FEDERAL ENVIRONMENTAL PROTECTION AUTHORITY (FEPA)

Report on Assessment of Greenhouse Gas (GHG) Mitigation Policy for Waste Management, Light Transit and Biofuel

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Addis Ababa, Ethiopia

TABLE OF CONTENT

List of abbreviations

BAU	Business-As-Usual
CRGE	Climate Resilience Green Economy
CSA	Central Statistics Agency
DM	Dry Matter
DOC	Degradable Organic Carbon
FGDs	Focus Group Discussions
FOD	First Order Decay
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
KII	Key Informant Interview
LFG	Land Fill Gas
MBT	Mechanical Biological Treatment
MCF	Methane Correction Factor
MoH	Ministry of Health
MoMP	Ministry of Mines and Petroleum
MoT	Ministry of Transport
MoTI	Ministry of Trade and Industry
MoUDC	Ministry of Urban Development and Construction
MoWIE	Ministry of Water, Irrigation and Energy
MRV	Measuring, Reporting and Verification
MSW	Municipal Solid Waste
MUDC	Ministry of Urban Development and Construction
NAMA	Nationally Appropriate Mitigation Actions
RDF	Refuse-Derived Fuel
UGI	Urban Greenery Infrastructure
UNFCCC	United Nations Framework Convention on Climate Change

List of tables

List of figures

1. INTRODUCTION

1.1 Conceptualizing Mitigation

Different international organizations have defined the term 'Mitigation" slightly differently but they are variations of the central objective established in the United Nations Framework Convention on Climate Change (UNFCCC), i.e. to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Mitigation is a human intervention to reduce the sources or enhance the sinks of Green House Gases (GHGs). The Intergovernmental Panel on Climate Change (IPCC) also assesses human interventions to reduce the sources of other substances that may contribute directly or indirectly to limiting climate change. As there is a direct relation between global average temperatures and the concentration of greenhouse gases in the atmosphere, the key for the solution to the climate change problem rests in decreasing the amount of emissions released into the atmosphere and in reducing the current concentration of carbon dioxide (CO_2) by enhancing sinks (e.g. increasing the area of forests).

Efforts to reduce emissions and enhance sinks are referred to as mitigation. Mitigation is considered as any action that contributes to the objective of stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system by promoting efforts to reduce or limit GHG emissions or to enhance GHG sequestration.

An activity will be classified as related to climate change mitigation if it promotes efforts to reduce or limit GHG emissions or enhance GHG sequestration. In all the above definitions, stabilizing GHG concentrations in the atmosphere can only be achieved through substantive mitigation actions, i.e. actions to limit anthropogenic GHG emissions by sources and to preserve or enhance sinks and reservoirs of GHGs. This can only happen when the actions are supported by a variety of stakeholders.

1.2 Description of Mitigation Actions, Policies and Measures

In order to measure the mitigation effort of a country, we would need to describe its various mitigation actions, policies and measures undertaken in a given timeframe and their mutual interactions. This may require coordinating different mitigation actions, policies and measures that are sometimes implemented and seen separately. Looking at them together, with quantifiable indicators, can enable a better assessment of the impact of the mitigation actions, policies and measures.

1.3 Mitigation Assessments and Approaches

Mitigation assessments are conducted to assess whether the GHG emissions reduction targets are being met, and to track the progress of national climate action and overall transparency. Different metrics and indicators can be used to assess mitigation. Quantitative indicators are usually more robust in showing the impacts and outcomes of mitigation action. National GHG Inventories are useful databases for an overview of the various mitigation pathways at the national level.

The methodological differences between the national (top-down) and more individual (bottom-up) assessments have limited the effectiveness of the assessments for some time. Fortunately, more hybrid approaches exist now that enable the use of GHG Inventories for both these approaches.

Data used in mitigation assessments may come from a variety of different sources. As mentioned earlier, here are two broad forms of data collection:

a) Bottom-up data: Data that is measured monitored and collected at the source, facility, and entity or project level.

b) Top-down data: Data that comprises of macro-level statistics collected at the national/regional jurisdiction or at the sectoral level.

1.4 Explaining Mitigation Potential

In a mitigation assessment, the identification of the "Mitigation Potential" associated with any particular policy or activity aimed at reducing GHG emissions is central to the assessment process.

Th**e** Mitigation Potential refers to the quantity of GHG emission or removal that can be achieved in relation to a baseline or reference case scenario, and projected case scenario. The assessment of mitigation actions, policies and measures can also provide information beyond the magnitude of the GHG emissions reductions and cost-effectiveness. Most notably, mitigation assessments can also generate information about an action's expected sustainable development benefits, amongst others.

1.5 Ex-ante Assessment of Mitigation Impacts

Before considering assessing mitigation initiatives or tracking their progress, it is important to comprehensively describe them. This helps in developing a common understanding of their technical and economic boundaries, effects and opportunities. In this context, the scope, description and objectives can work as a basic information package to which other relevant elements can be added, e.g. costs, non-mitigation benefits, amongst others. Ex-ante assessments of mitigation effects for any activity can be estimated and quantified in terms of their effect on GHG emissions. The first step in this process is to identify relevant data, methodologies and models to estimate a baseline scenario. Once this is done, a project scenario is developed that estimates the impact that can be achieved by the implementation of the project activity and associated mitigation measures in comparison to the baseline. The numerical difference between the baseline values and the project values for any parameter of interest can be considered as the impact of the project/intervention.

1.6 Tracking Progress and Ex-post Mitigation Impacts

A system of tracking progress is useful to identify whether a mitigation initiative is on track and being implemented as planned, and any gaps that will need to be addressed to deliver the expected results. Tracking progress needs to cover three main steps:

- Definition and application of progress indicators
- Estimation ex-post of the actions, policies and measures in terms of avoiding GHG emissions
- Monitoring of key performance indicators

1.7 An overview of Carbon Flows through Waste Management

An overview of carbon flows through waste management systems addresses the issue of carbon storage versus carbon turnover for major waste-management strategies including landfilling, incineration and composting. Because landfills function as relatively inefficient anaerobic digesters, significant long-term carbon storage occurs in landfills, which is addressed in the 2006 IPCC Guidelines for National Greenhouse.

Gas Inventories (IPCC, 2006). Landfill CH_4 is the major gaseous C emission from waste; there are also minor emissions of CO_2 from incinerated fossil carbon (plastics). The CO_2 emissions from biomass sources including the CO_2 in landfill gas, the CO_2 from composting, and CO_2 from incineration of waste biomass are not taken into account in GHG inventories as these are covered by changes in biomass stocks in the land-use, land-use change and forestry sectors (Figure 1).

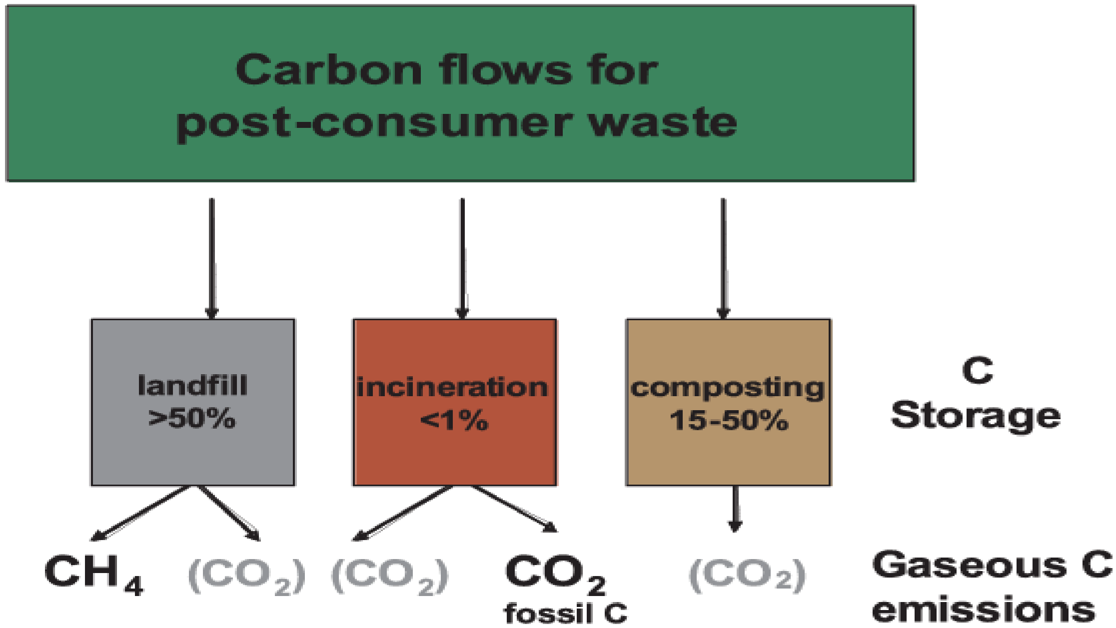

Figure 1: Carbon flows through major waste management systems including C storage and gaseous C emissions (Bogner *et al.*, 2008)

In field settings, stable C isotopic techniques have proven extremely useful to quantify the fraction of CH_4 that is oxidized in landfill cover soils (Chanton *et al.*, 2010). A secondary benefit of CH_4 oxidation in cover soils is the CO_2 oxidation of many non-CH_4 organic compounds, especially aromatic and lower chlorinated compounds, thereby reducing their emissions to the atmosphere (Bogner *et al.*, 2008). Other measures to reduce landfill CH_4 emissions include installation of geomembrane composite covers; design and installation of secondary perimeter gas extraction systems for additional gas recovery; and implementation of bioreactor landfill designs so that the period of active gas production is compressed while early gas extraction is implemented.

2. OBJECTIVES AND SCOPE OF THE ASSIGNMENT

2.1 General Objective

The aim of this work is to assess the impacts of GHG mitigation policies measures on waste management (landfill management), light rail transit and the use of biofuel and develop guideline on the formulation of mitigation policy measures assessment, which will provide a guidance and skill development road-map for experts in the stated sectors.

2.2 Specific Objectives

The assignment will be conducted on the mitigation policy measures, solid waste management (landfill management), light rail transit and biofuel.

- Assess the impact of the mitigation policy measures on solid waste management (landfill), light rail transit and biofuel; and,
- Develop guidelines on how the formulation of GHG emission mitigation policy measures and assessment, in practice, carried out.

