Republic of the Marshall Islands
Energy Future

Electricity Roadmap

Technical Note 04: GHG Inventory and Electricity Targets

Final version, December 2018

Prepared by: Joshua Curd

Reviewed by: Nicole Baker, Mahendra Kumar

Approved by: Andrew Revfeim, December 2018

The development of the Marshall Islands Electricity Roadmap
and related analysis was supported by the
New Zealand Ministry of Foreign Affairs and Trade.

Summary

The RMI has communicated targets to reduce its emissions of greenhouse gases (GHGs). To consider the potential for the RMI electricity sector to contribute to these targets the fraction of national emissions attributable to the electricity sector (due to combusting diesel for generation) needs to be known. This technical note firstly describes the calculation of an estimate of this fraction, and secondly outlines the impact this has on the required emissions reduction in the electricity sector to achieve these economy-wide targets. This note does not purport to develop a definitive GHG inventory for RMI, but rather has produced an estimated/assumed GHG inventory, and outlines the impact this has on the required emissions reduction in the electricity sector.

IPCC guidelines dictate that fuel bunkered within RMI to fishing vessels should be included in the national inventory. However RMI is an unusual case where the fuel bunkered within RMI to fishing vessels operating over large international distances would form a significant proportion of national emissions. For this reason, and because the amount of fuel bunkered offshore is unknown, emissions due to commercial fishing activity have been excluded from the estimated total.

GHG emissions from the RMI electricity sector were estimated to be around 60 $GgCO_2$-e[1] in 2010 and 52% of estimated 2010 national GHG emissions. National emissions in 2010 were estimated to be around 116 $GgCO_2$-e in 2010, excluding fishing. If fishing emissions were included, electricity sector emissions would have been around 36% of national emissions. Electricity sector emissions were estimated to be around 57 $GgCO_2$-e in 2016 and 47% of estimated 2016 national GHG emissions (2016 was the most recent year of fuel data available).

The waste emissions calculated include large cumulative uncertainties due to the difficulty in getting waste volume and composition data, and due to the various methodologies for calculation available. Assuming that the waste, transport and other sectors meet various emissions reductions targets indicated in the RMI's NDC, this means that to meet national emissions reductions targets the RMI electricity sector would need to reduce emissions from 2010 levels by 50% by 2025, and by 65% by 2030.

[1] A gigagram (Gg) is equivalent to a kiloton (kT), and the 2 units can be used interchangeably.

Contents

1 Background / Introduction

The RMI has committed to a quantified economy-wide target to reduce its emissions of greenhouse gases (GHG) to 32% below 2010 levels by 2025; and has communicated indicative targets to reduce its emissions of GHGs to 45% below 2010 levels by 2030 [1], and to zero emissions by 2050.

To consider the potential for the RMI electricity sector to contribute to these targets, the fraction of national emissions attributable to the electricity sector needs to be known. This technical note firstly summarises what this fraction is assumed to be, and secondly outlines the impact this has on the required emissions reduction in the electricity sector to achieve these economy-wide targets.

2 Previous inventories of RMI 2010 GHG emissions

RIMI's Intended Nationally Determined Contributions (INDCs) to GHG reductions are stated relative to a 2010 emissions baseline. A number of references (either in the form of reports or spreadsheets) to previously calculated GHG inventories for the year 2010 are summarised in this section.

2.1 RMI INDC communication [1]

The methodology for the baseline included in the INDC communication followed 1996 IPCC guidelines.

Total nationwide emissions in 2010 according to this document - excluding land use, land use change, and forestry (LULUCF) - were approximately 184 Gg CO_2-e in 2010. These included electricity generation, transport (land and shipping), other (LPG and kerosene cooking and lighting) and waste. Emissions from other sectors were assumed negligible.

The sectoral mix was:

- Electricity generation ~54%
- Land and sea transport ~12%
- Waste ~23%
- Other sectors ~11%

Planned actions included reducing electricity emissions by 55% in 2025 and 66% in 2030; transportation (including domestic shipping) by 16% in 2025 and 27% in 2030; waste by 20% by 2030; and 15% from other sectors (cooking and lighting) by 2030.

2.2 RMI Second National Communication [2]

This is an earlier work which predominantly focused on the year 2000 as the baseline year, however included some details of 2010 emissions. The methodology followed 1996 IPCC Tier 1 guidelines.

Total nationwide emissions in 2010 according to this document - excluding land use, land use change, and forestry (LULUCF) - were 169.8 Gg CO_2-e in 2010.

Assumptions used included:

- Electricity emissions consist of diesel combustion by MEC and Kajur only;

- All Mobil diesel imports and the remainder of MEC's inland diesel imports is for domestic transport;
- All gasoline imported is for domestic transport.

Residential and commercial use of kerosene (786 MT) and LPG (548 MT) together emitted 12.2 Gg CO_2-e in 2010.

Waste emissions (predominately methane) included solid waste management and disposal, and domestic and commercial wastewater handling. Waste emissions in 2010 were 36 GgCO_2-e.

Depositions at the Majuro landfill average 20.3 tons of MSW per day, with a composition as shown in Figure 5.

2.3 The MHL_ghg-profile.xlsx spreadsheet

This Excel spreadsheet contains RMI GHG inventories for years 2000, 2005 and 2010. It presumably underpinned the RMI Second National Communication report as many of the numbers align with that document.

Table 1: Previous RMI GHG inventory

	Gg CO_2-e, 2010
Energy: Energy industries	98.8
Energy: Transport	22.5
Energy: Other sectors	12.2
Energy: total	**133.5**
Waste: Solid waste disposal on land	24.5
Waste: Wastewater handling	11.8
Waste: Waste incineration	not estimated
Waste: total	**36.3**
Total	**169.8**

2.4 The Final_RMI_GHGInventoryGraphs Scenario analysis.xls spreadsheet

This Excel spreadsheet contains RMI GHG inventories for years 2000, 2005 and 2010.

