Advances in Global Change Research 68

Anirudh Singh *Editor*

Translating the Paris Agreement into Action in the Pacific

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Translating the Paris Agreement into Action in the Pacific

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To the people of the Pacific
– we can do it.

Foreword

Global warming and its consequences on climate change are generally considered to be one of the biggest threats to humanity and biodiversity and to the very planet we live on. Climate change impacts have created some of the greatest global challenges we are facing today, including rise in sea level, ocean acidification, extreme weather patterns, food security and the list goes on. We have reached the stage where the Pacific, including other Small Island Developing States (SIDS), is at the forefront of these disastrous impacts. This is akin to a full climate emergency and one that has forced us to work collaboratively in finding innovative and sustainable solutions that work best for the Pacific.

This fascinating book produced by the dedicated team of the University of Fiji, titled *Translating the Paris Agreement into Action in the Pacific*, focuses primarily on how Fiji is attempting to address the global issue of climate change mitigation through the various possible renewable energy projects on the ground that can support its Nationally Determined Contribution (NDC) Implementation Roadmap for 2017–2030. This Roadmap sets Fiji's pathway for its emissions reduction target under the Paris Agreement.

The book is divided into three separate sections. The first section (Introductory Concepts and Techniques) presents introductory concepts and techniques used in mitigation actions.

Despite the Pacific's negligible emission contributions, the Pacific SIDS have joined the rest of the world in the endeavour to reduce global GHG emissions. All the Pacific countries have rather ambitious Nationally Determined Contributions (NDCs), with Fiji and the Marshall Islands also developing Low Emission Development Strategies (LEDS) as recommended by the Paris Agreement. The central goal of Fiji's LEDS is to achieve net zero carbon emissions by 2050 across all sectors of its economy. These sectors include electricity and other energy use, land transport, domestic maritime transport, domestic air transport as well as agriculture, forestry and other land use (AFOLU) and waste.

To realise this goal, the Fiji LEDS specifies four possible low emissions approaches which include (1) business-as-usual (BAU) unconditional scenario, (2) BAU conditional scenario, (3) high ambition scenario and (4) very high ambition scenario. Some of the key actions for decarbonising Fiji's sector on 'electricity and other energy use' are economy-wide energy efficiency measures, capacity building and education, capacity building for renewable energy and smart grids and new solar, hydro, biomass, wind, waste-to-energy, biogas, geothermal and energy storage installations.

Part II (Mitigation Actions) of this publication investigates the potential contributions of several renewable energy projects towards greenhouse gas (GHG) reductions in Fiji. While this list is not exhaustive by any means, the discussion it initiates is important, for we do need to translate the aspirations, expressed in agreements, strategies and plans, into workable solutions. We need to continue this research, and we seek the best and most suitable solutions for our people. This is especially with regard to their energy needs, for we must keep in our minds that hundreds of communities in the Pacific have never enjoyed the benefits of electricity through conventional means in their lives.

Part III (Outcomes) of this publication summarises the main outcomes and appraises the significance of the mitigation action in the light of the objectives of Fiji's NDC Implementation Roadmap. This is a discussion that needs to continue as we continue to learn about their impact within our communities.

This begs a very important question of how these studies or renewable energy projects in Fiji can be emulated in other Pacific island countries (PICs). Two important concepts need to be taken into consideration. These are replicability and scalability. Project replicability focuses on the possibility of establishing similar project in another location or PIC. On the other hand, scalability relates to the potential to increase the size of project volume or installation in relation to location and geodemography amongst other factors. This is achievable through more collaborative actions and information-sharing between government, private sector and civil society in the PICs with academic and research institutions such as the University of Fiji as partners.

The Pacific Islands Development Forum and the University of Fiji, through the Centre for Renewable Energy (CORE), will continue the research into new and sustainable energy solutions that work for the Pacific people. The CORE will also continue providing valuable training and capacity development to make optimum use of these technologies for the benefit of the Pacific island countries and communities.

Secretary General
Pacific Islands Development Forum
Suva, Fiji

François Martel

Introduction

The diverse impacts of climate change, projected or already recorded, represent a key challenge for people across the globe, and particularly for the Pacific region. The Pacific island countries (PICs) are highly vulnerable to the impacts of climate variability and extreme weather events because of the geographic and socioeconomic factors specific to these countries. These include small populations, high dependence on natural resources and low elevation. The array of small low-lying Pacific islands and atolls such as Tuvalu, Kiribati and Marshall Islands is highly threatened by sea level rise and coastal erosion, making some parts of these islands uninhabitable.

All PICs, large or small, are confronted by extreme weather events such as cyclones and environmental impacts such as coral bleaching which have serious effects on their livelihoods and ecosystem services. Tropical Cyclone Pam (2015) and Cyclone Winston (2016), for instance, have led to major losses in Vanuatu and Fiji, respectively.