2.3 Scope of the Assignment

The assignment focuses on the assessment of GHG mitigation policy on waste management (landfill management), light rail transit and the use of biofuel for the year 2011 to 2018.

Main Focus Areas of data collections

- Ministry of Health (MoH)
- Ministry of Transport and Logistics (MoTL)
- Minister of Industry (MoI)
- Ministry of Agriculture (MoA)
- Minister of Water and Energy (MoWE)
- Environmental Protection Authority (EPA)
- Ministry of Mines and Petroleum (MoMP)
- Minister of Urbanization and Infrastructure (MoUI)
- Federal Statistics Agency (CSA)
- Addis Ababa University (CES and Applied Chemistry Department)

3. METHODOLOGIES AND APPROACH

3.1 Estimating GHG Emissions

3.1.1 GHG Emissions from the energy par (light railway transit)

One of the most common approaches is defining an emissions factor and multiplying it with the available activity data .This is done as follows:

$$\mathbf{GHG_{Emissions} = Projected\ activity\ data = Emission\ factor}$$

However, if data is available for more parameters related to energy consumption and GHG emissions directly and indirectly related to the activity, the following formula could be used:

$$GHG_{Emissions} = Projected\ energy\ consumption \times Energy\ efficiency \times GHG\ intensity\ of\ energy\ generation + Non-energy\ GHG\ emissions$$

3.1.2 Description of Measuring System for Waste Management

For the waste management part calculation of emission reductions due to the mitigation action is based on the following principal formula:

$$ER_y = BE_y - (PE_y + LE_y)$$

Where;

- ER_y is Emission reduction in the year y (tCO_2e),
- BE_y is Baseline emissions in the year y (tCO_2e),
- PE_y is Mitigation action emissions in the year y (tCO_2e), and
- Ley is Leakage emissions in year y (tCO_2e)

3.1.3 Baseline Emissions Calculations

$$BE_y = W_y \times FE_y$$

Where:

W_y = Total amount of waste disposed in the baseline in the year y (t)

FE_y = Default value representing the emission reduction associated with the substitution of chemical fertilizer (tCO_2/ t)

$$W_y = \sum_{t=1}^{n} CT_{t,y}$$

Where

$CT_{t,}$ = Carrying capacity of truck t used in year y to deliver waste to the composting installation

t = Waste deliveries in trucks to the composting installation in year y

The overall assessment was done following the following conceptual framework.

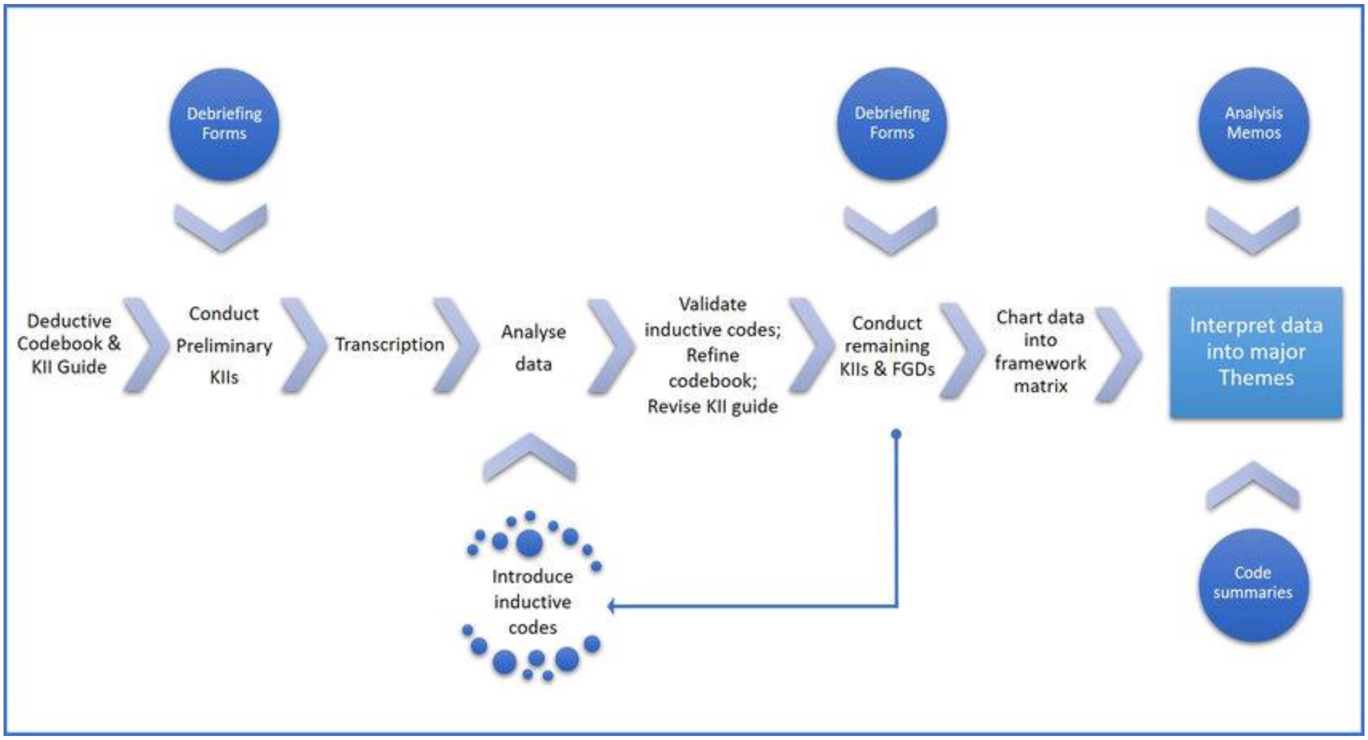

Figure 2: Approach used for data collection, analysis and appraisal

3.2 Focus Group Discussions (FGDs)

Focus group discussions (FGDs) were held with sectors staffs at MoTL, MoH, MOA, MOTI, MOMP, MoUI, CSA, AAU offices disaggregated by profession, seniority and leaders to get most reliable information from target groups. The consultant conducted each FGD with available participants using the FGD guide Annexed to this report. A total of 7 FGDs were conducted with 4 to 7 participants from Ministry of Water and Energy, Ministry of Urbanization and Infrastructure; Ministry of Transport and Logistics; Ministry of Mines and Petroleum; Ministry of Agriculture; Ministry of Industry and Ministry of Health. The FGD was participatory and the required qualitative and quantitative data was collected.

3.3. Key Informant Interview (KII)

In order to incorporate the knowledge and perspectives of decision makers, experts and special/subject matter advisors, semi-structure interviews were conducted at federal and regional level with concerned institutions, key stakeholders, implementers, research institutions, and academic institutions etc. Accordingly, 20 KIIs were held to know all about the implementation progress of the CRGE/GHG and to identify key gaps. Higher officials and senior experts from EPA, ministry of water and Energy; Ministry of Urbanization and Infrastructure; Ministry of Transport; Ministry of Mines and Petroleum; Ministry of Agriculture; Ministry of Industry and Ministry of Health and respective Bureaus had participated in the key informant interview. In addition, many stakeholders were addressed through KII, among them higher officials and senior experts who are involved in the CRGE/GHG implementation from development partners like Addis Ababa University, Centre for Environmental Science Program and Applied Chemistry Department were interviewed and the required data and information was gathered.

3.4 Data Recording and Response Rating

Standard checklists for FGDs and KIIs were used to record data from the ten target sectors found within Addis Ababa City Administration. For open-ended questions a separate notebook used to take responses of interviewees. Photos were taken during discussion and interview period.

3.5 Data Analysis and Interpretation

The analyses were conducted using qualitative methods for each policy measures. Tables were used to summarize results. The outputs presented using descriptive questions along with response rates reflected per assignment for all sectors.

4. TOOLS USED FOR WASTE MANAGEMENT (LAND FILL)

Ministry of Urbanization and Infrastructure (MoUI) developed Solid Waste Management strategy in 2014 G. C. to reduce the GHG emission from solid waste. The strategy contributes to the success of our green strategy by promoting the reuse of waste collected from houses and waste disposal centers and by the preparation of compost which could be used in agriculture to improve productivity.

Thus different enabling framework were created and enforced to support the ISWM, which includes

- ✓ Regulatory and relevant legal frameworks are harmonized at the federal and regional levels,
- ✓ Standards for ISWM at federal level are endorsed and transposed at the regional levels,
- ✓ Source sorting by households in all kebeles in selected municipalities and city administrations, supported by public incentives, an inter-sectoral communication plan and an awareness-raising campaign involving civil society actors,
- ✓ A national standard for organic compost is adopted, and quality assurance systems (QAS) are in place at the regional level,
- ✓ A twinning programme is developed with other cities experienced in ISWM, and institutions developing and implementing standards to inspire and build capacities,
- ✓ Urban development policy;
- ✓ Solid waste management Proclamation;
- ✓ Solid waste management strategy: based on integrated solid waste management approach;
- ✓ Solid waste management standard and manual.

4.1 Urban Greenery Infrastructure Development Program

One important aspect to making a city 'green' is the development of urban green infrastructure (UGI) or urban greenery. Generally, UGI supports sustainable urbanization, health and mental well-being, social cohesion (e.g., sport parks) and the preservation of the natural environment and ecology. Green infrastructure also plays a significant role in improving air quality and reducing vulnerability to climate change by absorbing pollutants such as ammonia, carbon dioxide and nitrogen dioxide. Accordingly, policies and strategies developed so far includes;

- ✓ UGI strategy and standard
- ✓ UGI manuals (17 UGI implementing manuals)

- Development of Amenity Green Space in Residential Areas Manual No.15/2016
- Development of communal Housing Green spaces. Part-AManual No.14/2016
- Green Roof and Wall Establishment and Management Manual No. 23/2016
- Institutional Compounds Green Infrastructure DevelopmentManual No.12/2016
- Lakes and Lake Buffer plantation and management
- Cemetery Management Manual NO.22/2016
- Religious Compounds Green Infrastructure Development Manual NO.16/2016
- Plaza and holyday celebration areas management manual No 16/2016
- Green open space around the communal housing areas
- Development of open green spaces in communal housing areas. Part-B Manual No.14/2016
- Private Garden Manual No.10/2008
- Recreational Parks Development and Management Manual No.13/2016

4.2 Estimation of GHG Emissions from Waste Transportation

MSW transportation consumed a significant amount of fossil fuel and led to GHG emissions due to fossil-fuel combustion. Therefore, the third sheet of the simulation has been developed for quantification of GHG emissions from waste transportation. Therefore, users are asked to enter the amount of waste transport per month and the corresponding amount of fossil fuel usage with respect to the two major types of fossil fuels.