2010 energy sectors fuel breakdown:

Table 2: Fuel inputs for a previous RMI GHG inventory

2010											
Total Import Fuel Consumption						Electricity	Residential	Commercial	Road Transport	Aviation	Sea Transport
Fuel	US Gallon	Liters	Density (Kg/L)	kg	MT	MT	MT	MT	MT	MT	MT
ADO		38,025,932	0.85	32,219,753	32,220	30,857	-	-	1,363	-	-
Motor Gasoline		7,805,397	0.74	5,794,649	5,795	-	-	-	5,795		
Jet Fuel (DPK)		52,392,551	0.82	42,729,269	42,729	-	786	-	-	41,943	-
LPG (in Pounds)		983,985	0.56	548,080	548	-	274	274	-	-	-
Lubes & Cres		505,290	0.88	444,655	445	289	-	-	156	-	-

Water-borne transport has been excluded from this inventory.

2010 waste emissions:

- Quantity of MSW: population 65,859 x 0.9 kg waste per person per day = 21,635t
- Composition: As per Table 5.

The organic portion of this composition was aggregated into four categories: Paper and textiles, Garden and park waste etc, Food waste, Wood and straw waste. Each of these four categories was multiplied with a Degradable Organic Carbon (DOC) factor, to produce a total DOC of 20% of the MSW.

2010 GHG inventory:

Table 3: Previous GHG inventory

GHG source	**$GgCO_2$-e**
Energy industries (Electricity production)	99
Transport (Road)	23
Other (Residential and Commercial)	12
Waste (Waste Disposal on Land and Waste Water Handling)	36
Total	170

2.5 Comparison of previous inventories

Table 4: Comparison of existing RMI GHG inventory documents & spreadsheets

	INDC		SNC		MHL xlsx		Final xlsx	
	Gg CO2-e	%	Gg CO2-e	%	Gg CO2-e	%	Gg CO2-e	%
Electricity generation	99.9	54			98.8	58	98.8	58
Land and sea transport	22.2	12			22.5	13	22.5	13
Waste	42.6	23	36.3	21	36.3	21	36.3	21
Other sectors	20.4	11	12.17	7	12.2	7	12.2	7
Total	185.0		169.8		169.8		169.8	

All these sources show similar emissions for the electricity sector and land and sea transport in 2010. All sources have similar numbers except the RMI INDC communication, which included higher emissions for waste and for other sectors.

3 Estimate of energy sector emissions – method

To consider what emissions targets are required for the electricity sector to contribute towards the economy wide targets, it is important to understand how much of national emissions are attributed to electricity. For this reason, our own crude estimate of economy wide national emissions was calculated (excluding land use, land use change, and forestry) to compare to the previous inventories summarised in the previous section.

3.1 Diesel combusted for electricity

Unlike later years, an MEC fuel sale/use breakdown was not available for 2010. Instead, a summary of MEC fuel sale/use [3] from the Economic Policy, Planning and Statistics Office (EPPSO) was used. This includes diesel used for electricity in the Majuro, Ebeye, Wotje, Jaluit, Bikini and Kili power stations. Any other electricity related emissions are assumed negligible. Data for 2011 is unavailable.

For years 2012 – 2017 MEC fuel sale/use breakdowns were used [4]. This includes diesel used for electricity in the PPF factory, and in the Ebeye, Bikini and Kili (2012-2014), Wotje, Jaluit and Majuro power stations. Any other electricity related emissions are assumed negligible.

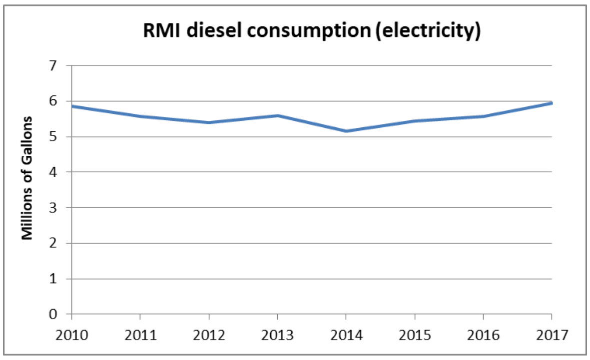


Figure 1: RMI diesel consumption for electricity generation over time

3.2 Diesel combusted for fishing operations

The 2006 IPCC guidelines [5] state that emissions relating to fishing should include *emissions from fuels combusted for inland, coastal and deep-sea fishing. Fishing should cover vessels of all flags that have refuelled in the country (include international fishing). By definition, all fuel supplied to commercial fishing activities in the reporting country is considered domestic, and there is no international bunker fuel category for commercial fishing, regardless of where the fishing occurs. Emissions from coastal and deep sea fishing should be allocated to the country delivering the fuel.*

However RMI is an unusual case where the fuel bunkered within RMI to fishing vessels operating over large international distances would form a significant proportion of national emissions.

For this analysis, only fuel sold to fishing vessels by MEC was accounted for – offshore bunkering was not included due to the lack of data available, and the uncertainty around whether it occurs within RMI waters.

For 2010, the EPPSO summary of MEC sales to fishing vessels was used. Data for 2011 was unavailable. For years 2012 – 2017 MEC fuel sale/use breakdowns were used. This includes sales to MIFV, Koos, PPF marine and assorted other fishing vessels.