In addition to natural hazards, climate change imposes long-term risks, particularly coastal degradation, health impacts and agricultural losses. The projected reduction in average rainfall in Fiji is also a matter of concern, since 55–65% of the country's electricity supply is produced through hydropower. Natural disasters have a huge impact on the economic progress and environments of the PICs, posing a challenge to their ability to meet the objectives of their sustainable development goals.

In 1988, the UN General Assembly recognised the need to manage anthropogenic activities that affected global climate patterns. Subsequent international negotiations through the UNFCCC led to several countries ratifying UNFCCC's mission to limit the concentrations of GHG in the atmosphere to reasonable levels. Fiji duly signed the convention at its launch in 1992 and ratified it in 1993. Its Initial National Communication (INC) provided an overview of Fiji's national status, mostly relating to climate change issues. It presented a GHG inventory, a vulnerability assessment as well as climate change mitigation and adaptation strategies.

The Second National Communication (SNC) was submitted to the UNFCCC in 2013 as a follow-up to the INC. The SNC presented comprehensive information on national circumstances, a GHG inventory and reports on various climate change initiatives in Fiji. The highlights included the National Climate Change Policy which was developed in 2012. It also included Fiji's focus on mitigation options to reduce GHG emissions by reducing the use of fossil fuels in power generation and transportation through renewable energy (RE) and reduction in energy consumption via energy efficiency (EE) practices.

The SNC prepared the way for Fiji to submit its Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015 prior to COP21 in Paris. This focused on the energy sector and also took into consideration Fiji's forestry sector via the REDD+ programme.

The COP21 held in Paris in November 2015 finally provided the avenue for the 197 parties to the UNFCCC to take a strong stance on climate actions and investments considered necessary for a sustainable low-carbon future. The Paris Agreement on climate change undertook to hold global temperature rise to well below 2 °C above pre-industrial levels through reductions in GHG emissions. In its ambitious efforts to combat climate change and adapt to its impacts, the Paris Agreement pledged support to assist developing countries in fulfilling their obligations to the UNFCCC.

According to the agreement, each member nation is to prepare and maintain a Nationally Determined Contribution (NDC) towards global reductions in GHG emissions. In the case of the energy sector, such reductions can be effected either by replacing fossil fuel use by renewable energy (RE) or by adopting energy efficiency (EE) measures. The specific strategy to adopt is left to the individual members. It is noteworthy that Fiji was the first country to ratify the Paris Agreement.

The Fijian Government has demonstrated its strong commitment to global efforts in combating climate change on various platforms. Thus, it comes as no surprise that Fiji became the first Small Island Developing State (SIDS) to assume the Presidency of COP23, held in Bonn, Germany, in 2017. It is during the COP23 that Fiji launched its NDC Implementation Roadmap, which aims to reduce emissions from the energy sector by 30% by 2030. It also intends to reach close to 100% renewable energy power generation by 2030. Fiji's NDC provides a detailed temporal pathway towards achieving its target and calls for a reduction of 627,000 tCO_2 emissions per annum by the energy sector by 2030 through its power generation, demand-side efficiency and transport subsectors.

Suggested actions include the use of new renewable energy (RE) power generation, increased biomass plantation for fuel use and grid extensions. In addition, the effective implementation of the Roadmap is reliant on several key factors, which are important to ensure that the mitigation measures under the Roadmap can be aptly financed and executed. These factors include financing, governance and intuitional arrangements and monitoring and evaluation. Financial aspect is no doubt the major factor contributing to the successful implementation of the Roadmap. There is an absolute need for new financial strategies and mechanisms to reach the mitigation target.

The Roadmap is indeed laudable for its intended aims, but it raises several issues that need further attention. These include, amongst other things, the availability and identification of new RE sources and their method of utilisation. There are other requirements for RE production apart from the resources that need to be fully understood. There is also a need for a careful analysis of GHG emissions from the new RE resources and technologies to ensure that they do indeed contribute to a net reduction in emissions. Full life cycle assessments of the RE production will therefore have to be carried out to ascertain more realistic values of the actual reductions.

The projections of the Implementation Roadmap do not fully account for the possibility that the availability of RE resources may vary over the years. As most of these sources of energy, in particular wind, solar and hydro energy, are dependent on climatic conditions, this is a highly likely scenario, and a method is therefore required for forecasting the actual energy production in the future.

This book brings together the results of several renewable energy projects that shed important insights into many of these issues. It describes actions in the form of specific renewable energy projects that are verifiable and can be easily monitored for emissions reductions. It goes on to demonstrate how RE can be successfully used to reduce net GHG emissions in the Pacific and reveals how the 2 °C target of the Paris Agreement can be translated into verifiable and quantifiable actions that can be easily monitored.

