which estimates annual electricity savings between 250GWh by 2030 due to the introduction of the standard and labelling program for electrical appliances. In addition to this, it is also assumed that the adoption of energy efficient star rated appliances (most prominently ACs, refrigerators and LED lights) would increase at the rate which could further propel significant electricity savings as presently there are no labelled appliances in the country.



wind energy may also be used subject to techno-commercial feasibility. Additionally, potential for deployment of offshore wind technologies including floating wind technologies may also be explored. Further, grid upgradation may also be necessary for deploying the renewable energy systems which needs to be ascertained through detailed technical studies.

An entirely renewables driven system may be vulnerable on account of weather undulations such as cloudy days wherein solar outputs may not be commensurate with demands. The deployment of solar along with battery storage systems may support to an extent in these conditions to serve electricity demand. However, in the interim, some of the existing diesel systems may also compliment as capacity support in times of system stress. With less diesel dependency, the requirement of transporting diesel across the islands is also reduced resulting in considerable reduction in emissions on sea transport. Further, lesser diesel dependency also mitigates the risk of spills during transportation and avoids undesirable consequences for Maldives’ marine ecosystem.

Accordingly, the emissions from solar + battery system are expected to be lower by ~100% compared to the BAU scenario with a cascading emission reduction in other sectors such as sea transport. Additionally, the new solar + battery system designed on the back of locally available energy sources will create employment opportunities, foster the energy security of the nation on account of reduced dependency on imports and provide long-term price guarantee on electricity generation costs.

Although the entire demand can be met using solar and battery technology if there are no constraints, other technological options like wind, biomass, etc. can also be considered subject to validation of their techno-commercial feasibility. Hydrogen can also be a source of energy for meeting demand growths beyond 2030. Hydrogen fuel cells may be capable of serving baseload demand, and depending on developments in this space, hydrogen-based technologies can be included in the supply mix to support solar and storage systems.

The summary of the supply options in Greater Malé region, other inhabited islands and resorts and industrial islands is as follows in table 3.

Table 3: Summary of supply options by 2030

Greater Malé	Other Inhabited Islands	Resorts and Industrial Islands
<ul style="list-style-type: none"> <li>• Solar</li> <li>• Battery</li> <li>• Wind</li> </ul>	<ul style="list-style-type: none"> <li>• Solar</li> <li>• Battery</li> </ul>	<ul style="list-style-type: none"> <li>• Solar</li> <li>• Battery</li> </ul>

In the presence of constraints, options like hydrogen fuel cells using Green Hydrogen may be explored. However, large scale deployment of hydrogen fuel cells is yet to achieve maturity and developments in this space need to be monitored closely along with timely actions for inclusion in the supply mix. Options for deployment of onshore and offshore wind projects in the Greater Malé Region may also be explored alongside evaluation of deployment possibilities for floating wind technologies.

The primary objective should be to meet demand using environmentally benign sources of energy such as renewables, green hydrogen-based technologies, etc. and only in case of severe technical limitations, other options may be explored.

#### 4.1.2.1 Investment requirement till 2030

Decarbonization of the electricity sector can be achieved using solar and battery technologies provided technical feasibility for floating solar technology at scale is established to overcome limitations posed by space constraints for ground-mounted or rooftop solar. Since the Greater Malé region has an estimated wind potential of ~80 MW, wind energy may also be used provided techno-commercial feasibility is proven. Detailed assessment should be made for offshore wind potential including floating wind technologies. If the potential



for renewables appears limited on account of technical constraints such as land availability, other options such as hydrogen fuel cells, etc. may be explored.

For an electricity system based on solar plus storage, the investment required till 2030 is expected to be in the range of ~ USD 3 - 4 billion as highlighted in table 4 below, subject to a detailed techno-commercial feasibility study.

Table 4: Electricity sector's indicative capacity and investment requirements by 2030

Solar installations in MW <sup>18</sup>	Battery storage requirement in MWh	Solar Investments (USD Mn)	Storage Investments (USD Mn)	Total Investments (USD Mn)
~1,600-2,000	~4,000-5,000	~1,800 – 2,000	~1,200 – 2,000	~3,000-4,000

The decarbonization measures in other sectors such as electrification of road transport and cooking might result in a slightly increased demand by ~10-20% and it is recommended that the incremental electricity demand be served using environmentally benign sources. Accordingly, the investment layouts may also increase by ~10-20% to **~USD 3,300 – 4,800** million.

The above capacity configurations and corresponding investment requirements as shown in table 4 are only indicative in nature derived using aggregate and representative estimates of energy demand, average hourly consumption profile, average solar generation profile, technical losses, ballpark capital costs, impact of energy efficiency, etc. Assessment of exact capacity and investment requirements will necessitate detailed and granular technical-commercial studies. The investment and capacity requirements in case constraints are activated would be contingent on the degree of renewable resource deployment, feasibility of other alternatives, etc., and hence has not been assessed under the scope of this report.

## 4.2 Transport

The transport sector accounts for 30% of the country's total GHG emissions, with marine transport being the major contributor, responsible for ~52% of transport emissions. Road transport and aviation account for ~21% and ~27% of the transport sector's emissions respectively. Going forward, under the BAU scenario, emissions from the transport sector are expected to increase from ~600 ktCO<sub>2</sub>e in 2020 to 1,100 ktCO<sub>2</sub>e by 2030 at a compound annual growth rate (CAGR) of 6.2%. As the second largest contributor of emissions in the country, developing the right strategy to achieve net-zero status in the transport sector is paramount.

### 4.2.1 Potential technology options

The range of options that can be considered for the transport sector have been listed below in table 5:

Table 5: Potential Technology Options – Transport

Technology	Usage	Current Deployment Status	Considerations / Challenges	Implementation Timeframe
<b>Land Transport</b>				
Electric Vehicles	2-wheelers (including both scooters and motorcycles), passenger cars, urban buses, and light commercial vehicles	Increase in sales and registration of battery scooter, battery car and electric bicycle have been observed	Supporting ecosystem needs to be developed for improving the penetration	Immediate Term

<sup>18</sup> The solar capacity indicated here is the estimated solar installation required to meet the net zero goal, considering electricity demand and growth scenario. As indicated in other parts of the report, this is a high-level estimate, which needs to be followed by detailed techno-commercial studies to validate these estimates, and assess the real potential in Maldives considering availability of land, lagoons, and shallow waters for floating solar, grid infrastructure, etc.