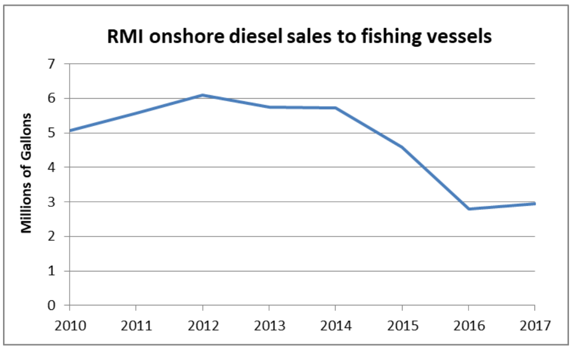


Figure 2: RMI onshore diesel sales to fishing vessels over time

The rapid decrease in recent years does not reflect a reduction in activity, but rather a trend towards offshore bunkering. This further highlights the complications of including fishing emissions in the national inventory.

Due to the way that the 2006 IPCC guidelines attribute fishing emissions, and the disproportionate effect it has on the RMI GHG inventory, for further analysis fishing emissions were excluded from the inventory.

3.3 Diesel combusted for land transport, domestic water-borne transport, and industry

It was not possible with data available to disaggregate between diesel used in land transport, domestic water-borne transport anddiesel used in industry (e.g. machinery), and so these were combined.

For 2010, the EPPSO summary of MEC sales (Majuro Sales, Govt vessels and other vessels, although it was not certain how many of the latter are actually to domestic vessels) [3] was used in addition to imports by Mobil. Data for years 2011-2013 and 2017 is unavailable. For years 2012 – 2016 MEC fuel sale/use breakdowns were used, as well as imports by Mobil. This includes MEC sales to PII,MFD, MISC and OTHERS, although it was not certain how many of the latter are actually to domestic vessels – this category likely includes international and domestic vessels as well as sales to outer atolls for small electricity generators.

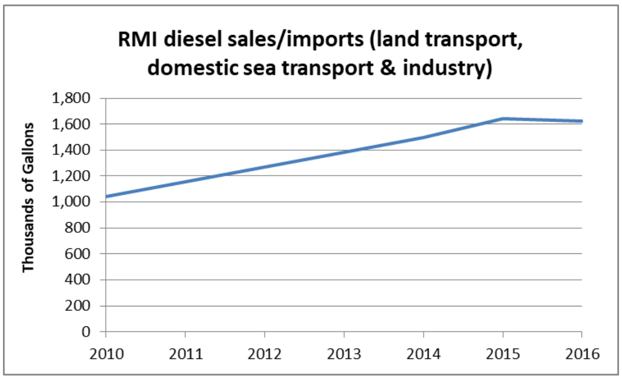


Figure 3: Sales or imports of diesel in RMI for land transport, domestic sea transport and industry over time (no data 2011 – 2013)

3.4 Gasoline combusted for transport

It is not possible with current data to disaggregate gasoline used in land transport from that used in sea transport or in small electrical generators. As a result, it was assumed that all gasoline is used for domestic transport. Gasoline combusted in years 2010 and 2014 – 2016 was assumed to equal the amount imported by Mobil during those years. Data for years 2011-2013 and 2017 is unavailable.

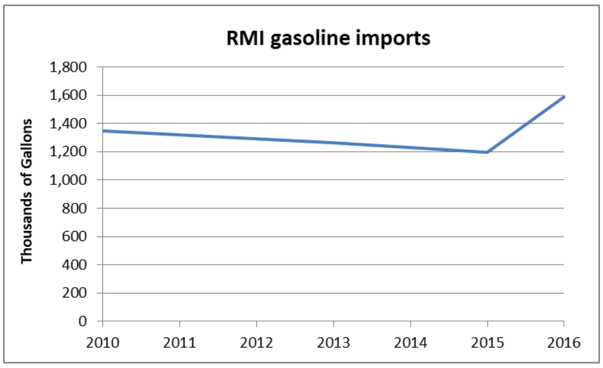


*Figure **4**: Imports of gasoline to RMI over time (no data 2011 – 2013)*

3.5 Jet fuel combusted for aviation

International flights refuel in Majuro, and United Airlines includes a short section between Majuro and Kwajalein. According to the 2006 IPCC guidelines [5], international flights should be excluded, but domestic flights (including domestic legs of international flights) should be included*. The international/domestic split should be determined on the basis of departure and landing locations for each flight stage and not by the nationality of the airline.* Emissions should include *emissions from civil domestic passenger and freight traffic that departs and arrives in the same country (commercial, private, agriculture, etc.), including take-offs and landings for these flight stages.*

Each week there are 3 Boeing 737-800 flights in each direction between Majuro and Kwajalein. This was estimated to consume 272,000 gallons of jet fuel each year.

In addition, Air Marshall Islands operates domestic flights within RMI, and has data available of fuel use for years 2015 – 2017 [6]. Fuel use of previous years was assumed to equal that of 2010.

Under these assumptions, a little over 400,000 gallons of jet fuel was assumed to be consumed each year for domestic flights.

3.6 LPG combusted for cooking

LPG (propane, butane or a blend) is combusted for cooking in homes and hotels/restaurants.

MEC have records of propane sales for years 2012 to 2017 [7]. 2010 and 2011 were assumed to be the same as 2012. Many families use portable cookers which are fuelled by disposable LPG canisters. As this quantity is unknown, it was assumed to equal LPG sold through MEC, resulting in a combined total of around 7-800,000 lbs per year.

3.7 Kerosene combusted for cooking

Some outer islands use kerosene for cooking and lighting. Lighting is assumed negligible. Although the quantity of kerosene used for cooking is unknown, the 2011 RMI census [8] reports that 39% of households cook with LPG and 6% with kerosene. Applying this ratio across all years, and assuming all families require similar MJ of cooking energy, an estimate of around 120,000 – 130,000 lb of kerosene per year was used.