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Contents

Part I
Introductory Concepts and Techniques

Chapter 1
Estimating Greenhouse Gas Emissions in the Pacific Island Countries

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Abstract A national Greenhouse Gas Inventory (GHGI) outlines estimates of emissions of greenhouse gases (GHGs) from various sectors of a country such as energy, agriculture, forestry and other land use (AFOLU), waste and industrial processes and product use (IPPU). The accuracy and consistency of the inventory is a basic requirement to ensure reliability of the estimates so that opportunities for potential reductions could be realized that would eventually lead to the development of low emission scenarios to achieve near zero emissions by 2050. An analysis of the second national communications of Pacific Island Countries (PICs) to UNFCCC shows that most of the emissions from PICs are from the energy sector and probably explains why Fiji's NDC Roadmap focuses on 30% emission reduction in the energy sector by 2030. This chapter discusses the IPCC 2006 guidelines to estimate emissions of CO_2 and other non-CO_2 greenhouse gases from different sectors. The uncertainties in emission estimates are discussed with more focus on data availability in the PICs. Research needed to derive country specific emission factors are also highlighted for certain sectors.

Keywords Greenhouse gas (GHG) · GHG inventory (GHGI) · Paris agreement · IPCC guidelines · Pacific Island countries (PICs) · Fiji NDC implementation roadmap

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1.1 Introduction

Estimating greenhouse gas emissions or developing a national greenhouse gas inventory is crucial in implementing mitigation policies and strategies to achieve climate goals. To execute an effective and feasible mitigation strategy it is critical to obtain robust emissions data before and after the implementation of the strategy to calculate the reduction of CO_2 equivalent achieved (Bi et al. 2011). The accuracy of the emission calculations depends on the consistency of the methodology applied, the robustness of the input data such as emission factors and other activity data required in the model (Kennedy et al. 2009).

The UNFCCC Article 4 – Commitments simply states "All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall:

- Develop, periodically update, publish and make available to the Conference of the Parties, in accordance with Article 12, national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties.

It is known that not all emissions can be measured. However, they can be estimated using credible methodologies that are generally accepted by the Conference of the Parties. To this end, the IPCC developed IPCC National Greenhouse Gas Inventory 1996 guidelines and good practice guidelines (GPG) 1996 which was then revised to IPCC National Greenhouse Gas Inventory 2006 guidelines and GPG2003. Currently a special Task Force is set up to refine the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, and the final draft of this new methodology report titled "2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories" will be considered by the IPCC for adoption/acceptance at its Plenary Session in May 2019. The development of such methodologies provide the much needed consistency in reporting emissions and providing comparable data to monitor progress in achieving reduction target set by international agreements.

The IPCC methodology is based on a simple inventory method highlighted in Fig. 1.1.

The complexity of the reporting methodologies depends on the extent of the availability of the activity data and the country specific emission factor. There are

Fig. 1.1 The basis of calculating greenhouse gas emissions from activity data and emission factor

three tiers in the methodology defined by IPCC 2006 namely, Tier 1, Tier 2 and Tier 3.

- ***Tier 1*** is a simple method that uses default emission factors and to some extent uses guided principles to estimate activity data and consequently has a large uncertainty associated with the estimates derived from such methodology.
- ***Tier*** 2 is similar to tier 1 methodology except that country specific emission factors and other nationally available activity data are used in the calculation.
- ***Tier 3*** is a more complex method involving process based models with detailed, geographically specific data. Such methods provide robust and accurate estimate but requires thorough uncertainty assessments via means of detailed documentation procedures to ensure consistency and comparability between countries (Lokupitiya and Paustian 2006).

The greenhouse gases for which emissions are reported are those GHG that are regulated by the mandate of the Kyoto protocol and includes the following; Carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), Hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and nitrogen trifluoride (NF_3) (Michael and Hsu 2008). The 2006 IPCC Guidelines for Greenhouse Gas Inventories, IPCC Good Practice Guidance (GPG) 2000 and 2003 takes a sectoral approach in estimating national greenhouse gas emissions and the following sectors (given below) are covered which are relevant for the PICs:

- Energy Sector
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste

The PICs have used the mentioned IPCC guidelines to prepare their national greenhouse gas inventories that were reported to the UNFCCC. Table 1.1 below gives sectoral emissions (CO_2eq in Gg/year) overview of the PICs as reported in their Second National Communication to UNFCCC.

It is apparent from the table that the energy sector is the major contributor in the PICs except in Tonga and Vanuatu. This is very obvious and is aligned with global scenario whereby cities in developed countries contribute over 67% to the global GHG emissions from fossil fuel use (Bi et al. 2011). In Vanuatu, the agriculture sector, particularly emissions from enteric fermentation in ruminants, was the dominant sector while land use changes in Tonga was the major emission source. The compiled data demonstrates the strength of each sector and clearly highlights which sector needs serious mitigation efforts in order to reduce the emissions in an effort to realize the objectives of the Paris agreement. Hence it is important that PICs develop capacity in generating valid and robust national greenhouse gas inventories using the IPCC guidelines for identification of opportunities for emission reduction. A classic example is Fiji's Nationally Determined Contributions (NDC) Roadmap which highlights 30% reduction in the energy sector by 2030 as the energy sector provides opportunities and feasible emission reductions.