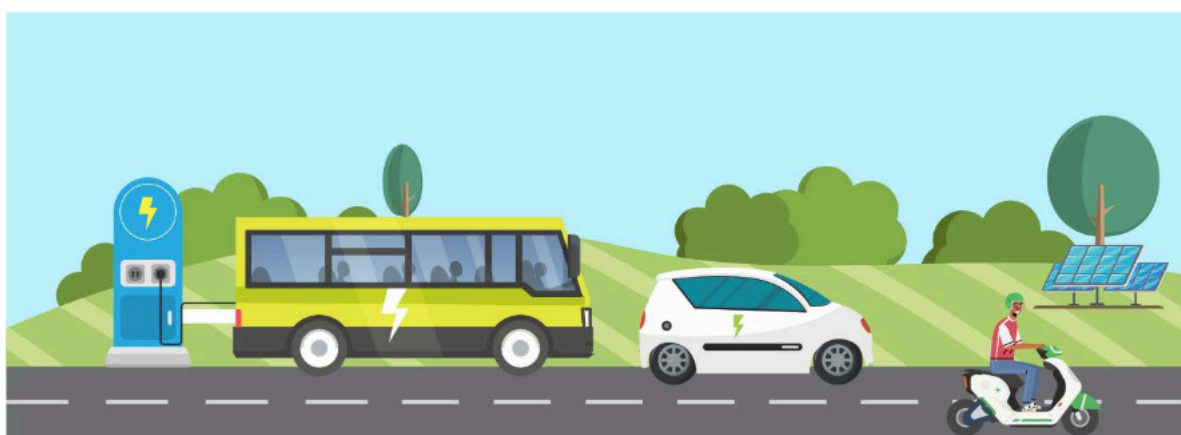
Technology	Usage	Current Deployment Status	Considerations / Challenges	Implementation Timeframe
Fuel Cell Electric Vehicles	Heavy duty and long-distance vehicles	-	Availability of hydrogen ecosystem is a key constraint	Immediate to Medium Term
Energy Efficiency	Existing vehicle fleet	-	Additional expenditure is needed to make the powertrains efficient	Immediate Term
Public and Active Transportation	Active transport modes such as cycling, and walking offer health benefits	-	Awareness of the health and decarbonization benefits	Immediate Term
Biofuels	For use in existing / new vehicle fleets	-	Availability of good quality biofuel is a key concern	Immediate to Medium Term
<b>Marine Transport</b>				
Energy Efficiency	Existing vessel fleet	-	Most studies indicate significant demand reduction at minimal expenditure	Immediate Term
Solar Boats	Existing vessel fleet can be retrofitted with solar	-	Significant emission reduction is observed; However, retrofitting may be expensive	Immediate Term
Electricity Boats	Replacement of existing vessels with electric boats	-	Technology and commercial maturity are yet to be achieved	Long Term
Green Hydrogen	Usage of green hydrogen as fuel in vessels	-	Expensive to store; Commercial maturity yet to be achieved	Long Term
Green Ammonia	Usage of green ammonia as fuel in vessels	-	Easier to store; But technology and commercial maturity yet to be achieved	Long Term
Biofuels	For use in existing / new vessel fleets	-	Availability of quality biofuel is a key concern	Immediate to Medium Term
Synthetic Fuels	For use in existing and new vessel fleets	-	Technological maturity is yet to be achieved	Long Term
Other Emerging Technologies (Kite, Flettner rotor)	To aid in energy demand reduction in existing vessels	-	Technical and commercial feasibility needs to be assessed	Long Term
<b>Air Transport</b>				
Sustainable Aviation Fuel	As a substitute for existing fuel	-	Technology is evolving and commercial feasibility needs to be improved	Medium Term



Technology	Usage	Current Deployment Status	Considerations / Challenges	Implementation Timeframe
Synthetic Fuels	As a substitute for existing fuel	-	Technology is not mature	Long Term
Electric Aircrafts	As a substitute for existing fuel	-	Technology is not mature	Long Term
Hydrogen Aircrafts	As a substitute for existing fuel	-	Technology is not mature	Long Term

#### 4.2.1.1 Land Transport

Out of 108,532 vehicles registered in Maldives, 83,428 (77%) vehicles are registered in Male, Hulhumale and Addu city<sup>19</sup>. These registered vehicles include 72,419 (87%) two wheelers and 5,120 (6.1%) cars. Overall, on a country wide level, motorcycles, cars, light commercial vehicles, heavy duty vehicles and buses account for 84%, 7%, 4%, 3% and 2% of the total vehicle fleet respectively. Accounting for ~21% of transport emissions, a range of technology options are available to decarbonize land transport as briefly discussed below.



- 1. Electric Vehicles:** Globally, electric vehicles are emerging as the clean technology for future mobility and offer significant advantages in decarbonization and energy security. The propensity for a vehicle category to transition to electric vehicles is dependent on factors such as daily run, route predictability, charging infrastructure requirement, and economic viability. Qualitative analysis shows that 2-wheelers (including both scooters and motorcycles), passenger cars, urban buses, and light commercial vehicles have a higher likelihood of transitioning to electric vehicles. Heavy-duty vehicles are relatively difficult to electrify on account of the requirement of large size batteries, high power requirement, and limits on the average range.
- 2. Fuel Cell Electric Vehicles (FCEVs):** FCEVs are powered by hydrogen fuel cells that convert hydrogen to electricity. FCEVs offer longer driving range and shorter refueling time compared to battery-operated Electric Vehicles (EVs) and may be attractive for heavy-duty and long-distance vehicle segments.
- 3. Energy Efficiency:** Energy efficiency is an important lever in the path to decarbonization in hard to abate sectors. Most studies indicate possibilities in the reduction of energy intensities through hybridization of the powertrain. Fuel consumption in vehicles can be reduced significantly by switching to energy-efficient Internal Combustion Engines (ICEs) or hybrid fuel vehicles.

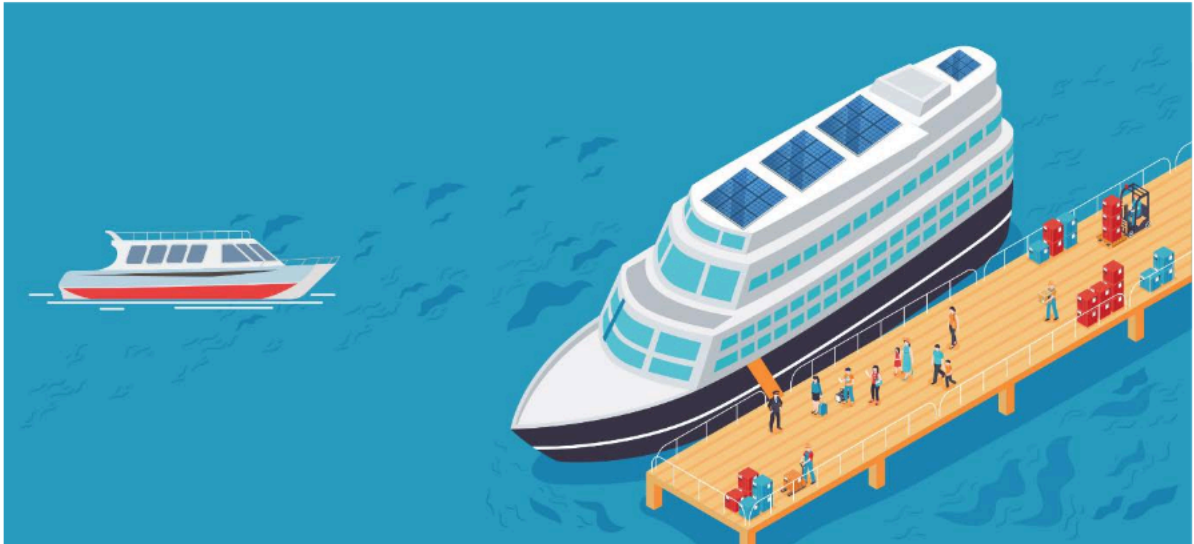
<sup>19</sup> National Bureau of Statistics, "Statistical Yearbook 2019," 2019. [Online]. Available: <http://statisticsmaldives.gov.mv/yearbook/2019/>. [Accessed 14 January 2021].