3.8 Energy sector emissions calculations

The quantities identified per Sections 3.1 - 3.8 were entered into IPCC inventory software[2] to calculate CO_2, CH_4 and N_2O emissions (other gases were ignored). These were converted to $GgCO_2$-e (carbon dioxide equivalent) emissions using the following IPCC Global Warming Potential (GWP) factors:

1 kg CH_4 has a similar impact on global warming as 25 kg CO_2.

1 kg N_2O has a similar impact on global warming as 310 kg CO_2.

[2] IPCC Inventory Software version 2.54.6396.19217

4 Estimate of waste sector emissions – method

Previous inventories calculated emissions due to wastewater treatment and handling, and also municipal solid waste (MSW).

MSW is disposed of in various ways; for example landfill, burying, incineration, composting, open scattering, feeding animals etc. The only emissions considered were those due to incineration and also due to anaerobic digestion in landfill producing methane.

According to the 2006 IPCC guidelines [9], landfill emissions should be calculated using a First Order Decay method, where the degradable organic component decays over decades, forming CH_4. The emissions attributed to a year are the emissions released during that year, based on the expected decay of remaining organics plus new additions. However the emissions calculated for the previous inventories appear to have used the alternative Mass Balance method allowed under the 1996 IPCC guidelines. This method attributes to a year the whole life cycle emissions of just the MSW added to landfill during that year.

To remain consistent with previous inventories, and also because it allows a more simple consideration of the effect of a Waste to Energy (WTE) plant, the Mass Balance method was used.

However it should be noted that the use of the mass balance method, which was the default (Tier 1) method in previous versions of the IPCC guidance, tends to lead to over-estimation of emissions in cases where the trend is for increased disposal of waste to SWDS over time. It was assumed that all CH4 would be released in the same year that the waste was deposited. The use of the revised and recommended FOD method removes this error and reduces the uncertainty associated with the method. However, use of this methodology requires good basic data and information such as activity data and emission factors for MSW, fraction of MSW to SWDS, composition of waste content, DOC, methane correction factor, oxidation factor, half-life etc. Thus using the FOD method, can lead to huge cumulative uncertainties given that the individual uncertainties can be as large as 20%.

Given that RMI will need to develop a GHG Inventory, as part of its Second National Communications (SNC) and Biennial Update Report (BUR) reports, under the UNFCCC reporting obligations, the figures could be revised, also as part of its NDC.

Emissions from MSW depend on, among other factors, the quantity and composition of the waste.

4.1 Estimates of MSW quantity

The Second National Communication [2] included a table from the National Waste Management Strategy 2012 – 2016 and Action plan, which listed waste generated as 0.9 kg/person/day (from waste characterisation studies), and waste landfilled as 20.3 tons per day from (MAWC records). As described in Section 2.4, 0.9 kg was applied to a total population of 65,859 for a total of 21,635 tonne. This total was then assumed to all be landfilled.

SCS Engineers produced a prefeasibility study of WTE for Majuro in 2010 [10]. During that year they performed a one week weighing survey of all MAWC collection trucks bring MSW to the Majuro landfill and concluded that about 36 tons per day (ie 8,491 tonne per year @ 5 days per week) were collected (this excludes MSW brought to landfill from areas without a collection run). If collection is performed 5 days a week, this might equate to around 8,500 tonne per year.

An Entura report [11] lists other studies; a 2010 MAWC study and 2013 and 2017 studies by JICA. These show estimates of annual waste deposited at the Majuro landfill (including MAWC collection, self-transportation and green waste) to be around 6,700 – 8,600 tonne per year.

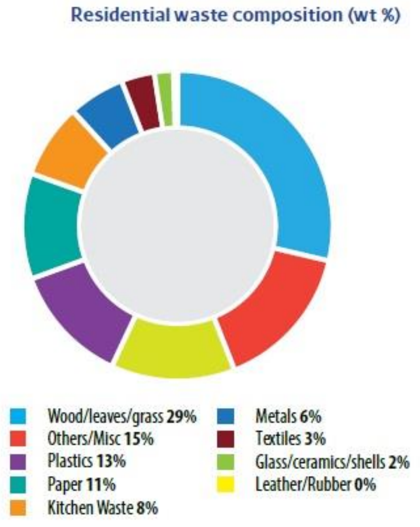
A waste stream analysis by from MAWC estimates that 34.8 ton per day MSW is deposited at the landfill, and forms 80% of total Majuro MSW. If collection is performed 5 days a week, this might equate to around 8,200 tonne per year to the landfill and around 10,200 tonne per year in total.

Based on the above, the assumptions used for the estimate of RMI MSW emissions include:

- 8,500 t/yr MSW is deposited at the Majuro landfill;
- A further 2,000 t/yr MSW is generated on Majuro, half of which is incinerated, half of which is deposited in private landfills;
- All MSW on Ebeye goes to landfill, the quantity is 1/3 that of Majuro excluding green waste (there is little vegetation on Ebeye);
- The quantity MSW on all other islands/atolls is 10% of Majuro and Ebeye combined excluding green waste (green waste is assumed not to be disposed of in landfill, resulting in no net emissions) – half of which is incinerated, half of which is deposited in private landfills;
- The total quantity of MSW remains the same each year since 2010.

4.2 Estimates of MSW composition

The Second National Communication [2] suggests the following Majuro MSW composition:



Source: Republic of the Marshall Islands - National Waste Management Strategy 2012-2016 and Action Plan

Figure 5: Majuro MSW composition in the SNC

The spreadsheet described in Section 2.4 suggests the following Majuro MSW composition, per a waste characterisation report.

Table 5: Majuro MSW composition used in the spreadsheet of Section 2.4

Break up of Waste Composition in the country	
Type	**%**
Paper	11.0%
Plastics	13.0%
Metals	6.0%
Glass	2.0%
Textiles	3.0%
Wood /Leaves/Grass	29.0%
Kitchen Waste	8.0%
Disposable Diapers	13.0%
Other	15.0%

The SCS Engineers report [10] relies upon a waste composition analysis performed in Samoa, and is disregarded.