GHG-Emissions from Waste Transportation (Menikpura *et al*., 2012)

a) Enter the amount of waste transported by diesel-fueled trucks (tons/Month) and monthly diesel requirement (Lit/Month)
b) Enter the amount of waste transported by natural gas-fueled trucks (tons/month) and monthly gas requirement (lit/month).

Therefore, the report is presented as KG of CO_2-Eq/tons of waste.

GHG emissions from extraction of crude oil, importation and the refining process are not included in this simulation since such emissions may not be significant (Menikpura *et al*, 2011). Also, CH_4 and N_2O emission from fossil fuel combustion is assumed to be negligible (IPCC, 2007). Therefore CO_2 can be considered as the major component of GHG emissions from waste transportation. Mathematical formulas have been assigned to quantify CO_2 emissions from each type of fossil fuel.

Total GHG emissions from combustion of any kind of fossil fuel during waste transportation can be calculated as follows:

$$Emission\ T = \frac{Fuel\ (Unit)}{Waste\ (tons)} Energy\ \left(\frac{MJ}{unit}\right) EF(\frac{KgCO_2}{MJ}$$

Where:

- $Emissions_T$ is Emissions from transportation (kg CO_2/tons of waste transported),
- Fuel (units) is Total amount of fossil fuel consumption per month, (diesel in Liters and Natural gas in kg),
- Waste (tons) – Total amount of waste transported per month in tons
- Energy (MJ/unit) – Energy content of the fossil fuel (e.g. Diesel 36.42 MJ/L, Natural gas 37.92 MJ/kg),
- EF is CO_2 emission factor of the fuel (e.g. diesel: 0.074 kg CO_2/MJ, Natural gas: 0.056 kg CO_2/MJ)

Some municipalities in developing countries are trying to replace diesel fuel by using natural gas aiming to reduce GHG emissions from waste transportation. Therefore, this simulation shows the GHG emissions resulting from diesel-fueled trucks as well as natural gas-fueled trucks per tons of waste transportation. If a municipality uses the both types of fuels, the results will show the aggregated effects due to the utilization of diesel as well as natural gas. Furthermore, monthly GHG emissions from transportation can be estimated as follows:

$$Monthly\ GHG\ Emissions\ (kg\ CO2eqt/mon) = GHG\ emissions\ per\ ton \times\ ton\ of\ waste\ transported/month$$

4.3 Estimation of GHG Emissions from Land Filling

Landfilling is the most common waste disposal method throughout the world. Landfill technologies have developed drastically over the last few decades, but these developments have not yet reached all parts of the world (Manfred *et al.*, 2009). For example, most of the developing countries in Asia are still practicing open dumping and landfilling without gas recovery. Most of the time, waste is disposed in open dumps without a landfill cover, while the Government promotes development of on-land disposal towards sanitary landfill. Therefore, in some cases, sanitary landfill technology has been applied without a landfill gas recovery system so that most of the landfill gas is released into the atmosphere without any treatment or control. The anaerobic decomposition of MSW in open dumps and landfills eventually generates landfill gas (LFG) which contains approximately 60% methane (CH_4) and 40% carbon dioxide (CO_2). The CH_4 component of LFG contributes to global warming whereas the CO_2component is generally regarded as being biogenic in origin and is thus not considered as GHG (CRA, 2010). The uncontrolled CH_4 emission from landfilling has been ranked as the third largest anthropogenic CH_4 emission source (IPCC, 2007).

The amount of methane generated at the disposal sites would depend on many factors such as quantity and composition of waste, moisture content, pH, and waste management practices. In general, methane production increases with higher organic content and higher moisture content in the disposal sites. A managed sanitary landfill has the potential of producing a greater methane yield than in anon managed disposal site (open dumps) where large amount of waste can decay aerobically in top layers. Deeper unmanaged solid waste disposal sites have greater methane emission than shallow unmanaged sites.

The IPCC 2006 Waste Model has the ability to calculate emissions from a variety of solid waste disposal site types, after deriving the default values considering country or region specific waste composition and climate information, and the situation of disposal sites. Therefore, to quantify the GHG emissions from normal waste management disposal practices in landfills, the IPCC 2006 waste model has been adopted in this simulation. The guidelines of IPCC strongly encourage the use of the First Order Decay (FOD) model, which produces more accurate emissions estimates since it reflects the degradation rate of wastes in a disposal site (IPCC 2006).

The following mathematical formula has been used in IPCC model to quantify GHG emissions from the landfilling or open dumping.

The basic equation for the first order decay model is:

(1) $$DDOC_m = DDOC_{m(0)} \times e^{-kt}$$

Where:

$DDOC_{m\ (0)}$ is the mass of decomposable degradable organic carbon (DDOC) at the start of the reaction, when t=0 and e^{-kt}=1, k is the reaction constant and t is the time in years. $DDOC_m$ is the mass of DDOC at any time.

From equation (1) it is easy to see that at the end of year 1 (going from point 0 to point 1 on the time axis) the mass of DDOC left not decomposed in the SWDS is:

(2) $$DDOC_{m(1)} = DDOC_{M(0)} \times e^{-k}$$

and the mass of DDOC decomposed into CH_4 and CO_2 will be:

(3) $$DDOC_{mdecomp(1)} = DDOC_{m(0)} \times (1 - e^{-k})$$

In a first order reaction, the amount of the product (decomposed $DDOC_m$) is always proportional to the amount of reactant ($DDOC_m$). This means that it does not matter when the $DDOC_m$ was deposited. This also means that when the amount of $DDOC_m$ accumulated in the disposal site, plus last year's deposit, is known, CH_4 production can be calculated as if every year is year number one in the time series. Then all calculations can be done by equations (2) and (3) in a simple spreadsheet. The default assumption is that CH_4 generation from all the waste deposited each year begins on the 1st of January in the year after deposition. The assumption is that decomposition of first year can happen aerobically where methane generation is not taking place (the time it takes for anaerobic conditions to become well established). However, when the calculation includes the possibility of an earlier start to the reaction, in the year of deposition of the waste, this requires separate calculations for the deposition year.

To calculate mass of decomposable DOC ($DDOC_m$) from amount of waste material (W):

(4) $$DDOC_{md(T)} = W_{(T)} \times DOC_f \times MCF$$

The amount of deposited DDOCm remaining not decomposed at the end of deposition year T:

(5) $$DDOC_{mrem(T)} = DDOC_{md(T)} \times e^{(-k.(\frac{13-M}{12})}$$

The amount of deposited DDOCm decomposed during deposition year T:

(6) $$DDOC_{mdc(T)} = DDOC_{md(T)} \times (1 - e^{(-k.(\frac{13-M}{12})})$$

The amount of DDOCm accumulated in the disposal site at the end of year T:

(7) $$DDOC_{ma(T)} = DDOC_{mrem(T)} + (DDOC_{ma}(T-1) \times e^{-k}$$

The total amount of DDOCm decomposed in year T:

(8) $$DDOC_{mdecomp(T)} = DDOC_{mdec(T)} + (DDOC_{ma(T-1)} \times (1 - e^{-k})$$

The amount of CH_4 generated from DOC decomposed

(9) $CH_{4generated(T)} = DDOC_{mdecomp(T)} \times F \times 16/12$

The amount of CH_4 emitted from disposal site:

(10) $CH_{4emitted\ in\ year\ T} = (\sum CH_{4generated(T)} - R_{(T)} \times (1 - OX_{(T)}$

Where:

- T is the year of inventory
- x is material fraction/waste category $W_{(T)}$ - amount deposited in year T MCF - Methane Correction Factor,
- DOC - Degradable organic carbon (under aerobic conditions),
- DOC_f - Fraction of DOC decomposing under anaerobic conditions (0.0-1.0) DDOC - Decomposable Degradable Organic Carbon (under anaerobic conditions) $DDOC_{md(T)}$ - mass of DDOC deposited year T,
- $DDOC_{mrem(T)}$ - mass of DDOC deposited in inventory year T, remaining not decomposed at the end of year,
- $DDOC_{mdec(T)}$ - mass of DDOC deposited in inventory year T, decomposed during the year,
- $DDOC_{ma(T)}$ - total mass of DDOC left not decomposed at end of year T,
- $DDOC_{ma(T-1)}$ - total mass of DDOC left not decomposed at end of year T-1. $DDOC_{mdecomp(T)}$ - total mass of DDOC decomposed in year T,
- $CH_4generated_{(T)}$ - CH_4 generated in year T,
- F - Fraction of CH_4 by volume in generated landfill gas (0.0 – 1.0) 16/12 - Molecular weight ratio CH_4/C,
- $R_{(T)}$- Recovered CH_4 in year T,
- $OX_{(T)}$ - Oxidation factor in year T (fraction),
- K - Rate of reaction constant,
- M - Month of reaction start (= delay time + 7),

In order to calculate the methane emissions from landfill or open dump site, numerous default values are required and the amount of methane generation is highly dependent on the accuracy of these factors. The details explanations of the required default values are presented in Table 1.

Table 1: The required factors and default values for application of IPCC 2006 waste model

Factor	**Unit**	**Method of deriving**
Amount of mix waste disposal	Tonne/month	Amount/ description
Amount deposited	Gg/Year	MSW disposal (tons/month) ×12/1000
Degradable Organic Carbon (DOC)	DOC	Derived based on IPCC default DOC content values, DOC_{MSW} = % of food waste×0.15+ % of garden waste×0.43 + % of paper waste × 0.4 + % of textile waste × 0.24
Fraction of DOC decomposing under Anaerobic condition (DOC_f)	DOC_f	IPCC default value is 0.5
Methane generation rate constant	k	k value will depend on waste composition of the location k_{MSW} =% of food waste×0.4+ % of garden waste×0.17 + % of paper waste × 0.07 + % of textile waste × 0.07 + % of disposal nappies × 0.17+ % of wood and straw × 0.035
Half- life time(t1/2, years)	h=In(2)/k	Can be calculated based on derived k value
exp1	exp(-k)	Can be calculated based on derived k value
Process start in decomposition year, month M	M	IPCC recommended value is after 12 months
Exp2	exp(-k((13-M)/12	Can be calculated based on derived k and M values
Fraction to CH_4	F	IPCC recommended value is 0.5
Methane Oxidation on Landfill cover	OX	IPCC recommended value for sanitary landfill with Landfill cover is 0.1. for open dumpsites the OX value would be zero
MCF for the landfill/open	MCF	According to the management practices, this value will be changed, IPCC recommended default MCF values for Managed (has landfill cover and liner), unmanaged-deep (> 5m waste),

dumpsite		Unmanaged-shallow (<5m waste), Uncategorized are 1, 0.8, 0.4 and 0.6 respectively.