4. **Public & Active Transportation:** Shifting to public transportation is one of the cheapest and easiest options available in the decarbonization pathway. Furthermore, active transport modes such as cycling, and walking offer health benefits in addition to the decarbonization benefit.
5. **Biofuels:** Biofuels have the potential to act as a commercially viable alternative to diesel fuel in the heavy-duty vehicle segment. However, the availability of biofuel at scale in Maldives will have to be assessed to ascertain the suitability of this technology.

#### 4.2.1.2 Sea Transport

Some of the potential technology options to decarbonize sea transport are as follows:



1. **Energy Efficiency:** Most studies indicate that improving the energy intensity of the existing vessels will reduce fuel consumption, resulting in a reduction in GHG emissions. ADB's report on 'A brighter future for Maldives powered by Renewables' has identified possibilities of improving the specific energy consumption of the vessels by 20-40%.
2. **Solar Boats:** Solar boats are a clean choice to decarbonize Maldives' large fleet of ferries and jetties. For a smoother transition, the option of hybridizing solar energy with diesel/petrol can also be explored. Solar boats are being deployed on a pilot basis in multiple countries and are yet to achieve commercial viability compared to conventional boats.
3. **Electricity:** Currently, the development of electric ships is in the demonstration stage. Low energy density and the high cost of battery technologies are limiting the emergence of electric vessels as an alternative solution to conventional ones.
4. **Green Hydrogen:** Hydrogen as a fuel for marine transport is still evolving and is more expensive to store. Hydrogen needs to be stored at -235 deg C in its liquid state<sup>20</sup> which increases storage costs. The suitability of using hydrogen for sea transport from a commercial standpoint should be evaluated again towards the end of the decade.
5. **Green Ammonia:** Given the concerns around the storage of hydrogen in ships, green ammonia is emerging as an alternative solution for decarbonization in the marine transport segment.
6. **Biofuels<sup>21</sup>:** Blending with biofuels appears to be a short-to-medium term solution for emission reduction till the time cleaner technologies evolve in marine transport.

<sup>20</sup> The potential for zero carbon bunker fuels in developing countries, World Bank

<sup>21</sup> Energy Technology Perspectives 2020, IEA



7. **Synthetic Fuels:** Synthetic fuels/e-fuels are produced by combining blue/green hydrogen with CO<sub>2</sub> captured through concentrated sources or direct air capture. Synthetic fuels aid in decarbonization given their advantages in easier storage, usage of existing infrastructure, etc. However, the technology to produce synthetic fuel is still evolving and the investment required for production is high.
8. **Other Emerging Technologies:**
  - **Plane Boat Hybrids:** Multiple technologies are evolving in the plane-boat hybrid segment and these technologies may aid in emission reduction through efficient transport of goods and people across the islands. Energy efficiency and usage of new-age fuel may aid in emission reduction.
  - **Kite<sup>22</sup>:** Kite is a technique for improving the energy efficiency of vessels. Kite works from wind power which is transferred to the ship and results in less engine power needed to move the ship. It is expected that the fuel consumption of the engines will be reduced by 1-5% by deploying kites.
  - **Flettner Rotors<sup>23</sup>:** Like a Kite, a Flettner Rotor aids in the reduction of fuel consumption in sea vessels. Flettner rotors are vertical cylinders that spin and lift due to the Magnus effect when the wind blows across the rotors. Studies indicate a fuel consumption reduction potential of 3-15% on employing Flettner rotors.
  - In the water sports segment, options for decarbonization are currently limited to technologies such as solar and electric jet ski. However, with advancements in technology, decarbonization options can be evaluated again in the mid-term.

#### 4.2.1.3 Aviation

The following decarbonization options can be explored in aviation segment:

1. **Sustainable Aviation Fuel:** Sustainable Aviation Fuel (SAF) will be required to mitigate emissions from the sector. International Energy Agency (IEA) predicts the share of biofuels to increase to 16% by 2030 in its Net Zero by 2050 report. Furthermore, in March 2021, Airbus demonstrated the operation of a flight using 100% SAF<sup>24</sup>. Thus, possibilities of using SAF to aid in decarbonization should be explored.
2. **Synthetic Fuels:** As discussed in the section under marine transport, the technology is still evolving, and investment costs are on the higher side. The report on Net Zero by 2050 (IEA) predicts a share of 2% and 33% for synthetic fuels in the aviation sector by 2030 and 2050.
3. **Electric Aircraft:** The lower energy density of the batteries compared to fossil fuels is limiting the emergence of electric aircrafts for long-distance travel. However, for shorter distances and smaller sizes, electric aircraft efforts towards commercialization are in an advanced stage.
4. **Hydrogen Aircraft:** Hydrogen fuel cell-based aircraft are still in the prototype stage. With the falling cost of green hydrogen and advancements in technology, fuel-cell-powered aircrafts may be a reality.

### 4.2.2 Net-zero investment framework

Decarbonization of the transport segment is comparatively more difficult than other sectors given that it is heavily dependent on advancements in technology and cost economics of evolving new-age technologies such as the battery, green hydrogen, green ammonia etc. While a higher degree of decarbonization can be achieved in the land transport segment through policy interventions and incentives, achieving a similar level of decarbonization in the marine and aviation segment is extremely difficult and expensive. Globally, the marine and aviation segments are expected to achieve net-zero status by 2050 with the development of synthetic fuels, low-sulphur fuels, improvement in powertrains, availability of commercially viable fuel-switching options etc.

<sup>22</sup> <https://glomeep.imo.org/technology/kite/>

<sup>23</sup> <https://glomeep.imo.org/technology/flettner-rotors/>

<sup>24</sup> <https://www.airbus.com/newsroom/stories/A350-fuelled-by-100-percent-SAF-just-took-off.html>



Using this context, the fuel mix expected in Maldives by 2030 under the net-zero scenario is as shown in table 6 below:

Table 6: Transport sector's net-zero investment framework, 2020-2030

Vehicle Category	Net-Zero Scenario <sup>25</sup>
<b>Land Transport</b>	
2-Wheelers, Passenger Cars, Buses	Electric – 100%
Light Commercial Vehicle (LCV)	Electric – 70%; FCEV – 30%
Heavy Duty Vehicle (HDV)	Electric – 30%; FCEV – 70%
<b>Sea Transport</b>	
Passenger (Speed Boat) Cargo (Except Barge) Tourism Speed Boats and Safari	Solar / Clean Technology – 100%
Cargo – Barge	Clean Technology – 30% + Offsets
Water Sports	Clean Technology – 50% + Offsets
<b>Air Transport</b>	
SAF Penetration	25% + Offsets
Sea Planes (Passenger and Cargo combined)	Electric – 100%

All the proposed technology options will reduce transport emissions by 18% reducing it from ~600 ktCO<sub>2</sub>e in 2020 to ~500 ktCO<sub>2</sub>e in 2030. The residual emissions (~600 ktCO<sub>2</sub>e) will be offset through NBS or purchase of carbon credits.