The *Majuro Power Network Strengthening Report* [11] presents the results of JICA sampling in 2013 and 2017, as shown Table 6.

Table 6: Majuro MSW composition, JICA sampling surveys

Survey of Waste Characteristics		Overall (%)	
Type	*Subtype*	*2017*	*2013*
Paper	Cardboard	11.2	10.6
	Other Paper	9.3	15.7
	Sub Total	20.5	26.3
Disposable diaper		9.5	5.6
Textile/Clothes		4.6	4.2
Synthetic Resin/Plastics	PET bottle	7.7	5.2
	Plastic Bags	2.0	2.8
	Styrofoam	0.9	1.0
	Plastic Packaging	2.0	3.0
	Other Plastic	3.3	8.3
	Sub Total	15.8	20.2
Leather/Rubber		0.5	0.4
Wood/Leaves/Grass	Compostable	23.8	16.7
	Other	6.9	4.1
	Sub Total	30.8	20.8
Kitchen Garbage		3.2	4.7
Metals	Aluminium Cans	5.9	5.8
	Steel Cans	1.6	3.9
	Other Metals	2.0	2.2
	Sub Total	9.6	11.9
Glass/Ceramic/Coral/Shell	Beverage Bottles	2.4	4.1
	Other Bottles	0.3	0.0
	Other	0.5	0.0
	Sub Total	3.2	4.1
Miscellaneous		2.3	1.7
	GRAND TOTAL	100.0	100.0

Given the higher quantity of organic materials in the 2017 sample, this is the MSW composition used for Majuro. Slightly recategorising, and adjusting for other atolls as previously described, the composition and quantity of MSW used for the analysis was as follows:

Table 7: Assumed RMI MSW compositions

	Majuro	Other atolls	Majuro landfill (MT)	Majuro incinerated (MT)	Other atolls landfill (MT)	Other atolls incinerated (MT)
Food waste	3.1%	4.3%	291	31	129	21
Garden and park waste	22.8%	0.0%	2,168	228	0	0
Paper, cardboard	19.7%	27.9%	1,867	197	826	138
Plastics	15.1%	21.5%	1,439	151	636	106
Glass	3.1%	4.3%	291	31	129	21
Ferrous Metals	3.5%	4.9%	328	35	145	24
Aluminium	5.7%	8.0%	537	57	238	40
Textiles	4.4%	6.3%	419	44	185	31
Rubber, leather	4.8%	6.8%	455	48	201	34
Nappies (disposable diapers)	9.1%	12.9%	865	91	383	64
Wood	6.6%	0.0%	628	66	0	0
Mineral waste	0.0%	0.0%	0	0	0	0
Others	2.2%	3.1%	209	22	93	15
Total			**9,500**	**1,000**	**2,964**	**494**

4.3 MSW emissions calculations

A spreadsheet calculator developed by IFEU Heidelberg was used to calculate RMI MSW emissions.

To compare this method with that used by previous inventories, this spreadsheet was used to calculate Majuro MSW emissions using the quantity and composition of MSW as described in Table 5. The result was 31 $GgCO_2$-e, which is similar to the 36 $GgCO_2$-e calculated in that study.

Next, applying the assumptions chosen to the spreadsheet, GHG emissions for Majuro waste were 19,361 tCO_2-e and emissions for other atolls were 5,797 tCO_2-e ; a total of 25,158 tCO_2-e. This figure includes large cumulative uncertainties in its calculation, and may be over-estimated due to use of the mass balance method.

4.4 Wastewater handling emissions

Wastewater handling emissions were estimated using IPCC 2006 Guidelines [12], and are a function of how much organic waste is generated, and an emission factor that characterises the extent to which this waste generates CH_4. There is no treatment of sewage in the RMI - all sewage is released directly to the sea. Septic tanks do not have sludge removed, therefore are assumed to function as latrines. The assumptions used were that in 2010:

- Population was 55,000, and the biological oxygen demand is 60g/person/day (estimated from comparison to country-specific figures in the IPCC 2006 Guidelines).
- 80% of the population use either toilets connected to sewer, which then flows out to sea, or no toilet (also to sea). This type of wastewater handling generates little methane and has an emissions factor (EF) of 0.06.
- 20% of the population use pit latrines, often with flush water and in a wet climate, which have a much higher EF of 0.42.
- Industrial waste water is negligible (there may be some high BOD wastewater from fish processing but the conversion to methane would be low.)

Emissions calculated using the above assumptions are around 3kt CO_2-e in 2010.

5 Estimate of RMI emissions – results

A crude estimate of economy wide national emissions was calculated for years 2010, 2014, 2015, and 2016.

Table 8: Results - estimate of RMI GHG emissions

	2010	Total 168 $GgCO_2$-e incl fishing, 116 $GgCO_2$-e excl fishing			
	Qty	**Units**	**Emissions (tCO2-e)**	**Emissions (%)**	**Emissions (%) excluding fishing**
Electricity generation	5,843,821	gal diesel	59,815	36%	52%
Domestic aviation	409,317	gal jet fuel	4,045	2%	3%
Land and sea transport, gasoline	1,346,672	gal petrol	11,969	7%	10%
Land and sea transport & industry, diesel	1,133,79	gal diesel	10,796	6%	9%
Fishing	5,058,118	gal diesel	51,793	31%	n/a
Residential & commercial LPG	718,683	lbs LPG	1,146	1%	1%
Residential kerosene	120,586	lbs kero			
Wastewater handling			3,000	2%	3%
Municipal Solid Waste	15,400	ton MSW	25,158	15%	22%