In this simulation, to calculate the total GHG emissions potential from a landfill or open dumpsite in a particular location, users are asked to enter the monthly average data such as amount mix waste landfilling, fossil fuel utilization for operational activities at the landfill and the composition of mixed MSW. In addition, the user is asked to select the type of landfill from Drop-down list. The total value of the different fractions of waste of waste should be equal to 100% in order to calculate the GHG emissions from the landfill; otherwise an error message would appear until the total value adjusts to the 100%.

The methane production per tons of waste of degradation throughout the life cycle will be calculated and presented as kg of CH_4 production per tons of waste. In addition, total GHG emissions from mixed waste will be calculated as follows:

$$GHG\ emission\ from\ mixed\ waste\ land\ filling/open\ dumping = CH_4\ emissions\ per\ tons\ of\ waste\ \times GWP_{CH_4} + GHG\ emission\ from\ operation\ activities$$

Where; GWP_{CH4} - Global Warming Potential of CH_4 (The GWP of CH_4 was considered as 21 times higher than CO_2 on a time horizon of 100 years)

Based on this estimated value, the simulation calculates the monthly GHG emissions from mixed MSW landfilling can be calculated for a particular location.

$$M\text{onthly GHG emissions (kg } \mathrm{CO_2} - \text{eqt per month)} = \text{GHG emissions per tons of waste} \times \text{total amount of waste landfilled per month (tons)}$$

4.4 Estimation of GHG Emissions from Composting

Importance of organic waste composting has been increasingly recognized in developing Asia. Amongst organic waste utilization technologies, local governments prefer composting as it is simple, easier to manage and low cost. Therefore, composting is becoming one of the popular waste management an option has been designed for quantification of potential GHG emissions from composting technology.

There are two major ways that composting could emit GHG: i) GHG emissions from utilization of fossil energy (e.g. electricity and diesel) for operation of composting; and ii) GHG emissions from organic waste degradation.

As far as GHG emissions from organic waste degradation are concerned, composting is an aerobic degradation process whereby a large fraction of the degradable organic carbon in the waste material is converted into CO_2. Such CO_2 emissions have biogenic origin and would not be taken into account for GHG calculation. CH_4 can be formed due to anaerobic degradation of waste in deep layers of composting piles. However, such CH_4 is oxidized to a large extent in the aerobic sections of the compost piles. Composting can also produce emissions of N_2O in minor concentrations. In this study, IPCC published average default emission factors (e.g. 4 kg CH_4/tons of organic waste in wet basis and 0.3 kg N_2O/tons of organic waste in wet basis) were used to quantify the GHG emissions from composting (IPCC,2006).

There is a potential for producing a significant amount of marketable compost from one tons of organic waste. The produced compost can be used for agricultural purposes to replace conventional fertilizer. As reported in literature, one tons of good-quality compost can be used to replace chemical fertilizer, since there is a possibility to supply the essential nutrients at the rate of 7.1 kg of nitrogen (N), 4.1 kg of phosphorus (P_2O_5) and 5.4 kg of potassium (K_2O) per tons of compost (Patyk, 1996). Based on these figures, GHG mitigation potential from avoiding chemical fertilizer production is estimated in this model. However, in practice, this co- benefit should not be included in the calculation if farmers do not decrease the use of chemical fertilizer after application of compost. Furthermore, as a result of composting, disposal of organic waste at the landfill can be reduced. Therefore, this simulation will estimate the potential GHG avoidance by avoided organic waste land filling.

In order to calculate all those potential emissions and avoidance, users are asked to enter the monthly average data such as the amount of organic waste use for composting, fossil-fuel utilization for operational activities, the total amount of compost production and percentage of produce compost utilization for agricultural activities.

The following mathematic formulas have been assigned to the spreadsheet cells in order to quantify the GHG emissions from composting.

GHG emission from operational activities due to fossil fuel combustions is calculated as follows. As mentioned earlier CH_4 and N_2O emissions from fossil fuel combustion assumed to be negligible, and thus it was not included in this equation (IGES, 2013).

$$Emissions\ operation = \frac{Fuel\ (L)}{Waste\ (tons)} \times Energy\ \left(\frac{MJ}{L}\right) \times EF(\frac{kgCO_2}{MJ}$$

Where:

- Emissions Operation is Emissions from Operational activities (kg CO_2/tons of waste transported),
- Fuel (L) is Total amount of fossil fuel consumption per month,
- Waste (tons), Total amount of organic waste utilization per month Energy (MJ/unit) – Energy content of the fossil fuel (e.g. Diesel 36.42MJ/L) EF – CO_2Emission Factor of the fuel (e.g. diesel: 0.074 kgCO_2/MJ),

GHG emission from waste degradation is calculated as follows:

$$Emission_{Degradation} = E_{CH_4} \times GHP_{CH_4} \times E_{N_2O} \times GWP_{N_2O}$$

Where:

- Emissions $_{Degradation}$ is Emissions from organic waste degradation (kg CO_2/tons of organic waste)
- E_{CH4} is Emissions of CH_4 during organic waste degradation (kg of CH_4/tons of waste); in this model, the default value of 0.4 (average value given by IPCC (IPCC, 2006)) is used. This value should be changed if the site-specific data is obtained,
- GWP_{CH4} - Global warming potential of CH_4 (21 kg CO_2/kg of CH_4),

- E_{N2O}- Emissions of N_2O during waste degradation (kg of N_2O/tons of waste); in this model, the default value of 0.3 (average value given by IPCC (IPCC, 2006)) is used. This value should be changed if the site specific data is obtained,
- GWP_{N2O}- Global warming potential of N_2O (310 kg CO_2/kg of N_2O)

In literature, there are different values of GWP for CH_4 and N_2O. However this model use value of 21 and 310 for CH_4 and N_2O respectively since those are the most widely used (including CDM calculation methodologies by UNFCCC) GWP values over 100 years timescale.

A total GHG emission from composting is calculated by adding GHG emissions from operation and waste degradation;

$$Total\ GHG\ emissions\ from\ Composting = Emissions_{Operations} + Emission_{Degradation}$$

Avoided GHG emission by replacing chemical fertilizer from compost is calculated as follows;

$$Avoided\ GHG_{Compost} = AC \times PC_{Agricultur} \times A_{GHG}$$

Where;

- Avoided GHG $_{Compost-}$ Avoided GHG from composting due to avoidance of chemical fertilizer production (kg CO_2-eq/tons of waste)
- AC is Amount of Compost produced (tons of compost/tons of waste),
- $PC_{Agriculture}$ is Percentage of compost use for agricultural and gardening purpose (%)
- A_{GHG} is GHG Avoidance potential from chemical fertilizer production which is equivalent to one tons of compost (kg CO_2-eq/tons of compost)

However, A_{GHG} should be excluded if compost users do not reduce chemical fertilizer use even after application of compost.

In addition, as a result of initiating a composting facility, a significant amount of organic waste landfilling can be reduced and thereby GHG emissions from organic waste degradation in landfill can be avoided. The potential GHG mitigation from avoided organic waste landfilling was calculated by using IPCC 2006 waste model. Detailed information and calculation parameters of IPCC 2006 waste model can be seen in the “Mix waste landfilling” sheet in the simulation. Total avoided GHG emissions are calculated as follows:

$$Total\ avoided\ GHG\ emission(kg\ CO2 - eqt\ per\ tons\ of\ worganic\ waste)$$
$$= Avoided\ GHG\ from\ compost\ use\ and\ replacement\ of\ chemical\ fertilizer$$
$$+ Avoided\ GHG\ from\ landfilling$$

In order to understand the overall climate benefit or the impact from composting technology, net GHG emission can be calculated as follows:

$$Net\ GHG\ emissions\ from\ compsting = Total\ GHG\ emissions - Total\ GHG\ avoidance$$

If the estimated net GHG emissions remain as a positive value (e.g. due to consumption of excessive amount of fossil fuel or ineffective utilization of produced compost for agricultural and gardening), users should understand that the current composting system is still contributing to climate impact and therefore further improvements are needed for mitigating GHG emissions. If it results in a net negative GHG emissions value, it indicates potential GHG savings from composting and possibility of compost use to act as a carbon sink.

Furthermore, monthly GHG emissions from composting can be estimated as follows:

$$Monthly\ GHG\ emissions\ (kg\ CO2 - eq\ per\ month)$$
$$= GHG\ emissions\ per\ ton$$
$$\times total\ amount\ of\ waste\ use\ for\ composting\ per\ month$$

4.5 Estimation of GHG Emissions from Anaerobic Digestion

Among the biological treatment methods, anaerobic digestion would be the most cost-effective, due to the potential of high-energy recovery linked to the process and its limited environmental impact (IGES, 2013).

There are two major ways that anaerobic digestion could emit GHG: i) GHG emissions from fossil fuel (e.g. electricity and diesel) utilization for operation; and ii) GHG emissions from the reactor due to unavoidable leakages. This model uses the average default value (2 kg of CH_4/tonne of dry organic waste; IPCC, 2006) for methane emissions due to unavoidable leakages. This value should be changed if the site specific value is available.

There is a potential for producing a significant amount of energy from anaerobic digestion. Biogas is the major output from anaerobic digestion, which has a calorific value of 20-25 MJ/m^3. Biogas can be converted to thermal energy (heat) or electricity by using various kinds of Technologies. For instance, burning of biogas in small engines (<200kW) and large internal- combustion engines (up to 1.5 MW) can generate a significant amount of electricity (Pöschl *et al*., 2010). The produced electricity or the thermal energy could be used to replace fossil-fuel-based conventional electricity and thermal energy production and thereby reduce the GHG emissions from those conventional processes.