Table 1.1 PICs emissions (Gg/year of CO_2 eq) from different sectors reported as Second National Communication to UNFCCC

	Cook Islands	Fiji	Kiribati	Marshalls	Nauru	Samoa	Solomons	Tonga	Tuvalu	Vanuatu
Energy	54.5	1570	64.0	85.0	13.3	174.4	350.6	94.9	11.2	122.4
AFOLU	0.08	977	0.84	NE	1.61	135.4	76.39	150.8	4.61	587.4
Waste	2.94	84	101.1	37.5	4.55	32.8	191.6	29.1	2.63	10.8
IPPU	0.59	NE	NE	NE	NE	9.51	NE	NE	NE	NE

Many developed cities have reported their carbon footprints using both GHG protocols and taking into account the Life Cycle Assessment (LCA) approach. The GHG protocol is based on the IPCC Guidelines whereas the LCA approach takes into account emissions from the initial stages to final stages of a product or service and is termed "cradle to grave" when considered from the resource extraction stage to the waste disposal stage (Reijnders 2012). In addition to GHG emissions, LCA offers the benefit of assessing other environmental impacts of products or services. It is becoming a widespread practice recently in greenhouse gas emission estimate that the IPCC guidelines are combined with the LCA approach to provide a more holistic estimate if a particular mitigation strategy is actually an emission reduction strategy (Ramaswami et al. 2008). The life cycle assessment of wind and solar energy, which are strong mitigating options in the energy sector, shows that they are not entirely emission free technologies. A comprehensive study involving published literature concludes that the LCA approach shows that the wind energy emits an average of 34.11 g CO_2eq/kWh and solar energy emits an average of 49.91 g CO_2eq/kWh (Nugent and Sovacool 2014).

1.2 Energy Sector

The energy sector emits GHGs mainly through the combustion of fossil fuels and Volume 2 of IPCC 2006 guidelines states that the key source categories in the energy sector are fuel combustion activities (stationary combustion), fugitive emissions from the oil refineries and carbon dioxide transport and storage. For PICs, stationary combustion is the only relevant key source category (See Fig. 1.2) as the advanced technologies in exploration and exploitation of fossil fuel and injection and storage of CO_2 underground are not available. The major greenhouse gas emitted by the energy sector is CO_2 although there are very minimal emissions of CH_4 and N_2O as well.

1.2.1 Estimating Emissions from the Energy Sector

1.2.1.1 Stationary Combustion Sub-Sector

The emissions from the stationary combustion sub-sector mainly included the sum of emissions from main producers of electricity generation, on-site use of fuel to generate its own electricity such as in generators in commercial and institutional buildings, manufacturing and construction industries, mining and quarrying industries, agricultural industries and most importantly all emissions from fuel combustion in households such as use of kerosene or natural gas for cooking.