Accordingly, the investment required for these options is expected to be ~USD 430 - 760 million along with an annual operating expense of ~USD 120 – 130 million for the aviation sector. Meanwhile, table 7 showcases the transport sector's indicative investment requirements by 2030.

Table 7: Transport sector's indicative investment requirements by 2030<sup>26</sup>

Particulars	Vehicle Stock Estimates (2030)	Indicative investment (USD mn)
<b>Land Transport</b>		<b>243 - 463</b>
Electric Vehicles	<ul style="list-style-type: none"> <li>2-Wheelers – 96,399</li> <li>Passenger Cars – 8,105</li> <li>Light Commercial Vehicles – 3,502</li> <li>Heavy Duty Vehicles – 909</li> <li>Buses – 2,552</li> </ul>	160 - 306
Fuel Cell Electric Vehicles	<ul style="list-style-type: none"> <li>Light Commercial Vehicles – 1,501</li> <li>Heavy Duty Vehicles – 2,120</li> </ul>	83 - 157
<b>Sea Transport</b>		
Electric	<ul style="list-style-type: none"> <li>Solar Boats - 4,860</li> </ul>	116 - 234
<b>Aviation</b>		<b>189 – 200*</b>
Fuel	<ul style="list-style-type: none"> <li>SAF</li> </ul>	114

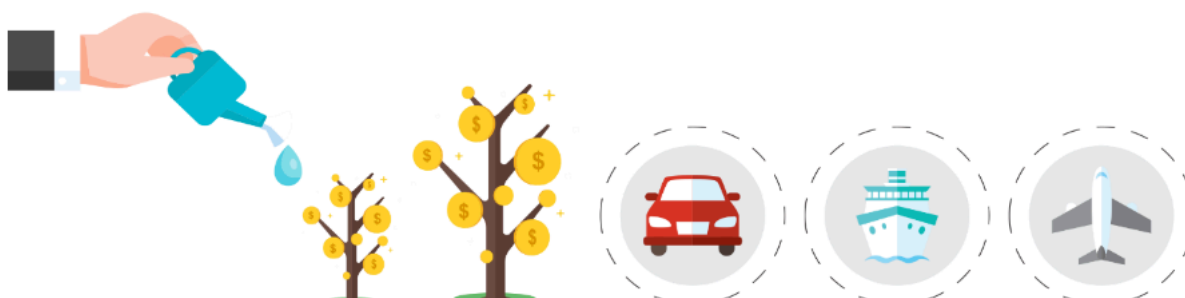
<sup>25</sup> For residual emissions from the transport sector, i.e. emissions that cannot be mitigated, carbon offsets can be utilized. **Carbon offset** refers to a reduction in carbon emissions through various measures or an increase in carbon storage through measures such as land restoration and tree plantation. A **carbon offset** is a tradable unit that represents 1 unit of carbon emissions (1 tonne). These offsets can be traded to transfer carbon benefit from one owner to another.

<sup>26</sup> Please note that the increase in electricity demand because of electrification of the transport sector is covered in the section covering electricity. This includes the investment required to cater to the increase in electricity demand in the form of electricity capacity augmentation, system strengthening, transmission infrastructure, etc.



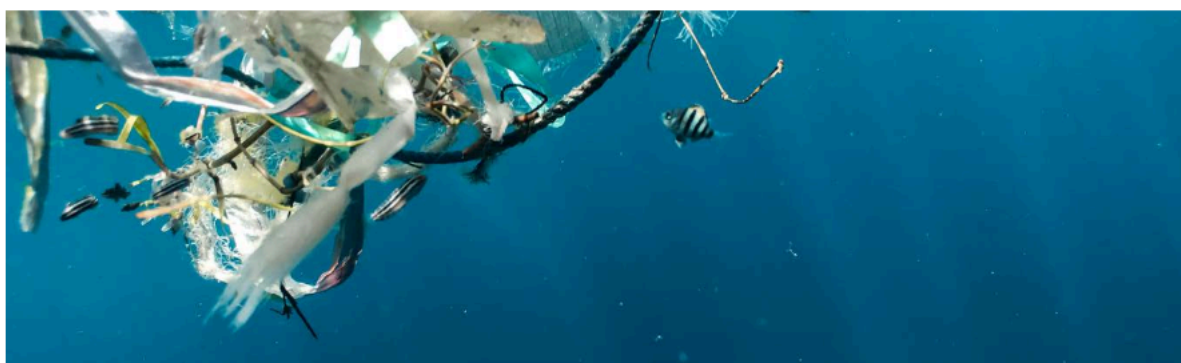
Particulars	Vehicle Stock Estimates (2030)	Indicative investment (USD mn)
Electric	• Sea Planes (Passenger and Cargo combined)	68
<b>Total Transport (CAPEX)</b>		<b>424 - 757</b>
<b>Total Transport (OPEX)</b>		<b>124 - 139</b>

**Note:** Investment requirements are high level indicative numbers estimated using secondary research and need to be validated through detailed techno-commercial studies. \*Including 7-18 mn considered under offsets



### 4.3 Waste

Emissions from open dumping and open burning of municipal solid waste (MSW) and tourism waste contributes to about 5% of the total emissions in the country and is expected to increase to 8% in 2030 if no action to treat/process waste is implemented. Currently, about 91% of the total waste generated in Malé is openly disposed at the designated landfill site, i.e., Thilafushi island. The rest is either dumped in the sea, recycled, or incinerated.



Open burning of waste is majorly practiced in other atolls due to the absence of inadequate waste collection and transportation services. Composting and small-scale incineration is practiced in some islands. A waste incinerator has been installed in R. Vanadhoo and while about 7 regional waste management centres have also been installed for sorting and treatment of waste, only a few centres are currently operational. Few large tourist resorts are practicing composting of organic waste and have even installed WTE plants for treatment of their waste. The remaining waste is collected by private contractors and transported to Thilafushi island.

Both MSW and tourism waste in the country contain high organic component which includes food, garden, paper and cardboard, and textile waste that decomposes and releases methane if left open in a landfill. About 3% of recyclable waste (glass, metal, rubber, and plastic) is recovered by informal waste collectors and exported to neighbouring countries in the absence of a robust recycling industry in Maldives<sup>27</sup>. Thus, managing this waste (approx. 1,300 TPD in 2030) is an important aspect for Maldives to handle, if it wishes to become net-zero by 2030.

<sup>27</sup> Regional Waste Management Strategy and Action Plan for Zone 6 in Maldives, Ministry of Environment, Republic of Maldives, 2019 [Accessed at: <https://www.iges.or.jp/en/pub/regional-waste-management-strategy-and-action/en>]



### 4.3.1 Potential technology options

The below mentioned strategies should be taken up to manage this increasing organic waste and decarbonize the waste sector.