Similar to the outcome of composting technology, anaerobic digestion is also contributing to the avoidance of organic waste landfilling in developing Asia and thereby avoiding GHG emissions that would otherwise occur during the degradation of organic waste in the landfills.

In order to calculate all those potential emissions and avoidance from a particular anaerobic digestion facility, users are asked to enter the monthly average data such as the amount of organic waste use for anaerobic digestion, fossil-fuel utilization for operational activities, electricity utilization for operational activities, approximate moisture content of the influent (the mixture of waste and water), the type of output production from anaerobic digestion (electricity or thermal energy).

At the local authority level, finding the accurate water content of the influent can be a challenging issue since it is required to dry the sample for 24 hours in a 105-110^{0}C oven. However, it can be estimated approximately based on the mixing ratio of waste and water. For instance, if 1 ton of vegetable waste mixes with 1 ton of water to make the influent, the total moisture in it would be 1.6 tons (approximate moisture content of vegetable waste is 60%). Therefore, moisture content of the influent would be 80% (1.6 tons/2tonnes x100).

The following mathematic formulas have been assigned to the spreadsheet cells in order to quantify the GHG emissions and GHG avoidance from anaerobic digestion with respect to the data entered by the users.

Users are asked to select the product from anaerobic digestion. For instance, if they select the option "electricity", the potential electricity production will be automatically calculated under the "outputs" corresponding with the data input. In order to calculate this figure, several literature figures have been used. A detailed quantification approach has been shown under the down part of the same spreadsheet for so-called "calculation of biogas and electricity".

Emissions of CO_2 owing to fossil fuel combustion and utilization of electricity for operating machines can be calculated as follows. As mentioned earlier, CH_4, N_2O emissions from fossil fuel combustion considered to be negligible.

$$Emissions_{operation} = \left(FC \times NCV_{FF} \times EF_{CO_2}\right) + (EC \times EF_{el})$$

Where:

- Emissions $_{Operation}$ is Emissions from operational activities (kg CO_2/ton of organic waste)
- FC is Fuel consumption apportioned to the activity type (mass or volume/ton of organic waste) NCV_{FF} is Net calorific value of the fossil fuel consumed (MJ/unit mass or volume)
- EF_{CO2} is Emission factor of CO_2 by combustion of fossil fuel (kg of CO_2/MJ)
- EC is Electricity consumption for operation activities (MWh/ton of organic waste)
- EF_{el} is Emission factor of country grid electricity production (kg CO_2-eq/MWh)

GHG emissions (mainly CH_4) due leakages from the anaerobic digestion system can be calculated as follows:

$$Emissions_{Treatment} = E_{CH4} \times DM \times 1000 \times GWP_{CH4}$$

Where:

- Emissions $_{Treatment}$ is Emissions from treatment of organic waste (kg CO_2/tonne of organic waste)
- E_{CH4} is Emissions of CH_4 due to leakages (kg of CH_4/kg of dry matter)
- DM is Dry matter percentage in the influent (%) (DM =100 - % of water in the influent)
- 1000 – Conversion factor to calculate dry matter content per ton of organic waste,
- GWP_{CH4} – Global warming potential of CH_4 (21 kg CO_2/kg of CH_4),

Total GHG emissions from anaerobic digestion can be calculated by adding GHG emissions from operational activities and GHG emissions due to leakages.

$$Total\ GHG\ Emissions = Emissions_{Operation} + Emissions_{Treatment}$$

In addition, mathematical formulas were derived to estimate the potential avoidance of GHG emissions due to electricity production or use of biogas as a thermal energy. If a municipality develops an anaerobic digestion facility for electricity production from biogas, the contribution for potential GHG avoidance can be calculated as follows:

$$Avoidance\ GHG_{electricity} = C_{Biogas} \times P_{CH4} \times E_{CH4} \times \frac{1}{CF_{Energy}} E_{Power\ plant} \times EF_{el}$$

Where;

- Avoidance $GHG_{Electricty}$ –Total GHG avoidance due to electricity production (kg CO_2 –eq/tonne of organic waste
- C_{Biogas} – Used amount of Biogas (m^3/ton of organic waste)
- P_{CH4} – Percentage of CH_4 in biogas (%)
- E_{CH4} – Energy content of CH_4 (MJ/m^3)
- CF_{Energy} – Conversion Factor of Energy (3.6 MJ/kWh)
- $E_{Powerplant}$ – Efficiency of the Power plant (%)
- EF_{el} - Emission factor of country grid electricity production (kg CO_{2-}eq/kWh)

If a municipality develops an anaerobic digestion facility to use biogas as a thermal energy source, GHG avoidance potential can be calculated as follows:

$$Avoidance\ GHG_{Thermal} = C_{Biogas} \times P_{CH4} \times E_{CH4} EF_{CO2}$$

Where;

- Avoidance $GHG_{Thermal}$ –Total GHG avoidance due to thermal energy production (kg CO_2 –eq/tonne of organic waste ,
- C_{Biogas} – Collected amount of biogas (m^3/tonne of organic waste)
- P_{CH4} –Percentage of CH_4 in biogas (%),
- E_{CH4} –Energy content of CH_4 (MJ/m^3)
- EF_{CO2-} Emission factor of CO_2 by combustion of liquid petroleum gas (LPG) (kg of CO_2/MJ) (in this model, it was assumed that LPG consumption can be substituted by using biogas

In addition, as a result of using organic waste for anaerobic digestion, organic waste landfilling can be reduced. Avoided GHG emissions from avoided organic waste landfilling should be accounted for, in order to calculate total avoidance. In this simulation, the IPCC 2006 waste model was used to estimate GHG mitigations via avoided organic waste landfilling. Detailed information and calculation parameters of the IPCC 2006 waste model can be seen in the “Mix waste landfilling” sheet in the simulation

Total avoided GHG emission from anaerobic digestion can be calculated as follows:

$$\text{Total avoided GHG emissions (kg } CO_2 \; eq \; per \; ton \; of \; Organic \; Waste) = \text{Avoided GHG from energy recovery} + \text{Avoided GHG from landfilling}$$

In order to understand the overall climate benefit or the impact from anaerobic digestion as an organic waste management option, net GHG emissions are calculated as follows:

$$\text{Net GHG emissions from anaerobic digestion (kg CO2} - \text{eq per tonne of organic waste)} = \text{Total GHG emissions} - \text{Total GHG avoidance}$$

Similar to the composting technology, if the estimated net GHG emissions remain as a positive value, it means that the anaerobic digestion technology is still contributing to climate impact and therefore efficiency of energy recovery should be further improved for mitigating GHG emissions. If the result is a net negative GHG emission value, it indicates the potential GHG savings from anaerobic digestion and the possibility to be a carbon sink. Furthermore, monthly GHG emissions/savings from a particular municipality can be calculated by using the estimated results of GHG emissions/ savings per tonne of organic waste.

Monthly GHG emissions/savings (kg CO_2-eq/month) = GHG emissions per tonne of organic waste × Total amount of organic waste use for anaerobic digestion per month (tonnes).

4.6 Estimation of GHG Emissions from Mechanical Biological Treatment (MBT)

Generally, Mechanical Biological Treatment (MBT) is used as a pre-treatment either before thermal treatment or as the final disposal of solid waste. MBT can reduce the volume of waste through the decomposition of organic substances prior to landfilling, minimize GHGs emissions (methane) from landfill sites, and enhance separating different material fractions, such as compost-like materials and high-energy fractions after stabilization of waste prior to final disposal. MBT facilitates organic waste to be degraded rapidly under optimized conditions (homogenization, ventilation, irrigation). The total mass loss during the MBT process would be as high as 50%. The stabilized material can be screened into three parts such as compost-like materials, waste plastics (use to produce Refuse-derived fuel (RDF)) and inert materials.

As far as GHG emissions from MBT process are concerned, the major cause for GHG emissions is utilization of fossil fuel, grid electricity for operational activities in the various stages, and degradation of organic waste. Under good management, there is considerably less possibility for Production of GHG from waste piles if organic waste degradation occurs under aerobic conditions.

If CH_4 production may take place in the bottom layer of MBT piles, most of the CH_4 can be oxidized to a large extent in the aerobic sections of the piles. Thus, the possibility of releasing CH_4 into the atmosphere would be very small. Generally, MBT is an aerobic process and therefore, a large fraction of the degradable organic carbon in the waste material is converted into CO_2. CO_2 emissions have biogenic origin and would not be taken into account for GHG calculations. According to IPCC guidelines, MBT process also produces N_2O in minor concentrations. In this simulation, IPCC published the average values of 4 kg CH_4/ton of organic waste on a wet basis (range of 0.03-8 kg CH_4/ton of waste) and 0.3 kg N_2O/ton of organic waste on a wet basis (range of 0.06-0.6 kg N_2O/ton of waste) and these values were used to quantify the GHG emissions from degradation of organic waste in MBT piles.

Similar to composting or anaerobic digestion technology, MBT process can contribute to minimizing organic waste landfilling in developing Asia and thereby avoiding GHG emissions that would otherwise occur during the degradation of organic waste in the landfills. In addition, there is a possibility for utilization of degraded organic waste as compost and consequently, a reduction in the amount of chemical fertilizer used. Avoidance of chemical fertilizer utilization would greatly contribute to GHG reduction. However, there is concern about heavy metal contamination in the compost-like product from MBT of mixed waste. Levels of heavy metal contamination should be measured prior to decision-making on whether this material should be applied as compost Furthermore, there is growing interest in developing Asia on the recovery of the plastic fraction from degraded mixed waste for RDF production or for extraction of crude oil via pyrolysis process. Even though, there is an additional energy requirement for production of RDF or crude oil, energy recovery from plastic via both processes would contribute for further GHG reduction. Taking into account all the potential GHG avoidance, overall contribution of MBT process for climate impacts can be estimated.

This would calculate both GHG emissions and GHG avoidance potentials from MBT processes. Similar to other spreadsheets, users are asked to enter the monthly average data of MBT processes such as the amount of total waste for MBT, the amount of fossil fuel required for operational activities at the MBT plant, and the amount of electricity required for the operational activities at the MBT plant. In addition, if users select the option of “Utilization of degraded materials as compost” as “Yes”, and then the users should enter the data related to compost production such as the amount of compost production per month and the percentage of produced compost used for soil amendment. If the answer to the above option is “No” there is no data entry requirement with respect to compost production.