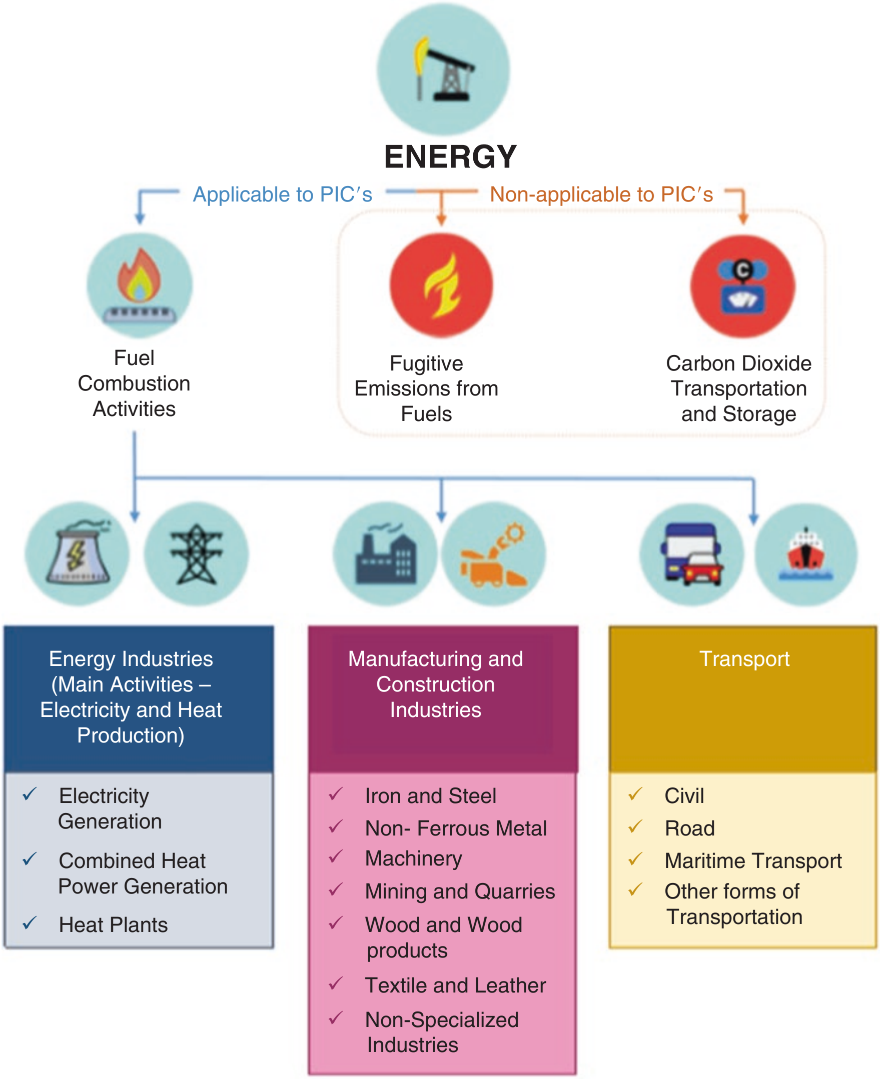

Fig. 1.2 The key source categories in the energy sector and the only relevant source category for PICs are fuel combustion activities

The Tier 1 approach requires data on the amount of fuel combusted in the source category and the default emission factor (See Table 1.2) as shown in the equation below:

$$\text{Emissions}_{GHG,fuel} = \text{Fuel Consumption}_{fuel} * \text{Emission Factor}_{GHG,fuel}$$

Table 1.2 Emission factors for different GHG and fuel type typically used in the Pacific Islands

Fuel Type		CO_2 (kg-CO_2/TJ)	CH_4 (kg-CO_2/TJ)	N_2O (kg-CO_2/TJ)
Crude Oil		73 300	3	0.6
Natural Gas Liquids		64 200	3	0.6
Gasoline	Motor Gasoline	69 300	3	0.6
	Aviation Gasoline	70 000	3	0.6
	Jet Gasoline	70 000	3	0.6
Jet Kerosene		71 500	3	0.6
Other Kerosene		71 900	3	0.6
Gas/Diesel Oil		74 100	3	0.6
Liquefied Petroleum Gases		63 100	1	0.1
Ethane		61 600	3	0.6
Coal		94 600	1	1.5
Coke		107 000	3	1.5
Residual Fuel Oil		77 400	3	0.6

Where;

- $Emissions_{GHG, fuel}$ = emissions of a given GHG by type of fuel (kg GHG)
- $Fuel\ Consumption_{fuel}$ = amount of fuel combusted (TJ)
- $Emission\ factor_{GHG, fuel}$ = default emission factor of a given GHG by type of fuel (kg gas/TJ). Refer to Table 1.2.

It should be noted that to use the above equation to calculate the emissions, the fuel consumption data in mass or volume units must be converted into the energy content of these fuels in terajoules (TJ). Tier 2 approach is used when a country specific emission factor for the source category and fuel for each gas is available. Tier 3 takes a more complex approach where different technologies to combust fuels are taken into account as some technologies maybe more fuel efficient and may influence emissions.

There have been some documented evidences on research into country specific emission factors to generate a more reliable estimate of GHG emissions from combustion sources. A study conducted on obtaining country specific emission factors for energy sector in Mauritius clearly demonstrated that emissions calculated with the experimentally derived country specific emission factors showed that the emission reported under the Third National Communication (TNC) was overestimated by 10% in the power subsector (Ramphull and Surroop 2017). Similarly in China the estimates from fossil fuel combustion were revised using two sets of comprehensive new measurements of emission factors as the fuel composition in China is known to vary widely from year to year especially for coal (Liu et al. 2015). The new revised emission estimate was lower than what was reported in the inventory earlier which was the consequence of the emission factor for Chinese coal being on average 40% lower than the IPCC recommended values (Liu et al. 2015).

1.2.1.2 Mobile Combustion Sub Sector

The greenhouse gas emissions from mobile combustion are due to major transport activity, i.e., road, off-road, air, railways, and maritime transport. The major greenhouse gas emitted is CO_2 with minute emissions of CH_4 (2%) and N_2O (1%). The following equation is used to calculate CO_2 emissions from the transport sector:

$$\text{Emission} = \Sigma\left(\text{fuel type} \times EF\right)$$

Where:

Emission = Emissions of CO_2 (kg)
Fuel = fuel sold (TJ)
EF = emission factor (kg/TJ)

The activity data needed to estimate emissions is the amount of fuel sold and to engage in higher tier approach than further classification is required in terms of amount of fuel sold to a particular type of vehicle with known emission control technologies such as catalytic converters. The aviation source category takes into account the emissions associated with the international bunkers and should be prepared as part of the national inventory but excluded from the national total and reported separately. It should be cautioned when considering emissions from biofuels used in vehicles. Only the CO_2 emissions from the fossil fuel component is accounted for whereas CO_2 emissions from the combustion of biogenic carbon is accounted for under the AFOLU sector and double counting should be avoided.