	2014	Total 172 $GgCO_2$-e incl fishing, 113 $GgCO_2$-e excl fishing			
	Qty	**Units**	**Emissions (tCO_2-e)**	**Emissions (%)**	**Emissions (%) excluding fishing**
Electricity generation	5,161,692	gal diesel	52,820	31%	47%
Domestic aviation	409,317	gal jet fuel	4,045	2%	4%
Land and sea transport, petrol	1,232,207	gal petrol	10,833	6%	10%
Land and sea transport & industry, diesel	1,524,416	gal diesel	15,871	9%	14%
Fishing	5,715,467	gal diesel	58,651	34%	n/a
Residential & commercial LPG	728,529	lbs LPG	1,158	1%	1%
Residential kerosene	122,238	lbs kero			
Wastewater handling			3,000	2%	3%
Municipal Solid Waste	15,400	ton MSW	25,158	15%	22%

	2015	Total 164 $GgCO_2$-e incl fishing, 117 $GgCO_2$-e excl fishing			
	Qty	**Units**	**Emissions (tCO_2-e)**	**Emissions (%)**	**Emissions (%) excluding fishing**
Electricity generation	5,440,263	gal diesel	55,701	34%	48%
Domestic aviation	409,317	gal jet fuel	4,045	2%	3%
Land and sea transport, petrol	1,195,694	gal petrol	10,509	6%	9%
Land and sea transport & industry, diesel	1,642,793	gal diesel	16,998	10%	15%
Fishing	4,581,079	gal diesel	47,016	29%	n/a
Residential & commercial LPG	738,727	lbs LPG	1,177	1%	1%
Residential kerosene	123,949	lbs kero			
Wastewater handling			3,000	2%	3%
Municipal Solid Waste	15,400	ton MSW	25,158	15%	22%

	2016	Total 150 $GgCO_2$-e incl fishing, 122 $GgCO_2$-e excl fishing			
	Qty	**Units**	**Emissions (tCO_2-e)**	**Emissions (%)**	**Emissions (%) excluding fishing**
Electricity generation	5,625,625	gal diesel	56,935	38%	47%
Domestic aviation	433,476	gal jet fuel	4,284	3%	4%
Land and sea transport, petrol	1,586,411	gal petrol	13,943	9%	11%
Land and sea transport & industry, diesel	1,641,420	gal diesel	16,994	11%	14%
Fishing	2,784,764	gal diesel	28,579	19%	n/a
Residential & commercial LPG	774,210	lbs LPG	1,233	1%	1%
Residential kerosene	129,902	lbs kero			
Wastewater handling			3,000	2%	2%
Municipal Solid Waste	15,400	ton MSW	25,158	17%	21%

Comparing this with previous 2010 inventories (Table 9), significant discrepancies are noted between the estimate and the previous inventory. This may be due to invalid assumptions or gaps in the data for this estimate, or may be due to errors in the previous estimate.

Table 9: Comparison between previous inventories and calculated estimate

	INDC		**SNC**		**RMI Roadmap (excl fishing)**		**RMI Roadmap (incl fishing)**	
	Gg CO_2-e	**%**	**Gg CO_2-e**	**%**	**Gg CO_2-e**	**%**	**Gg CO_2-e**	**%**
Electricity generation	100	54	99	58	60.3	52	59.8	36
Domestic transport and industry	22	12	23	13	26.8	23	26.8	16
Waste	43	23	36	21	28.2	24	28.2	17
Other sectors	20	11	12	7	1.1	1	1.1	1
Fishing							51.8	31
Total	**185**		**170**		**116.4**		**167.7**	

Noting the significantly larger diesel fuel for electricity used in previous inventories, and given the reasonable level of certainty that this estimate captures the majority of diesel emissions for electricity[3], the results of the estimate were used to determine recommendations for appropriate targets for emissions reductions in the electricity sector, to enable RMI to achieve the INDC target.

Figure 6 shows that electricity emissions had reduced by 2016 from 2010 levels, but that transport and industry emissions have risen since 2010.

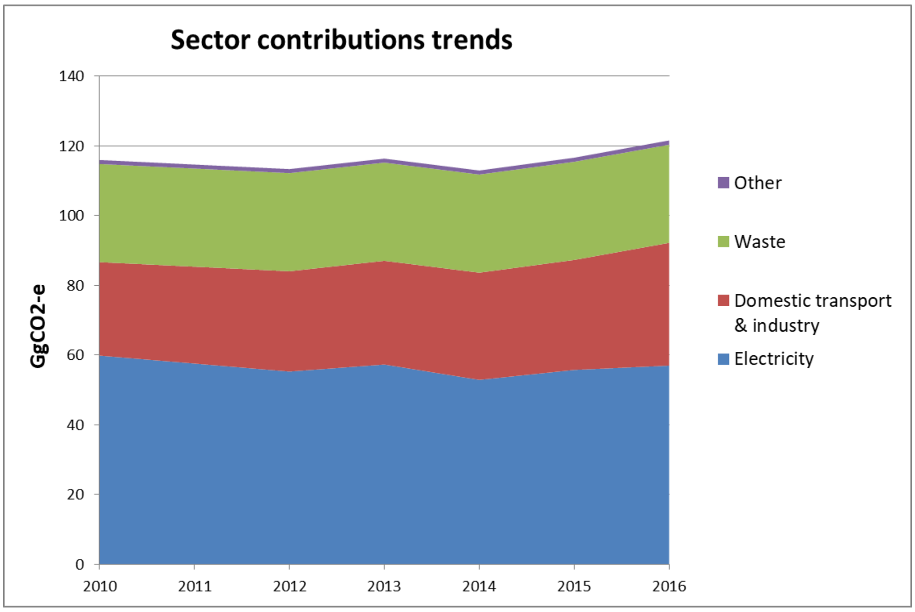


Figure 6: Assumed contributions of sectors to RMI GHG emissions over time (no data available for 2011 – 2013 other than 2012-2013 electricity)