The next step is selecting the answer to the option of “Separation of plastic at the end of MBT” from the drop-down list. If users select the options either “Yes-for RDF production” or “Yes-for Crude oil production," they are asked to enter such data as the amount of recovered waste plastics for crude oil/RDF production, the amount of diesel required for crude oil/RDF production, the amount of electricity required for crude oil/RDF production and percentage of produced crude oil/RDF use for energy production. If the answer to the above option is “No” there is no data entry requirement with respect to production of RDF/crude oil.

If users enter all the required data, the amount of compost use for crop production and amount of RDF/crude oil use for energy purpose per ton of waste input in MBT plant will be displayed in the output. Furthermore, this simulation would calculate GHG emissions, GHG avoidance and net GHG emissions from the entire MBT process per ton of waste input.

Emissions of CO_2 owing to fossil-fuel combustion and utilization of electricity for operating machines at MBT plant can be calculated as follows. As mentioned before, in this simulation, CH_4, N_2O emissions from fossil-fuel combustion are considered to be negligible.

$$Emissions_{Operation} = (FC \times NCV_{FF} \times EF_{CO2}) \times EC \times EF_{el}$$

where

- Emissions $_{Operation}$ – Emissions from operational activities (kg CO_2/ton of waste),
- FC – Fuel consumption apportioned to the activity type (mass or volume/ton of waste)
- NCV_{FF} –Net calorific value of the fossil fuel consumed (MJ/unit mass or volume),
- EF_{CO2} – Emission factor of CO_2 by combustion of fossil fuel (kg of CO_2/MJ),
- EC – Electricity consumption for operation activities (MWh/ton of waste),
- EF_{el} – Emission factor of country grid electricity production (kg CO_2-eq/MWh),

GHG emission from waste degradation in MBT piles is calculated as follows:

$$Emission_{\ Degradation} = E_{CH4} \times OW_{percentage} \times GWP_{CH4} \times E_{N2O} \times OW_{percentage} \times GWP_{N2O}$$

Where:

- Emissions $_{Degradation}$ – Emissions from organic waste degradation (kg CO_2/tonne of organic waste),

- E_{CH4}- Emission of CH_4 during organic waste degradation (kg of CH_4/tonne of organic waste),
- $OW_{Percentage}$- Percentage of Organic Waste in the mixed waste (%),
- GWP_{CH4}- Global warming potential of CH_4 (21 kg CO_2/kg of CH_4),
- E_{N2O}- Emission of N_2O during waste degradation (kg of N_2O/ton of waste),
- GWP_{N2O}- Global warming potential of N_2O (310 kg CO_2/kg of N_2O)

Total GHG emissions from MBT would be calculated by adding GHG emissions from operational activities and GHG emissions from degradation of organic waste under the anaerobic condition in the deep layers of the piles.

$$Total\ GHG\ emissions = Emissions_{Operation} + Emissions_{reatment}$$

Furthermore, if the recovered plastic fraction is used for the production of RDF or crude oil, the GHG emissions from those processes is estimated in this simulation by using the mathematical formula below:

$$Emission_{RDF\ \text{Crude oil production}} = (\mathrm{FC} \times \mathrm{NC}V_{FF} \times \mathrm{E}F_{CO2}) \times (EC \times EF_{el})$$

Where;

- $Emissions_{operation}$ – GHG Emissions from RDF and crude oil production (kg CO_2/tonne of waste)
- FC – Fuel consumption apportioned to the operational activities (mass or volume/tonne of waste)
- NCV_{FF} – Net calorific value of the fossil fuel consumed (MJ/unit mass or volume),
- EF_{CO2} – Emission factor of CO_2 by combustion of fossil fuel (kg of CO_2/MJ)
- EC – Electricity consumption for operation activities (MWh/tonne of waste)
- EF_{el} – Emission factor of country grid electricity production (kg CO_2-eq/M

As mentioned before, there are several ways that initiation of MBT process could contribute to GHG mitigation. GHG avoidance by utilizing the degraded organic materials as compost can be estimated as follows:

$$Avoided\ GHG_{\text{Compost}} = AC \times PC_{agriculture} \times A_{GHG}$$

Where;

- Avoided $GHG_{Compost-}$ Avoided GHG from composting due to avoidance of chemical fertilizer production (kg CO_2-eq/tonne of waste),
- AC – Amount of Compost produced (tonne of compost/tonne of waste input) $PC_{Agriculture}$ – Percentage of produce Compost use for agricultural purpose (%),
- A_{GHG} – GHG avoidance potential from chemical fertilizer production which is equivalent to one tonne of compost (kg CO_2-eq/tonne of compost)

In addition, as a result of operating a MBT plant, a significant amount of organic waste landfilling can be avoided and thereby GHG emissions from organic waste degradation under anaerobic condition can be minimized. The potential GHG mitigation from avoided organic waste landfilling is calculated by using IPCC 2006 waste model..

It should be noted that production of energy using RDF or crude oil would not greatly contribute as a climate friendly solution since this energy production has a fossil-fuel-based origin (waste plastic originated as a product of virgin crude oil). In other words, emissions from combustion of RDF and crude oil would be equivalent to the emissions of virgin fossil fuel combustion. Therefore, GHG avoidance due to combustion of produced RDF or crude oil has not been accounted for in this simulation. However, GHG emissions related to virgin oil extraction, transportation and processing of fuel are included since utilization of RDF/crude oil may indirectly influence avoidance in the virgin fuel production chain. Also it is noteworthy to identify that the produced RDF or crude oil can be substituted to replace the virgin crude oil Production process so that it would contribute to fossil-fuel savings and thus avoid abiotic resource depletion.

Total avoided GHG emissions from MBT can be calculated as follows:

$$\begin{aligned}
&Total\ avoided\ GHG\ Emissions(kgCO_2 - eq\ per\ ton\ of\ waste)\\
&= Avoided\ GHG\ from\ replacement\ of\ Chemical\ fertilizer\ using\ compost\ like\ product\\
&+ Avoided\ GHG\ from\ organic\ waste\ land\ filling\\
&+ Avoided\ GHG\ emission\ from\ virgin\ fossil\ fuel\ production
\end{aligned}$$

In the next step, estimation of net GHG emissions is important in order to understand the overall climate benefit or the impact from the MBT process. The net GHG emissions are calculated as follows:

$$Net\ GHG\ emission\ from\ MBT(kg\ CO_2 - eq\ per\ ton\ of\ waste) = Total\ GHG\ emissions - Total\ GHG\ avoidance)$$

If the estimated net GHG emissions remain as a positive value, it does mean that MBT process is still contributing to climate impact. However, significant GHG reduction can be expected as compared to the 100% of generated waste landfilling without prior treatment. If the result is a net negative GHG emissions value, this indicates the potential GHG saving potential from MBT and the possibility to be a carbon sink.

Furthermore, monthly GHG emissions/savings from a particular municipality/location can be calculated by using the estimated results of GHG emissions or savings per ton of waste management by means of MBT.

$$\text{Monthly GHG emissions savings(kg C}O_2 - eq\ per\ mont) = \ GHGEmissions\ per\ ton\ of\ waste \times Total\ amount\ of\ waste\ use\ for\ MBT\ per\ mont(ton)$$

4.7 Estimation of GHG Emissions from Recycling

It has been convincingly argued and proved that recycling is an extremely sustainable option since a significant number of valuable materials can be recovered from the recycling process. Consequently, this would create tremendous outcomes in the environmental, economic and social fields. One of the key environmental benefits from recycling is its significant contribution to GHG mitigation. Thus, incorporating recycling into integrated waste management would be the most valuable action to drive the entire system towards sustainability.

Similar to any other technology, the recycling process also contributes to significant GHG emissions. Recycling is not a simple process, and it requires a great deal of energy for pre-processing at the sorting facility, transportation of pre-processed recyclables to the recycling facilities by heavy-duty trucks, as well as recycling processes of different type of recyclables at Various recycling facilities. All these activities would emit a considerable amount of GHG. On the other hand, material recovered from the recycling processes can be used to replace the virgin production of an equivalent amount of materials, thereby avoiding a massive amount of GHG emissions that would otherwise occur through the production of the virgin resource. Therefore, estimation of net GHG emissions from a recycling scheme would be very important to make the decision on overall climate impacts.

Recycling entails more than a one-stage process. Sorted recyclables in a particular municipality might have to be sent to various recycling facilities, which are located in different provinces. Therefore, obtaining site-specific data related to recycling of different types of recyclables is a challenging issue. Due to this reason, it would be difficult to find more country-specific GHG emissions from recycling. In order to do a detailed assessment on GHG emissions reduction from recycling activities in a particular location, data are required related to the composition of recyclables, operation activities in pre-processing facilities, total fossil fuel and electricity requirement for pre-processing activities (cleaning, particle size reduction, baling etc), transportation distance to the recycling facilities, fossil energy and electricity consumption data for recycling, country-specific emissions factors from fossil energy combustion and grid electricity production, recyclability of different recyclables, as well as calculating the amount of recovered materials. This makes recycling quite a complex process, and it requires the involvement of different levels of stakeholders. For instance, at the municipal level, the availability of data will be limited to the amount of monthly generated recyclables and composition of the recyclables. Numerous types of other data need to be collected from transportation companies and recycling companies. Due to the unavailability of these data at the local authority level, it would be difficult to calculate life cycle GHG emissions overall recycling process more precisely. Therefore, development and handling of a reliable database on the recycling process chain is an urgent issue in most developing countries.