The national statistics for Fiji shows that a total of 707 million litres of fuel was imported of which 50% was re-exported to other PICs. Sectoral breakdown showed that 29% of the fuel stock was used for electricity generation, 64% was consumed by the transport sector; land transport (16%), air (26%), marine (22%) and the remainder was used for off grid electricity generation, household lighting and cooking (Holland et al. 2014). It was noteworthy that for PIC based scenario, emissions from the marine transport is sizeable portion and there have been some efforts in the emission reduction in maritime transport through sustainable sea transport research programme at the University of the South Pacific (Holland et al. 2014). The Maritime Technology Cooperation Center in the Pacific (MTCC-Pacific) provides initiatives for climate mitigation in the maritime industry and has contributed significantly to Kiribati's Nationally Determined Contributions (NDCs) and broader Sustainable Development Goals.

1.2.2 *Uncertainties in Energy Sector Estimation*

The uncertainties in estimating emissions in the energy sector arise from the fact that activity data is not available in the correct format to be used directly in the equation above. The fuel data is usually provided in litres and to convert it into mass, the density is used which is dependent on temperature. However the temperature effects on density are not considered and this could introduce a bias of ±3%. In compiling the national greenhouse gas inventory for TNC, it was noted that instead of fuel consumption data, the total amount of fuel imported was used to calculate the emissions for combustion activities. This may add bias to the emission estimate as the total fuel imported in the particular year is not what is consumed in that particular year. The quality of emission inventories for the most important greenhouse gas, CO_2, depends mainly on the accuracy of fuel use statistics. Ideally the fuel consumption data should be used for estimating emissions but the major challenge in the PICs is the unavailability of the sale data of different fuel types from the private oil companies. Although IPCC 2006 guidelines assign the uncertainty levels at 2% for emissions from fuels but for PICs it estimated to be approximately 10% due to unavailability of consumption data.

1.3 Agriculture, Forestry and Other Land Use (AFOLU) Sector

The AFOLU sector deals with the estimation of GHG emissions and removals from managed lands through biological and physical processes. Managed land is defined as land where anthropogenic activities influence the natural ecosystem for agricultural, ecological and social functions (IPCC 2006). This sector considers emissions from the agricultural subsectors such as CH_4 emissions from livestock enteric fermentation, CH_4 and N_2O emissions from manure management, CH_4 emissions from rice cultivation, direct N_2O emissions from N-based fertilizer application, indirect N_2O application from managed soils, CO_2 emissions from liming and urea application and non-CO_2 emissions from biomass burning. The Forestry and other land use sub-sectors take into account emissions and removals from forest land remaining and land converted from one category to another such as forest land converted to cropland or grassland or settlements. The forestry sector uses net changes in C stock over time to estimate CO_2 emissions and removals from dead organic matter, soil organic matter of organic and mineral soils and harvested woody products (HWP) for all managed lands.

In the PICs context, the key categories identified in the agricultural sector are CH_4 emissions from ruminant animals and CH_4 emissions from manure management whereas CH_4 emissions from rice cultivation and N_2O emission from fertilizer application are negligible. In Fiji the estimated emissions from the ruminants and manure management accounted for 37%, as reported in second national communication to UNFCCC, whereas Vanuatu recorded the highest emissions from the agricultural sector amounting to 86% in 2010.

1.3.1 Estimating Emissions from Forestry and Other Land Use

The key source category under this section is estimating emissions or removals from managed forest land. Chapter 4 of Volume 4 of IPCC 2006 guidelines describes three tiers in estimating changes in carbon stock from managed forests that have been under the forest land for over 20 years. The primary step in calculating emissions/removals from the forestry sector is to estimate the biomass gain or loss. There are basically two different methods for estimating biomass gains and losses: Gain-Loss method and a stock difference method. The Gain–Loss method is more appropriate for Tier 1 approach where country specific activity data are not available. There are seven basic steps outlined in Volume 4 of IPCC 2006 to estimate change in carbon stocks in biomass (ΔC_B) using the Gain-Loss method. The seven steps are as follows:

Step 1: Categorizing the area of forest land into appropriate forest types of different climatic or ecological zones.
Step 2: Estimate the annual biomass gain in forest land using equations 2.9 and 2.10 in chapter 2 of IPCC 2006 guidelines.
Step 3: Estimate annual carbon loss due to wood removals
Step 4: Estimate annual carbon loss due to fuelwood removals
Step 5: Estimate annual carbon loss due to disturbance
Step 6: from the estimated losses in steps 3–5 estimate the annual decrease in carbon stock due to biomass losses (ΔC_L) from equation 2.11 in chapter 2
Step 7: Estimate the annual change in carbon stocks biomass (ΔC_B) using equation 2.7 in chapter 2.