6 Assumed future emissions of domestic transport and industry

Domestic transport and industry emissions increased from 2010 to 2016: from 26.8 to 35.2 $GgCO_2$-e and from 23% to 29% of the total (excluding fishing). Although this is likely a more difficult sector to decarbonise than electricity in the Marshall Islands, the INDC does indicate effort will be made to reduce transportation emissions (including domestic shipping) from 2010 levels by 16% in 2025 and 27% in 2030. For the analysis of the electricity sector, the assumption was made that a 16% reduction in combined transport and industry emissions from 2010 levels will be achieved by 2025, and a 27% reduction by 2030. This results in expected emissions for these combined sectors of 22.5 $GgCO_2$-e in 2025 and 19.6 $GgCO_2$-e in 2030.

While the electricity roadmap does not address how this will be achieved, it does assume that a partial contribution to the 2030 reduction will be from uptake of electric passenger cars

[3] MEC confirmed that fuel for electricity generation outside of MEC records in 2010 is minor, personal communications

and electric outboards thereby displacing gasoline, assumed to be equivalent to a reduction of 30% of 2010 gasoline use.

30% of 2010 gasoline use - or 476,000 gal - is equivalent to a 4.1 GgCO_2-e reduction. This amount of fuel would contain approximately 57.6 TJ of energy – to provide this motive force at the driveshafts is assumed to require an additional 6 GWh of electricity on the Majuro grid in 2030.[4]

7 Assumed future emissions of waste

Likewise, it was also assumed that the INDC suggestions of a 20% reduction in waste emissions by 2030 will be achieved. A further assumption has been made of an interim reduction of 10% by 2025. This results in expected waste emissions of 25.3 GgCO_2-e in 2025 and 22.5 GgCO_2-e in 2030.

Although the electricity roadmap does not address how this will be achieved, it did consider one specific scenario of a 1MWe Waste to Energy plant operating by 2025. As detailed in the technical note *The potential for Waste-to-Energy technology to reduce GHG emissions on Majuro*, this has the potential to exceed this target, with a reduction of 13,361 tCO_2-e, equivalent to a 47% reduction of waste emissions by 2025. This scenario results in expected waste emissions of 14.8 GgCO_2-e in both 2025 and 2030. However, given that the feasibility of waste to energy plant in Majuro is yet to be established, and the GHG reductions are heavily dependent on the composition of waste used as feedstock, this scenario was not included in the final electricity analysis.

8 Assumed future emissions of lighting and cooking

It was assumed that the INDC suggestion of a 15% reduction in non-electric fossil fuel cooking and lighting by 2030 is achieved. This results in expected lighting and cooking emissions of 970 tCO_2-e in 2030.

While this is likely through electrification, the commensurate addition to electricity generation is not calculated, as it is considered negligible.

9 Assumed future business-as-usual electricity demand

Although it is very uncertain what future electricity demand will be, an assumed future demand is as follows:

Majuro

Prior to 2020, an average quantity of 200 40ft refrigerated containers at the port is added to the Majuro load (connections to accommodate this new load are already being installed). Each container is assumed to draw an average of 7kW [13].

Population growth will be 3.5% from 2016 to 2020, then another 5.6% to 2030 [14], then flat thereafter. 36% of electricity demand (ie the residential loads) will scale up with the population increase.

[4] Assuming an ICE fuel to driveshaft efficiency of 30% , and an EV charging to driveshaft efficiency of 80%

Although the PPF factory may connect to the grid rather than using private generation, the generator efficiency is assumed the same and so no net changes to electricity demand.

By 2030, an extra 6 GWh consumption is added due to the electrification of some transport as described in Section 6 (equating to around 9% of Majuro demand).

Ebeye

Population growth will be 1.4% from 2016 to 2020, then another 1.4% to 2025 [14], then flat thereafter. 36%[5] of electricity demand will scale up with the population increase.

Other islands

No change

10 Emissions targets for RMI electricity generation

Given the estimated 2010 inventory, and the listed assumed contributions of other sectors to the economy wide targets, the required reductions in electricity emissions from 2010 levels were calculated.

If fishing emissions are ignored, by 2025 a 50% reduction in emissions from electricity from 2010 levels will be required. By 2030, a 65% reduction in emissions from electricity from 2010 levels will be required. This equates to a maximum diesel fuel consumption of 2.9 million gallons and 2.0 million gallons respectively. The required reduction in emissions against the expected increase in demand is shown on the following wedge diagrams (to 2030 and also to the 2050 net zero emissions target).

This is partly based on the assumption that electricity sector emissions in 2010 were 52% of national emissions. If fishing emissions are included in the 2010 inventory, then this figure is more like 36%. If fishing emissions were included, then clearly the required reductions in electricity emissions would be significantly larger than this. The required reduction has not been calculated, since the expected applicable fishing emissions in years 2025 and 2030 are not known. Future fishing activity in the Pacific region will depend on fish stocks, movements and price; and the location of bunkering is unknown. Influence over fishing activities may take a regional rather than national approach.

As previously noted, due to the way that the 2006 IPCC guidelines attribute fishing emissions, the disproportionate effect it has on the RMI GHG inventory, and the uncertainty around how much bunkering continues to occur in-country, for this analysis fishing emissions have been excluded from the inventory.