GHG emissions from recycling have been calculated based on emissions of CO_2 owing to fossil fuel combustion and utilization of electricity for operating machines at sorting plants and recycling facilities. As mentioned earlier, CH_4, and N_2O emissions from fossil fuel combustion is considered to be negligible. GHG emissions from each type of waste recycling can be calculated as follows:

$$Emissins_{recycling=}(FC \times NCV_{FF} \times EF_{CO2}) \times (EG \times EF_{el})$$

Where;

- Emissions $_{\textbf{Recycling}}$ – Emissions from recycling (kg CO_2/ton of recyclables),
- FC – Fuel consumption apportioned to the activity type (mass or volume/ton of recyclables) NCV_{FF} –Net calorific value of the fossil fuel consumed (MJ/unit mass or volume),
- EF_{CO2} – Emission factor of CO_2 by combustion of fossil fuel (kg of CO_2/MJ),
- EC – Electricity consumption for operation activities (MWh/ton of recyclables) EF_{el} – Emission

factor of country grid electricity production (kg CO_2-eq/MWh)

In order to quantify the GHG avoidance potential materials recovery from each type recyclables should be accounted. The recovered materials from each type of recyclable can be estimated as follows;

$$Recovery\ of\ materials(kg/\ ton\ of\ recyclable) = amount\ of\ recyclables(kg/ton) \times recyclablity(\%)$$

In order to quantify the total GHG emissions from a recycling scheme, the following formula can be adopted:

$$GHG\ emissions\ from\ recyclable\ mix(kg\ of\ CO2 - eq\ per\ ton\ of\ recyclables) = GHG\ emission\ from\ paper\ (kg\ CO2 - eq\ per\ ton) \times percentageof\ paper\ waste(\%) + GHG\ emission\ from\ plastics(kg\ CO2 - eq\ per\ ton \times percentage\ of\ plastics\ (\%) + GHG\ emission\ from\ glass(kgCO2 - eq\ per\ ton\ \times percentage\ of\ glass\ (\%) + GHG\ emission\ from\ Alumunium(kgCO2 - eq\ per\ ton) \times percentage\ of\ Alumunium\ (\%) + GHG\ emission\ from\ metal(kgCO_2 - eq\ per\ ton\ \times percentage\ of\ Metal)(\%)$$

A similar approach can be followed to quantify the GHG avoidance potential per ton of mixed recyclables. Once the quantification is done for GHG emissions and GHG avoidance per ton of mixed recyclables, net GHG emissions can be estimated as follows:

$$Net\ GHG\ emissions\ from\ recycling(kgO_2 - eq\ per\ ton\ of\ mixed\ recyclables = Total\ GHG\ emissions - Total\ GHG\ avoidance)$$

If the estimated net GHG emissions remain as a positive value, it implies that the recycling process is still contributing to climate impact. In most cases, a net negative GHG emissions value may be expected due to the avoidance of a massive amount of GHG emissions that would occur from virgin resource production chains. If the result is a net negative GHG emission value, it indicates the potential GHG saving potential from recycling process chain and the possibility to be a carbon sink. Furthermore, based on the estimated net GHG emissions value from recycling of per ton of mixed recyclables, monthly GHG emissions/savings from the particular municipality/location can be calculated. This estimation will show the overall climate impacts from recycling.

$$Monthly\ GHG\ emissionsavings(KgCO2 - eq\ per\ month) = GHGemissions\ per\ ton\ of\ mixed\ recyclables \times total\ amount\ of\ waste\ recycled\ per\ month(ton)$$

It is important to mention that, as compared to other waste management technologies, GHG mitigation potential from appropriate recycling schemes would be remarkable. Holistic approach would be very useful to provide systematic methodology and then to quantify potential GHG mitigation from recycling businesses. The results would be useful for applying carbon credits under the new market mechanisms.

4.8 Estimation of GHG Emissions from Incineration

Initially, waste incineration has been commissioned with the main goal of decreasing the waste mass by 75%, volume by up to 90%. Nowadays there is a big interest for energy recovery from waste as a solution for the energy crisis and also it enables financial benefits via energy recovery. Due to these reasons, there is a growing interest in the application of incineration as a near-term solution to tackle the growing waste management problems in Ethiopia. As far as climate impact is concerned, incineration technology would directly eliminate methane emissions from anaerobic degradation at the landfill site and also displace fossil fuel-based electricity generation.

In general, the application of waste-to-energy technologies which are well-designed to suit the local situation would significantly contribute to GHG mitigation and energy recovery. However, inefficiencies can be noticed as a common obstacle to most of the existing incineration plants in developing Asia which has been influenced for the failure cases. For instance, the composition and moisture content of the waste have a great effect on the efficiency of the incineration plant.

In order to do a detailed assessment on GHG emissions from incineration in a particular location, data are required related to the composition of combustibles, total fossil fuel and grid electricity requirement for on-site operational activities and total electricity and heat recovered from incineration process.

Incineration process is releasing a significant amount of CO_2 into the atmosphere and thus makes a real contribution to the greenhouse effect. However, as recommended in the IPCC guidelines, only the climate-relevant CO_2 emissions from the combustion of fossil based waste are considered for GHG emissions estimation (IPCC, 2006). Since the municipal waste incinerated is a heterogeneous mixture of wastes, in terms of sources of CO_2 a distinction is drawn between carbon of biogenic and carbon of fossil origin. Only CO_2 emissions resulting from oxidation, during incineration of waste containing fossil origin such as plastics, certain textiles, rubber, liquid solvents, and waste oil) are considered. The CO_2 emissions from the combustion of biomass materials (e.g. paper, food, and wood waste) contained in the waste are biogenic emissions and should not be taken to account in GHG emission estimation (IPCC, 2006). IPCC default values of dry matter content of different type of waste, total carbon content, fossil carbon fraction and oxidation factors have been used in this tool in order to quantify GHG from incineration process.

In addition, as stated in IPCC guidelines, there is a possibility to emit CH_4 and N_2O like GHG during the combustion process. However, the magnitude of such emissions depends on the type of the incinerator and the management practices. Therefore, in this simulation an option as given to choose the type of the incineration technology and the default values of CH_4 and N_2O emission will be automatically selected with respect to the selected option.

GHG emissions due to utilization of fossil fuel and grid electricity for plant operation can be quantified as explained in the following formula.

$$Emissions_{Operation} = \left(FC \times NCV_{FF} \times EF_{CO_2}\right) \times (EC \times EF_{el})$$

Where;

- $Emissions_{Operation}$ – Emissions from operation (kg CO_2/ton of combustibles),
- FC – Fuel consumption for on-site activities (mass or volume/ton of combustibles),
-
- NCV_{FF} –Net calorific value of the fossil fuel consumed (MJ/unit mass or volume)
- EF_{CO2} – Emission factor of CO_2 by combustion of fossil fuel (kg of CO_2/MJ),
- EC – Electricity consumption for on-site activities (MWh/ton of combustibles)
- EF_{el} – Emission factor of country grid electricity production (kg CO_2-eq/MWh)

IPCC recommended Tier 2 approach was adapted (IPCC, 2006) in this simulation to quantify the fossil CO2 emissions from combustion of one tonne of wet MSW.

$$CE \sum_i (SW_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times \frac{44}{12}$$

Where;

- CE - Combustion Emissions kg CO_2/tonne of waste),
- SW_i-total amount of solid waste of type i (wet weight) incinerated (kg/tonne of waste) ,
- dmi - dry matter content in the waste (partially wet weight) incinerated ,
- CF_i -fraction of carbon in the dry matter (total carbon content), (fraction; 0.0-1.0) ,

- FCF_i - fraction of fossil carbon in the total carbon, (fraction; 0.0-1.0) ,
- OF_i - oxidation factor, (fraction; 0.0 – 100%) ,
- 44/12 - conversion factor from C to CO_2
- i - type of fossil-based waste incinerated such as textiles, rubber and leather, plastics

When waste is incinerated, most of the carbon in the combustion product oxidizes to CO_2. However, a minor fraction may oxidize incompletely due to the inefficiencies in the combustion process, which leave some of the carbon unburned or partl oxidized. However, for waste incineration, it was assumed that the combustion efficiencies are close to 100 percent so that OF_i can be assumed as 1.

Once the quantification was done for CO_2 emissions from the above phases, life cycle GHG emissions from incineration can be calculated as follows;

$$Total\ GHG\ emission\ from\ incineration(kgof\ CO2 - eq\ per\ ton) = (OE + CE)$$

Where;

- OE – Operation emissions (kg CO_2-eq/tonne of combustibles)
- CE – Combustion Emissions (kg CO_2-eq/tonne of combustibles)

Furthermore, total GHG avoidance potential from incineration can be calculated as follows;

$$\begin{aligned}&\text{Total avoided GHG emissions (kg CO2} - \text{eq per ton of combustibles)}\\&= \text{Avoided GHG from replacement of equivelent amount of conventional electricity}\\&+ \text{Avoided GHG from replacement of equivelent amount of heat which is produced via fossil fuel}\\&+ \text{Avoided GHG emissions from landfilling (BAU)}\end{aligned}$$

Please note that, landfilling without a gas recovery system has been considered as the business as usual practice.

In the next step, estimation of net GHG emissions can be done in order to understand the overall climate benefit or the impact from the incineration process. Net GHG emission from incineration can be estimated as follows;

$$\begin{aligned}&Net\ GHG\ emissions\ from\ incineration(KgCO_2 - eq\ per\ ton\ of\ combustibles)\\&= Total\ GHG\ emissions - Total\ GHG\ avoidance)\end{aligned}$$

Similar to any other technology, if the estimated net GHG emissions from incineration remain as a positive value, it implies that the incineration is contributing to climate impact. If the incineration is resulted, a net negative GHG emissions value that may be expected due to the avoidance of a massive amount of GHG emissions that would occur from conventional production of electricity and heat and landfilling of organic waste. Furthermore, if the result is a net negative GHG emission value, it indicates the potential GHG saving potential from incineration. Based on the estimated net GHG emissions value from incineration of per ton of combustibles, monthly GHG emissions/savings from the particular municipality/location can be calculated. This estimation will show the overall climate impacts from incineration.

$$Monthly\ GHG\ emissions\ or\ savings(kgCO2-eq) = GHG\ emissions\ per\ ton\ of\ wet\ waste\ combusition \times Total\ amount\ of\ waste\ combusted\ per\ month(tons)$$

4.9 Estimation of GHG Emissions from Open Burning

There is an increasing trend in uncontrolled burning a massive amount of waste in the open dump sites and landfill sites as people believe that it is the cheapest, easiest means of volume reduction for saving the land and disposal of combustible materials. However, this kind of primary methods cannot be accepted any longer due to its serious threats to the environment as well as to the local community. Regulations are needed to prohibit such unacceptable practices.