- **Waste Minimization at Source:** Minimization of waste generation at source is the most preferred waste management strategy in the waste sector as it helps reduce handling, treatment, and disposal costs and emissions. The GoM can implement the following to ensure waste reduction at source:
  - **Awareness** generation programmes for waste producers to sensitize them about the waste management issues.
  - **Guidelines/regulations** that ensure a minimum of 5-10% of waste is treated by large waste producers such as large townships or resorts through small-scale initiatives such as composting or waste-to-energy.
  - **Quantity-based Waste Fee** will significantly help drive behavioural change amongst the waste producers. However, this measure will have to be supported with strict regulations/mechanisms (such as fines and penalties) to ensure that waste is not disposed in the sea or openly burnt.
- **Material Recovery and Recycling:** Recyclable waste such as glass, metal, rubber, plastics, and e-waste should be recovered and recycled for use in future industries and/or sold to industries in neighbouring countries.
- **Recycling Waste through Composting:** Organic waste such as food waste and leaves can be composted and used for agriculture and gardening purposes in the country. Use of this compost is likely to reduce emissions from chemical fertilizer use. As agriculture is not a significant economic activity in the country the potential of use in the agriculture sector may be limited. However, there is a significant potential of use for gardening purposes especially in the tourist spots and resorts across the country. Similarly, exporting compost to other countries is another revenue generation avenue. This market potential should be assessed before implementing this solution on a large scale.
- **Waste-to-energy (WTE):** Organic waste can also be converted into renewable energy (biogas or electricity). WTE<sup>28</sup> can convert almost 90% of the waste to ash, helping reduce waste that is sent to landfill significantly. Considering that the islands in Maldives are scattered, small-scale decentralized WTE plants may be more viable than a large-scale WTE plant as long distance transportation of biogas/heat/electricity may increase the operational cost (and transport related emissions) and may not be economically viable.
- **Waste-to-Hydrogen:** Another renewable option that Maldives can explore is converting food waste to hydrogen, a fuel that does not produce greenhouse gases when burned. While this technology is currently at a nascent stage of development, but once proven, Maldives can explore its implementation in the medium to long-term. The hydrogen produced from this technology can be further used for other purposes such as electricity generation or fuel-blending.
- **Landfill Gas Recovery:** The landfill gas from existing landfills can be recovered and utilised for power and heat generation that can be further used by the industries located in the surrounding area. It is estimated that a landfill gas recovery project will capture roughly 60 to 90% of the methane emitted from the landfill, depending on system design and effectiveness<sup>29</sup>. The captured methane is destroyed (converted to water and the much less potent CO<sub>2</sub>) when the gas is burned to produce electricity.

<sup>28</sup> While waste to energy projects offer a useful approach to waste management, there are sensitivities around its contribution to air pollution. It is therefore recommended that new project installations also include air pollution control systems to tackle this issue effectively.

<sup>29</sup> <https://www.epa.gov/lmop/benefits-landfill-gas-energy-projects>



A detailed assessment should be undertaken to determine the feasibility of these technology options (ensuring both environmental as well as economic viability) given the physical and chemical characteristics of waste in the country as well as the market potential of outputs such as compost or biogas.

### 4.3.2 Net-zero investment framework

Considering the technology options available and Maldives' current waste management plans of composting and waste-to-energy, a net-zero investment plan has been devised covering both municipal as well as tourism related waste. Details and assumptions taken under the plan have been provided in the table 8 below:

Table 8: Waste sector's net-zero investment framework, 2020-2030

Parameter	Municipal Waste	Tourism Waste
Technology options	<ul style="list-style-type: none"> <li>Waste minimization at source: 10%</li> <li>MSW waste treatment options:               <ul style="list-style-type: none"> <li>✓ Material recovery and recycling of 6% MSW (glass, metals and rubber)</li> <li>✓ Composting of 20% MSW</li> <li>✓ WTE for the remaining 74% MSW</li> </ul> </li> <li>Offsets/NBS</li> </ul>	<ul style="list-style-type: none"> <li>Waste minimization at source: 10%</li> <li>Tourism waste treatment options:               <ul style="list-style-type: none"> <li>✓ Material recovery and recycling of 7% of tourism waste (glass, metals and rubber)</li> <li>✓ Composting of 33% tourism waste</li> <li>✓ Bio-methanation of 50% of tourism waste</li> <li>✓ WTE for the remaining 10% waste</li> <li>✓ Offsets<sup>30</sup>/NBS</li> </ul> </li> </ul>
Emission reduction achieved in 2030	54% (~150 ktCO <sub>2e</sub> )	
Emissions offset in 2030	46% (~130 ktCO <sub>2e</sub> )	

About 54% emission reduction may be achieved if 100% waste generated is treated in 2030. Residual emissions even with a 100% treatment of waste generated by 2030 is primarily due to the waste dumped at the landfill before 2030 that will continue to undergo anaerobic decomposition emitting CH<sub>4</sub> for another 10-20 years. To achieve complete net-zero, elaborate plans would be essential to completely treat the current waste produced to include the waste already dumped at the landfill site.

The total investment required for the proposed technologies are as provided in table 9 below:

Table 9: Waste sector's indicative capacities and investment requirements by 2030

Technology	Capacity (TPD)	Indicative investment requirement till 2030 <sup>31</sup> (USD mn)
Waste Minimization	-	0
Material recovery for recycling/reuse	62	0
Composting	244	~ 1.3

<sup>30</sup> For residual emissions from the waste sector, i.e., emissions that cannot be mitigated, carbon offsets can be utilized. **Carbon offset** refers to a reduction in carbon emissions through various measures or an increase in carbon storage through measures such as land restoration and tree plantation. A **carbon offset** is a tradable unit that represents 1 unit of carbon emissions (1 tonne). These offsets can be traded to transfer carbon benefit from one owner to another.

<sup>31</sup> Investment requirements are high level indicative numbers estimated using secondary research and need to be validated through detailed techno-commercial studies.



Technology	Capacity (TPD)	Indicative investment requirement till 2030 <sup>31</sup> (USD mn)
Bio-methanation	111	~ 2.3
WTE	640	~155
Offset	-	3 – 6
<b>Total</b>	-	<b>160 - 165</b>

## 4.4 Others

### 4.4.1 Potential technology options (residential and tourism energy use)

Energy use in residential and tourism sectors includes LPG consumption for cooking purposes. LPG consumption in residential and tourism sectors has been projected to increase from 17 ktons in 2020 to 24 ktons by 2030.

While emissions from LPG consumption contribute to about 2% of the total GHG emissions in Maldives and is considered to be a clean fuel as compared to other fuels traditionally used for cooking, kerosene, coal, and biomass (such as wood chips), a few additional measures can further decarbonize residential and tourism cooking activities. These measures include:

#### **Demand-side Management:**

- **Adopting Cookstove Efficiency Standards:** Implementing a national level programme for increasing cookstove efficiency through developing cookstove efficiency standards and guidelines, labelling of energy efficient (EE) cookstoves, and awareness generation activities.
- **Promoting Use of Electric Stoves:** Maldives can promote the use of modern electric stoves instead of LPG-based stoves, which will significantly help this sector become net-zero since the electricity supply will be 100% green. Moreover, the electricity produced from the waste-to-energy plants can also be diverted for cooking purpose. These plants will have the capacity to produce about 118 GWh annually.