[5] This proportion was not known and so the Majuro value was used

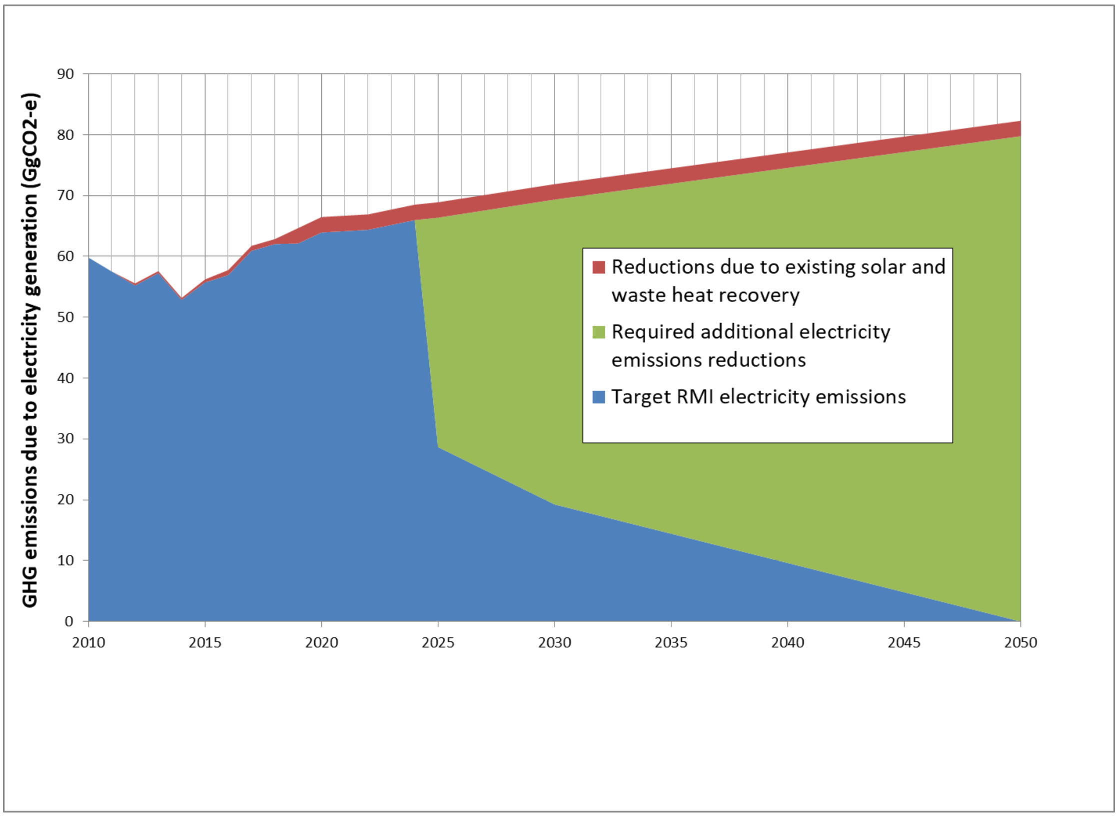


Figure 7: Required emissions reductions in the RMI electricity sector

11 Conclusions and Recommendations

In 2010 electricity was estimated to contribute to around 52% of national GHG emissions, excluding fishing (if fishing emissions are included it is more like 36%). Assuming that the waste, transport and other sectors meet the emissions reductions recommended by the INDC, this means that to meet national emissions reductions targets the RMI electricity sector would need to reduce emissions from 2010 levels by 50% by 2025, and by 65% by 2030.

As a next step, the RMI roadmap will investigate measures and technologies to address the "Required additional electricity emissions reductions" areas in the charts above, such as:

- Supply side energy efficiency
- Demand side energy conservation and efficiency
- Renewable energy generating technologies
- Alternative fuels

An accurate and definitive RMI GHG inventory (including the year 2010) should be developed to further define actions required, however this is outside of the scope of the RMI electricity roadmap.

12 References

[1] RMI Govt, *Republic of the Marshall Islands Intended Nationally Determined Contribution*, Communicated to the UNFCCC on 21 July 2015.

[2] Subbarao, Srikanth & Mucadam, Riyad, *Second National Communication of the Republic of the Marshall Islands*, United Nations Development Program/Global Environment Facility, Suva, Fiji 2015.

[3] Economic Policy, Planning and Statistics Office, Republic of the Marshall Islands, GDP SURVEY FY10.xls, supplied by MEC.

[4] MEC Monthly Fuel Report FY20xx.xlsx, supplied by MEC.

[5] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *Vol 2 Energy Ch3 Mobile Combustion* (sourced http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_3_Ch3_Mobile_Combustion.pdf), and IPCC, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Primer (sourced https://www.ipcc-nggip.iges.or.jp/support/Primer_2006GLs.pdf)

[6] Email communication, Ben Wakefield.

[7] MEC Propane Report FY20xx.xlsx, supplied by MEC.

[8] Economic Policy, Planning and Statistics Office, Republic of the Marshall Islands, and the SPC Statistics for Development Programme, Noumea, New Caledonia, *Republic of the Marshall Islands 2011 Census Report,* 2012

[9] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Vol 5 Waste Ch3 Solid Waste Disposal* (sourced https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf)

[10] SCS Engineers, *Final report, Pre-Feasibility Study, Waste-to-Energy, Majuro Atoll, Republic of the Marshall Islands,* 2010.

[11] Hydro-Electric Corporation trading as Entura, *FINAL REPORT TA-9225 RMI: Majuro Power Network Strengthening, Asian Development Bank*, March 2018.

[12] IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, *Vol 5 Waste Ch6 Wastewater Treatment and Discharge* (sourced https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf).

[13] GDV, *Container handbook, Ch8.1.2. Actual Power Consumption*, 2018 (sourced http://www.containerhandbuch.de/chb_e/wild/index.html?/chb_e/wild/wild_08_01_02.html)

[14] Office of the Chief Secretary, RMI, *Republic of the Marshall Islands Population, Historical Review and Projections to 2027,* 2018