In addition to calculating the changes in biomass, changes in carbon stock from other carbon pools needs to be estimated such as dead organic matter (DOM) and soil organic matter (SOM) and emissions of CO_2 and non-CO_2 gases from forest burning. In Tier 1 approach it is assumed that changes in carbon stock due to DOM is zero. It is also noteworthy that in Tier 1 method, carbon stock changes for mineral soils it is assumed there is no change with forest management and it is assumed to be zero. However, for organic soils, carbon emissions due to drainage of forest organic soils are addressed. The C emissions can be calculated by multiplying the area of drained organic soil with the emission factor for annual losses of CO_2.

Basically similar approaches as above are applied to estimate emissions from croplands and grasslands. There is also guidance provided to report GHG emissions from managed wetlands particularly peat lands managed for peat extraction and lands flooded in reservoirs as flooded lands. The emissions due to croplands, grasslands, wetlands and settlements are detailed in chapter 5, 6, 7 and 8 of Vol 4, IPPC 2006 guidelines respectively.

1.3.2 Estimating Emissions from the Agricultural Activities

1.3.2.1 Enteric Fermentation

Methane emissions from enteric fermentation in ruminant animals and to a lesser extent, of non-ruminants are estimated as such:

$$\text{Emissions}\left(CH_4\right)_\text{T} = EF\left(\text{T}\right) \times \frac{N_T}{10^6}$$

Where;

Emissions $(CH_4)_T$ = methane emissions for animal category T, Gg CH_4 year^{-1}
$EF_{(T)}$ = emission factor for animal type, T, kg CH_4 head^{-1}
$N_{(T)}$ = number of heads for animal category T
T = animal category

1.3.2.2 Manure Management

This source category considers CH_4 emissions from anaerobic manure decomposition processes and direct and indirect N_2O emissions from animal excretion. Direct N_2O emission is related to the total amount of N in manure treated in different manure management systems (MMS). The indirect N_2O emission refer to N in manure that volatilizes as NH_3 and NO_x or lost through run-offs and leaching and when these N is deposited in some other place through the redeposition processes, it will be transformed by microbial activity into N_2O.

The methane emission from the manure management is estimated as such:

$$CH_{4(\text{T})} = \text{N}_\text{T}{}^{*} EF$$

Where;

$CH_{4(T)}$ = CH_4 emissions in kg CH_4year^{-1} for animal category, T.
N_T = number of head f animal category T, heads year^{-1}
EF = default emission factors expressed in units of kg CH_4 head^{-1} year^{-1}.

To estimate the direct N_2O emissions from animal excretion in a particular MMS it is imperative to estimate the total N excreted from manure management systems for animal category as such:

Firstly, calculate the excretion rate per animal using the equation below:

$$Nex_{(\text{T})} = \text{N}_\text{rate} \times TAM_{(\text{T})} / 1000 \times 365$$

$Nex_{(T)}$ = Nexcreted in manure for animal category T, kg N animal^{-1} year^{-1}
$Nrate_{(T)}$ = default N excretion rate per mass, kg N (tonnes animal mass)$^{-1}$ day^{-1}
$TAM_{(T)}$ = typical mass for animal category T, kg animal^{-1}

Then calculate the manure N content in a particular MMS as such:

$$NE_{MS(\mathrm{T})} = \left(\mathrm{N}_{(\mathrm{T})} \times Nex_{(\mathrm{T})} \times MS_{(\mathrm{S,T})}\right)$$

Where:

$NE_{MS(T)}$ = Total nitrogen excreted from MMS for animal category, T, heads year^{-1}.
$N_{(T)}$ = number of head f animal category T, heads year^{-1}
$Nex_{(T)}$ = annual N excretion for animal category T, kg N animal^{-1} year^{-1}
$MS_{(S,T)}$ = share of manure treated in each systems S for animal category T
T = animal category
S = manure management system

Hence direct N_2O emissions are calculated as follow:

$$\text{Direct emissions}\left(\mathrm{N_2O}\right)_{\mathrm{T}} = \Sigma\left[NE_{MS} \times EF_{3(\mathrm{s})}\right] \times 44/28 \times 10^{-6}$$

Where;

Direct emissions $(N_2O)_T$ = Direct N_2O emissions from MMS for animal category T, kg N year^{-1}
$EF_{3(S)}$ = Emission factor for direct N2O emissions from each MMS system, S, kgN20N/kg N.
T = Animal Category
S = manure management system (MMS)

The indirect emissions of N_2O is estimated as follows:

$$\text{Indirect emissions N2O} = NE_{MS(\mathrm{T})} \times \left[\left(\mathrm{Frac}_{\mathrm{GASMS(S)}} \times EF_4\right) + \left(\mathrm{Frac}_{\mathrm{LeachMS}} \times EF_5\right)\right] \times 44/28 \times 10^{\ 6}$$

Where;

Indirect emissions $(N_2O)_T$ = Indirect N_2O emissions produced from the atmospheric deposition of N volatilized from manure management systems for animal category T, Gg N_2O year^{-1}
$NE_{MS(T)}$ = Total N excreted from manure management
$Frac_{GASMS(S)}$ = fraction of N from MMS that volatilizes as NH_3 and NO_x, kg N volatilized from each system S
EF_4 = emission factor indirect N_2O emissions from atmospheric deposition of N on soils.