#### **Supply-side Management:**

- **LPG Blending with Green Hydrogen:** While LPG is already a clean fuel, blending it with 20-60% hydrogen will make it cleaner and greener<sup>32</sup>. Maldives can take advantage of the hydrogen infrastructure for electricity and transportation sectors to further this solution.
- **Replace LPG with Carbon Neutral Fuel - Renewable Natural Gas (RNG):** RNG (biogas) that will be generated if Maldives installs bio-methanation plants for managing its organic waste<sup>33</sup> and it could be utilized for cooking purposes in nearby areas. This can be implemented in tourism areas where there is a significant amount of organic waste available as well as an opportunity for consumption of the RNG that can be produced without any cost of transporting/bottling.
- **Replace LPG with Carbon Free Fuel – Hydrogen:** To completely abate emissions from energy use in residential and tourism sectors for cooking, Maldives can also explore complete replacement of LPG with hydrogen in the coming years subject to addressing supply chain issues.

<sup>32</sup><https://economictimes.indiatimes.com/industry/renewables/riils-entry-could-give-a-boost-to-green-hydrogen-industry-h2e-power-ceo-siddharth-mayur/articleshow/86779622.cms?from=mdr>

<sup>33</sup> Organic waste is any material that is biodegradable and comes from either a plant or an animal



## 4.4.2 Net-zero investment framework (residential and tourism energy use)

Considering the available options, the following net-zero investment framework has been developed for residential and tourism energy use as mentioned in table 10:

Table 10: Residential and tourism energy use net-zero investment framework, 2020-2030

Abatement potential	Sector linkages	Net-zero pathway		
		Immediate	Medium	Long
Moderate	Energy Waste	Cookstove efficiency standards LPG cookstoves with electric cookstoves	Replacement with RNG (biogas) LPG cookstoves with electric cookstoves	LPG cookstoves with electric cookstoves/ Replacement with hydrogen

With the current proposed bio-methanation initiative in the waste sector roadmap, biogas can replace about 1,160 tons of LPG in 2030 and the remaining LPG can be reduced by replacing LPG cookstoves with electric cookstoves. This will lead to an additional electricity demand of 284 GWh in 2030. 40% of this electricity demand can be catered through the WTE plants proposed under the waste roadmap, which would have the capacity to produce about 118 GWh electricity annually. The remainder, 166 GWh, might result in a slightly increased demand from an overall electricity perspective and it is recommended that the same be served using the same renewable energy sources detailed under the electricity roadmap. Table 11 showcases residential and tourism energy use indicative investment requirements by 2030, while Figure 7 represents the residential and tourism energy GHG emissions trajectory from 2020 to 2030.

Table 11: Residential and tourism energy use indicative investment requirements by 2030

Parameter	Net-zero framework
Technology options	<ul style="list-style-type: none"> <li>Replacement with RNG (biogas) in 2030: 5%</li> <li>Replacement with electric cookstoves in 2030: 95%</li> </ul>
Indicative investment requirement by 2030 <sup>34</sup>	<ul style="list-style-type: none"> <li>Replacement with RNG (biogas) in 2030: Covered under waste sector investment requirements</li> <li>Replacement with electric cookstoves in 2030: <b>USD 10.5 million</b> (USD 130 per electric cookstove installed in exchange of LPG cookstove)</li> </ul>

The investment requirement estimated for replacement with electric cookstoves is the differential cost that consumers will have to bear from switching from a normal LPG cookstove to an electric cookstove.

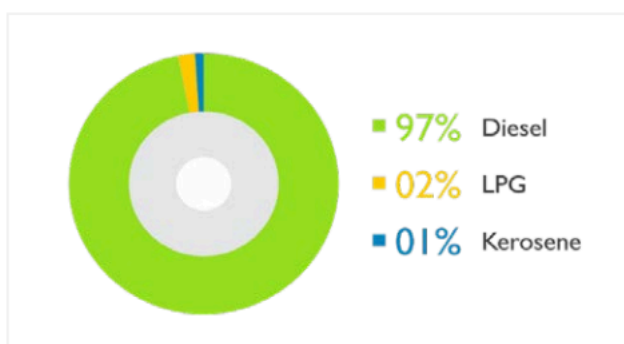
<sup>34</sup> Investment requirements are high level indicative numbers estimated using secondary research and need to be validated through detailed techno-commercial studies.



### 4.4.3 Potential technology options (fisheries energy use)

Fisheries sector involves the use of diesel, LPG and kerosene in fishing vessels. The sector currently contributes to about 2% – of the total GHG emissions. Figure 8 shows the breakdown of fuel use in fisheries sector in 2020.

Figure 8: Breakdown of fuel use in fisheries sector, 2020



The fishing vessels travel far and long for the catch and thus majority of the emissions are from diesel consumption (refer figure) while LPG and kerosene are used for the cooking purposes in these vessels.

To reduce the emissions from energy use in the fisheries sector, Maldives can explore the following technological options:

- **Solar Powered Fishing Vessels:** The present diesel-based fishing vessels if replaced with solar will help in getting closer to net-zero in this sector. In addition to reducing emissions, solar boats also offer several environmental benefits, i.e., reduced air and noise pollution, health benefits and reduced impact on marine biodiversity. While this seems to be a feasible option in terms of implementation, a detailed study to assess potential of solar boats in the sector should be carried out. Alternatively, a diesel-solar hybrid can also be explored and assessed for implementation.
- For cooking purposes, use of electric induction stoves should be mandated for all the fishing vessels through national level regulations and programmes.

### 4.4.4 Net-zero investment framework (fisheries energy use)

The net-zero pathway for fisheries sector could include a 100% replacement of diesel-based fishing vessels with solar boats along with 100% replacement of LPG and kerosene based cookstoves with electric cookstoves. The investments for replacement of solar powered vessels have been included in the transport sector.

## 4.5 Offsets

Offsets<sup>35</sup> will only be considered as a measure of last resort. The target will be to adopt technologies to the extent possible based on their development and commercialization over the coming decade. The technologies which are presented in the respective sections may mature before the estimated timeline. For example, the unprecedented pace of development of solar PV beyond expectations, driven through policy measures and scale up, leading to economies of scale and cost reduction of more than 90% over less than a decade. Similar developments are seen in the battery storage space and other areas. In the event of consideration of offset for net zero, the aim will be to generate offsets through implementation of high-quality nature-based solution projects that contribute to carbon sequestration and improve well-being of communities.

Table 1: Summary of offset requirements and indicative investments in 2030

Offset requirement (ktCO <sub>2</sub> e)	Indicative investment requirements (USD million)
~600	12 – 31

Note: Offsets and their investment requirements are already included in respective sector roadmaps

<sup>35</sup> For residual emissions, i.e., emissions that cannot be mitigated, carbon offsets can be utilized. **Carbon offset** refers to a reduction in carbon emissions through various measures or an increase in carbon storage through measures such as land restoration and tree plantation. A **carbon offset** is a tradable unit that represents 1 unit of carbon emissions (1 tonne). These offsets can be traded to transfer carbon benefit from one owner to another.



## 5 Resource mobilization

The aforementioned net-zero investment framework for Maldives is heavily contingent on receiving international support in terms of finance, technology, and capacity. A summary of sector-wise investment requirements has been provided in the table below. These sector-wise estimates as shown in table 13 represents the minimum costs that Maldives will have to pay to successfully achieve net-zero status by 2030.

Table 13: Maldives' net-zero investment requirements by 2030

Sector		Indicative investment requirements (USD mn)
Electricity	Direct	3,000 – 4,000
	With decarbonization of transport and cooking (@10-20%)	300 – 800
Transport	Land	243 – 463
	Sea	116 – 234
	Aviation	189 – 200 <sup>36</sup>
Waste		160 - 165
Others	Residential and tourism LPG use	10.5
	Fisheries	Included in sea transport
<b>Total (round-off)</b>		<b>4,000 – 5,900</b>

### 5.1 Financing mechanisms

There are various existing and/or new financing mechanisms that can be used for mobilizing resources for achieving net-zero emissions status in Maldives. These include grants, public/private loans, climate/green bonds, risk sharing mechanisms such as guarantee and insurance, viability gap funding, capital subsidy, feed-in tariffs, Renewable Energy Certificates (RECs), result based payment, and payment for ecosystem services (PES), amongst others. These mechanisms can be utilized by a range of stakeholders from the government, private sector funders, to international funders based on their objectives.

Each of the financial instrument/mechanism identified has been evaluated based on certain parameters to understand its effectiveness in mobilizing resources for implementation of decarbonization measures under different sectors. The details of these parameters are mentioned as under:

- **Instrument maturity:** This parameter evaluates the instruments/mechanisms based on its current maturity and wider adoption in global markets.
- **Experience:** This parameter takes into account existing experiences and capacities of stakeholders within Maldives to implement the financial instrument/mechanism
- **Scalability:** This parameter evaluates the instruments/mechanisms based on its possibility of being leveraged for multiple projects and sectors across regions indicating its scalability potential. For instance, grants applicable provided for projects will not be able to scale up as compared to an instrument like green bonds.

<sup>36</sup> For aviation segment, investment required is ~USD 68 million and annual operating expense required is ~USD 120 – 130 million



- Leverage private sector capital: This parameter evaluates the instrument based on whether and to what extent it enables wider investor base to participate and incentivize participation of private sector in implementation of net-zero measures.

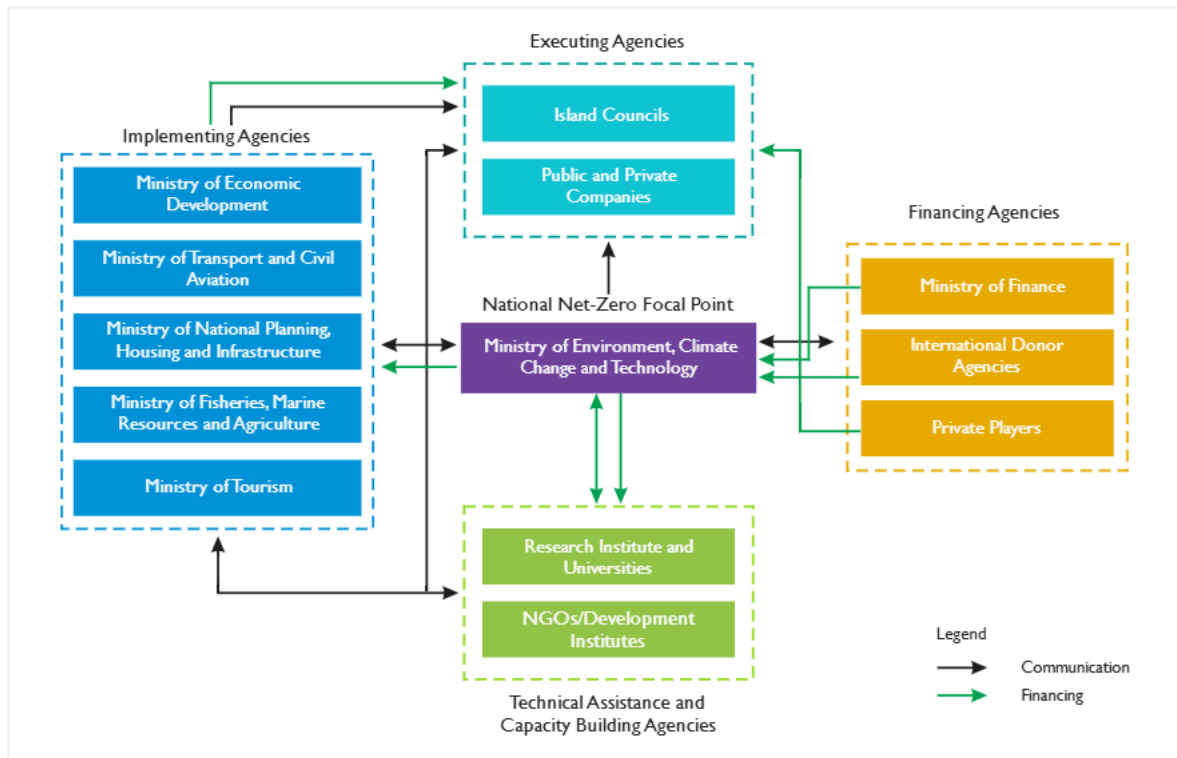
Based on this evaluation, each instrument has been rated against each of the evaluation parameters on the scale of high (green), medium (amber) or low (red). Details on evaluation of financial instruments or mechanism is provided in Annexure 2.



## 6 Institutional Framework

In addition to financial resources, an efficient governance framework having personnel with requisite skill set is a must. A high-level institutional framework as illustrated in figure 10 below can be set-up to support Maldives with the implementation of the proposed strategies.