$Frac_{Leach}$ = fraction of N leaches as NH_3 and NO_x
EF_5 = Emission factor indirect N_2O emissions from N leaching and run-off, kg N_2O/kg N
T = animal category
S = manure management

1.3.2.3 Rice Cultivation

Methane emission from rice cultivation is the result of anaerobic decomposition of organic matter in paddy fields. The default IPCC seasonally integrated EF of 20 g CH_4 m^{-2} $year^{-1}$ is used and this is further modified by the scaling factor for the water regime and application of organic amendments. For irrigated farms the scaling factor is one whereas the rainfed is 0.7 and 0 for upland and dry conditions. If organic manure or straw incorporation is applied in the rice paddies then a scaling factor of 1.4 is considered.

$$\text{Emissions}\left(CH_4\right) = \frac{EF\ x\ SF_o\ x\left(Ai + \left[Aj\ x\ SFj\right]\right)}{10^5}$$

Where;

Emissions (CH_4) = Methane emissions per rice paddy, Gg CH_4 $year^{-1}$
EF = Seasonal methane emission factor, g m^{-2} $year^{-1}$
Ai,j = Rice paddy area harvested in the two water regimes, irrigated and rainfed, ha $year^{-1}$
SFo = 1.4 correction factor for organic amendments, for all countries
SFj = 0.7 scaling factor for Aj

In the PICs, Fiji has limited rice farming with total methane emissions of 0.09 Gg/year in 2004 and a recent assessment showed emissions to be 2.29 Gg/year in 2017 (Chand 2018). The increase in methane emission was observed due to the commitment from the Fiji Government to promote rice farming and to become self-sufficient by 2030 which led to an increase in land area of rice farming. The study also derived the emission factor for both rainfed and continuously flooded water regimes and it was noted that the country specific emission factors were within the range of the IPCC default emission factors (Chand 2018).

1.3.2.4 Synthetic Fertilizers

The application of nitrogen based synthetic fertilizers lead to direct emission of N_2O from the agricultural land due to microbial nitrification and denitrification processes. To estimate emissions of N_2O the following formula is used:

$$\text{Direct Emissions}\left(\mathrm{N_2O}\right) = \mathrm{N} \times 44/28 \times EF \times 10^{-6}$$

Where;

Direct emissions (N_2O) = Direct N_2O emissions from synthetic nitrogen additions to the managed soils, GgN_2O year^{-1}
N = Consumption in nutrients of nitrogen fertilizers, kg N input year^{-1}
EF = Emission factor for N_2O emissions from N inputs, kg N_2O–N/kg N′

The FAOSTAT database could be used to attain the main activity data on consumption of fertilizer in different years. The default emission factor for direct N_2O emissions from the application of synthetic fertilizer is 1% of N-input (IPCC 2006).

1.3.3 Uncertainties in the Agriculture Sector

The major uncertainty usually comes from the Tier 1 (default) methodology of the IPCC 2006 guidelines. The uncertainties in the agriculture sector emanate from the reliability of the activity data and the emission factors. The Food and Agriculture Organization (FAO) database is normally used to extract the activity data such as ruminant animal population, however during the compilation of Fiji's SNC it was noted that there were large discrepancies between the national statistics and the FAO database on ruminant animal population. The FAO database for Fiji ruminant population was projected from the animal surveys done in 1990s but in reality the cattle and dairy industry suffered huge loss due to economic viability and the foot and mouth disease that saw ruminant animal population dwindling in the recent two decades. The emission factors in the agricultural sectors were derived from studies in advanced western countries and have been used for tropical developing countries. There is a dire need for research to derive country or region specific emission factors. A study carried out in Sub-Sharan African region taking into account the field measurements of live weight, live weight change, milk production, dry matter intake and local climatology showed that the country specific emission factors were approximately 30–40% lower than IPCC default emission factors (Goopy et al. 2018). A study on measuring N_2O flux from the application of N-fertilizer in sugarcane plantations in Fiji suggested an emission factor of 5% as compared to the default value of 1% (Nisbat 2018). A thorough assessment of published literature on emission factors showed that the emission factor for direct N_2O emissions from synthetic fertilizer ranges from 0.013% to 21% with very few studies done in the tropical region (Nisbat 2018). Hence the default emission factor of 1% is a very poor proxy and introduces large uncertainty in the estimates. It is highly recommended that country specific emission factor should be derived to enable N_2O emission estimates from synthetic fertilizer more robust.