Figure 44: Potential institutional framework for Maldives' net-zero mission



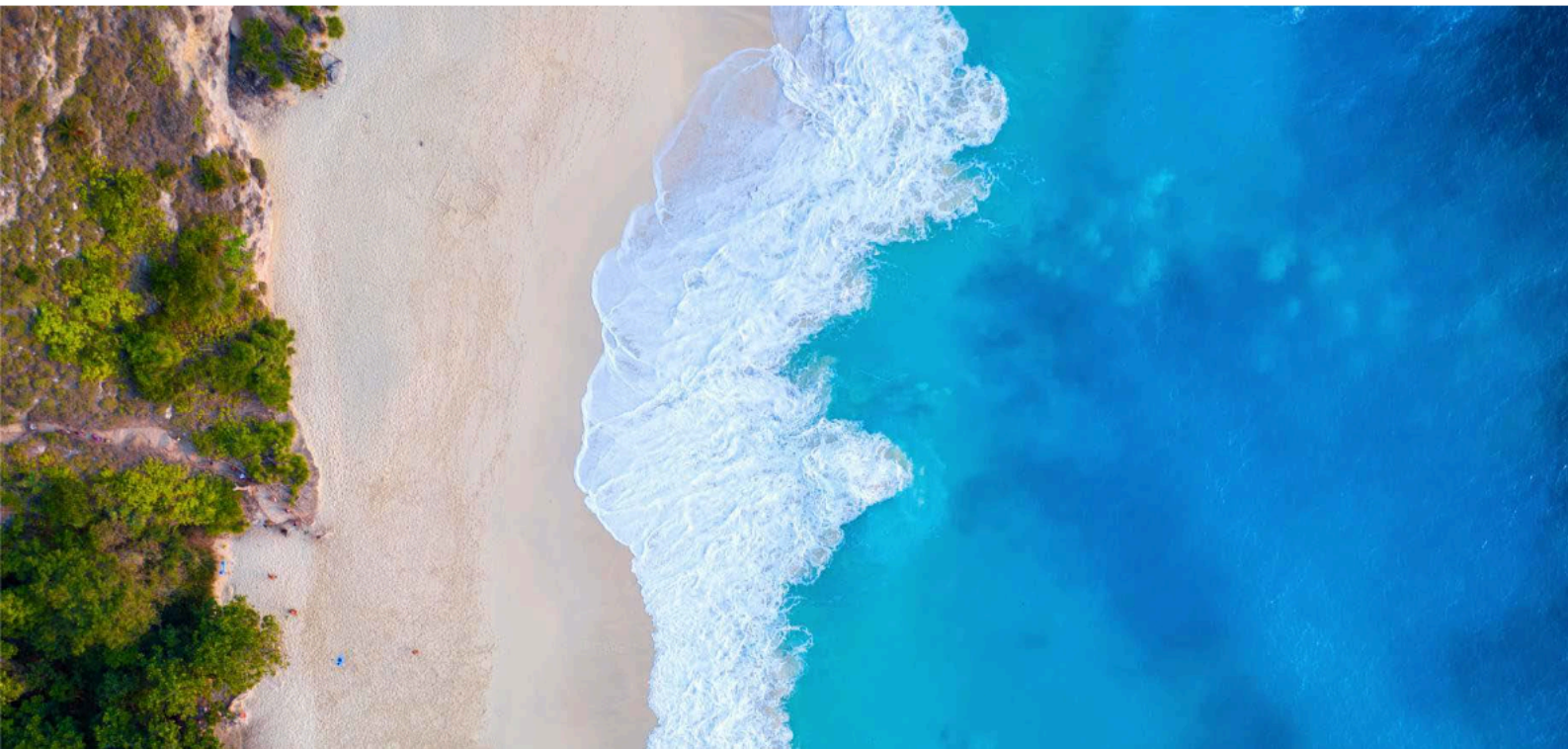
The key stakeholders have been categorized under the following:

- **National Net-zero Focal Point**
  - The National net-zero focal point is the key stakeholder responsible for implementing/overseeing the implementation of the proposed net-zero strategies
  - Climate change department within the Ministry of Environment, Climate Change and Technology will act as the focal point
- **Implementing Agencies**
  - Agencies responsible for designing and planning specific projects and strategies for implementation. These agencies will report to the National net-zero focal point and will be responsible for supporting the executing agencies with implementation of projects.
  - National level ministries will act as implementing agencies.
- **Executing Agencies**
  - Agencies responsible for implementing, regular monitoring of project progress and reporting to respective implementing agencies



- Local/regional level government bodies, public and private operators and other non-governmental organizations will act as Executing Agencies. Some of these agencies include Island Councils, Maldives Energy Authority (MEA), Waste Management Corporation (WAMCO), State Electric Company (STELCO), Fenaka Cooperation Pvt. Ltd., Maldives Transport and Contracting Company (MTCC), State Trading Organizations (STO), Maldives Airports Cooperation Limited, Island Aviation (Maldivian Airlines), amongst others.
- **Technical Assistance and Capacity Building Agencies**
  - Agencies that can provide necessary technical assistance
  - Some of these include research institutes, universities, NGOs, development institutions and external consultants
- **Financing Agencies**
  - Agencies that can support in financing/mobilizing financing for net-zero strategies
  - Some of these include Ministry of Finance, International Funders and Private Players

Setting up an institutional framework will ensure effective coordination and implementation of various net-zero strategies. The Ministry of Environment, Climate Change and Technology needs to ensure that requisite personnel are designated within each of the implementing and executing agencies showcased in the diagram and define roles and responsibilities for them.



## 7 Way Forward

Developed under the auspices of the ARISE project, this report is a joint effort by the Maldives government and the World Bank that puts forth an investment roadmap that Maldives can leverage to begin its decarbonization journey with the aim of achieving net-zero status by 2030.

This study provides a direction for the country to align itself with the commitments made by the country's government and leadership at global forums. The intent of the study is to showcase the country's commitment towards its stated vision, and a message for the global community for the proposed net-zero options to understand their techno-commercial feasibility for implementation. This will also help in understanding the need for introducing any new policies or mechanisms to attract developers in the form of concessions, access to land and other resources. As a next step, over the span of 2-3 years, it will be important to carry out detailed studies, pilot tests and research and development (R&D) for the proposed net-zero options to understand their techno-commercial feasibility for implementation.

Some of the technologies such as solar and electric vehicles, which are easily accessible and mature can be considered for implementation in the immediate term. For the remaining technologies, implementation will be considered based on the outcomes of pilot tests and R&D. The Accelerating Sustainable Private Investment in Renewable Energy (ASPIRE) within the Sustainable Renewables Risk Mitigation Initiative (SRMI) has supported the GoM in implementing solar projects that have gradually increased the renewable energy capacity from 1.5 megawatts to 17.5 megawatts. Results from the SRMI framework indicates its potential to create an enabling environment for mobilizing private investments and improve the bankability of RE projects across other countries, particularly Island nations.

For the Government of Maldives, the combined investment estimate for achieving net-zero is expected to be in the range of **~USD 4.0 – 5.9 billion**, subject to detailed techno-commercial feasibility studies. Collaboration with various international donors and multilateral organizations will be critical in gaining access to requisite finance and undertake technical assistance for assessments as well as implementation. Additionally, successful implementation of this roadmap significantly hinges on the degree to which the private sector aligns its investments towards adopting technologies and R&D efforts with the roadmap. Therefore, it will be important to initiate dialogues with donors and private sector players to ensure increased participation.

Collaboration with various international donors and multilateral organizations is key in gaining access to finance and technical assistance for assessments as well as implementation. Additionally, successful implementation of this roadmap significantly hinges on the degree to which the private sector aligns its investments towards adopting technologies and R&D efforts with the roadmap. Therefore, it will be important to initiate dialogues with donors and private sector players to ensure increased participation.

The lessons from Maldives' can also be integrated into the SRMI framework for the benefit of other small island developing states (SIDS). Furthermore, the study does not take into account any indirect cost of implementation of this strategy such as training and skill development costs and the impact on equity. In order to ensure that this transition to net-zero is a just transition, further studies to understand the social impacts in terms of shifts in jobs and skill requirements will have to be conducted to make the process fair for all stakeholders.



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