Beside fossil based CO_2 emission from combustion, open burning is responsible for generation of various kinds of toxic by-products from incomplete combustion such as hydrocarbons, particulate matter and black carbon, benzene and carbon monoxide. Recent research has shown that black carbon is the second largest contributor to global temperature increases, with CO_2 remaining as the number one contributor to global warming. However, still there are no published default values from IPCC or any other international organization to quantify the climate impact from black carbon. Therefore, in this version, only fossil based CO_2 emissions from open burring has been considered to quantify the climate impact.

Unlike in landfill management, fossil fuel is not required to do any operational and maintenance activities and therefore there is no any GHG emission with respect operational activities.

IPCC recommended Tier 2 approach was adapted (IPCC, 2006) in this simulation to quantify the fossil CO_2 emissions from open burning of wet MSW. As explained in IPCC guidelines, for open burning, all the default values are similar to the incineration except the oxidation factor. In open burning process higher fraction of waste oxidize incompletely due to the inefficiencies in the combustion process, IPCC recommended oxidation factor (OF) for open burning is 58%.

Once the quantification was done for fossil-based CO_2 emissions from open burning process, it can be considered as the gross GHG emissions. Unlike other treatment methods, open burning has no any possibility for avoidance of GHG emissions process. Therefore, net GHG emission would be equal to the gross GHG emission process.

It should be noted that in order to quantify to overall climate impact from open burning, the impact from black carbon emission should be taken into account. Such improvements will be made in the next version of the tool.

4.10 Estimation of GHG Emissions from an Integrated Solid Waste Management System

This simulation can be applied to quantify the climate benefits from individual treatment technologies as well as from integrated waste management systems. In order to estimate the net GHG emissions from an integrated system, the net GHG emissions from individual technologies will further be aggregated based on the fraction of waste treated by those technologies. By aggregating different type of waste, such as organic waste, recyclables, combustibles and mixed MSW, GHG emissions can be estimated “per ton of collected waste” in a particular location. The following mathematical formula is used for this estimation in the “home” sheet.

$$
\begin{aligned}
&Net\ GHG\ emission\ from\ the\ integrated\ system\ (kg\ CO2 - \\
&eq\ per\ ton\ of\ collected\ waste) = Net\ GHG\ emissions\ from\ land\ filling(kg\ CO2 - \\
&eq\ per\ ton\ of\ mixwaste\ land\ filling) \times percentage\ of\ waste\ use\ for\ landfiling + \\
&Net\ GHG\ emissions\ from\ composting(kg\ CO2 - eq\ per\ ton\ of\ organic\ waste) \times \\
&percentageof\ waste\ use\ for\ composting + \\
&Net\ GHG\ emission\ for\ an\ aerobic\ digestion(kg\ CO2 - eq\ perton\ of\ organic\ waste) \times \\
&percentageof\ waste\ use\ for\ an\ aerobic\ digestion + Net\ GHG\ emission\ from\ MBT(Kg\ CO2 - \\
&eq\ per\ ton\ of\ Organic\ waste \times percentage\ of\ waste\ use\ for\ MBT + \\
&Net\ GHG\ emissions\ from\ recycling(kg\ CO2 - eq\ per\ ton\ of\ stored\ recyclables) \times \\
&percentage\ of\ waste\ use\ for\ recycling + Net\ GHG\ emissions\ from\ incineration(kg\ CO2 - \\
&eq\ per\ ton\ of\ combustables) \times percentage\ of\ waste\ use\ for\ incineration + \\
&Net\ GHG\ emissions\ from\ open\ burning(kg\ CO2 - eq/ton\ of\ waste) \times \\
&percentage\ of\ waste\ use\ for\ open\ burning
\end{aligned}
$$

It is important to mention that when aggregating technologies to quantify GHG mitigation from an integrated system, GHG savings via avoided organic waste landfilling should be excluded from organic waste treatment technologies in order to avoid double counting since that effect has resulted in fewer GHG emissions from the existing landfill. The estimated net GHG emissions from the integrated system indicate the overall progress of the systems.

This kind of holistic approach would be very beneficial to provide systematic methodology and then to quantify potential GHG mitigation from an integrated waste management system. GHG emissions estimation results would be very useful for the local governments for enabling the decision-making process on selecting climate friendly waste management technologies.

5. TOOLS USED FOR GHG MITIGATION

5.1 Tools Used for GHG Mitigation for Light Transit

The transport sector, contributed about 3% of Ethiopia's total GHG emissions in 2010 Eth. C., although this percentage has been increasing rapidly. When the challenges associated with meeting Ethiopia's transport needs are identified, the most common themes that emerge are increasing demand, congestion and the burgeoning cost of building, maintaining and upgrading transport infrastructure. Thus, this emission growth trend remains likely in the future, making the sector a key priority to containing Ethiopia's GHG emission growth.

The CRGE strategy is a key document setting the targets and directions for transport sector development transport policy is focused on assuring sustainable mobility for people and goods with a strong emphasis on contributing to a very ambitious greenhouse gas (GHG) emission targets. More specifically, the CRGE strategy and its related activities are expected to significantly reduce Ethiopia's dependence on imported fuels and reduce carbon emissions in transport by 30% compared to 2030 G. C. business-as-usual (BAU) emissions scenario.

The Ministry of Transport has conducted an overall assessment on the general status of transport sector, "**Assessment of Ethiopian's transport sector"** in order to establishing climate resilient green economy strategy document in transport sector.

The objective of the assessment was to:

(i) develop a comprehensive climate resilient, low carbon transport sector strategy;

(ii) identify opportunities to integrate associated climate-related actions into transport related operational program and

(iii) Develop the institutional tools necessary to inform policies and monitor their economic and environmental impacts. In this manner, a solid analytical base for impact assessment and climate-related decision-making will be established.

Based on the result of the assessment, MOT established the **"Ethiopia's Climate Resilient Transport Sector Strategy",** which can help transport services and infrastructure reach its economic, social and environmental goals over the next 15 years by improving environmental sustainability and by reducing air pollution. The main outcomes of the strategy was "Reduced exposure to the negative impacts of transport pollution on human health, safety and environment" and "Reduced greenhouse gas (GHG) emissions from the transport network”

5.2 Tools Used for GHG Mitigation for Biofuel

5.2.1 The Evolution of Ethiopia’s Biofuel Policy

To elucidate the scope of the debate, we will start with a historical overview of biofuel development in Ethiopia. Initial attempts to produce ethanol from sugar cane to blend with gasoline were made in 1979 (NegeraBeshana2008). However, commercial production of feedstock for ethanol and biodiesel did not start until almost thirty years later. In 2005, Sun Biofuels, a company that no longer exists, was the first to launch commercial biofuel production in Ethiopia. At that time, there was no debate yet in Ethiopia about the production and governance of biofuels. It took two more years until the next important milestone in the development of the Ethiopian biofuel sector was reached: the First High-Level Seminar on Biofuels, which was held in Addis Ababa in the summer of 2007. The seminar, which was jointly organized by the African Union Commission, the government of Brazil and the United Nations Industrial Development Organization, laid out a biofuel roadmap for African countries and can be considered the starting point of the biofuel debate in Ethiopia (IISD 2007).

The Declaration acknowledges the role of biofuels in developing the agricultural sector in rural areas; it calls for institutional frameworks at the regional and national levels, enhanced biofuel research and capacity development, and active participation in global sustainability discussions. The Biofuel Development and Utilization Strategy of Ethiopia was issued in September 2007, shortly after the seminar. It was prepared by the Ministry of Mines and Energy, the Ministry of Trade and Industry and the Ministry of Agriculture and Rural Development together with Sun Biofuels. Other actors for example, from Ethiopia’s well-developed floricultural sector – were not involved, even though a focus on other agro-industrial branches had been defined as important in the Action Plan.

The Biofuel Strategy aims to boost agro-industrial biofuel production, to cover domestic demand in the transport sector and to export surplus production. Covering local household energy demand is not a goal of the Biofuel Strategy. “Biofuel development strategy and direction formulation are among the energy development efforts being carried out [to meet] the national economic development objective” (FDRE 2007: 7). Accordingly, the goals outlined in the Strategy are to replace imported fossil fuels and to export surplus production, thereby reducing Ethiopia’s energy dependence, improving the currency balance and boosting economic development. This is to be achieved by promoting both biodiesel and ethanol, mainly from Jatropha curcas, castor, palm oil and sugar cane (FDRE 2007). Enhanced agricultural productivity, food security, poverty reduction and environmental rehabilitation are expected to follow this agro-industrial growth.

6. RESULTS AND DISCUSSION

6.1 Result Discussion on Waste Management (landfill)

6.1.1 Co-benefits of GHG Mitigation Policies

Most policies and measures in the waste sector address broad environmental objectives, such as preventing pollution, mitigating odours, preserving open space and maintaining air, soil and water quality (Burnley, 2001). Thus, reductions in GHG emissions frequently occur as a co-benefit of regulations and policies not undertaken primarily for the purpose of climate change mitigation (Austrian Federal Government, 2001).

Table 2: Summary of adaptation, mitigation and sustainable development issues for the waste sector

Technologies and practices	Vulnerability to climate change	Adaptation implications &strategies to minimize emissions	Sustainable Development dimensions			Comments
			Social	Economic	Environmental	
Recycling, reuse & waste minimization	Indirect low vulnerability or no vulnerability	Minimal implications	Usually positive Negative for waste scavenging without public health or safety controls	Positive Job creation	Positive, Negative for waste scavenging from open dumpsites with air and water pollution	Indirect benefits for reducing GHG emissions from waste, Reduces use of energy and raw materials. Requires implementation of health and safety provisions for workers
Controlled landfilling with landfill gas recovery and utilization	Indirect low vulnerability or positive effects: Higher temperatures increase rates of microbial methane oxidation rates in cover materials	Minimal implication May be regulatory mandates or economic incentives Replaces fossil fuels for process heat or electrical generation	Positive Odour reduction (non-CH_4 gases)	Positive, Job creation Energy recovery potential	Positive Negative for improperly managed sites with air and water pollution	Primary control on landfill CH_4 emissions with >1200 commercial projects, Important local source of renewable energy: replaces fossil fuels, Landfill gas projects comprise 12% of annual registered CERs under CDM[a],

						Oxidation of CH4 and NMVOCs in cover soils is a smaller secondary control on emissions
Controlled landfilling without landfill gas recovery	Indirect low vulnerability or positive effects: Higher temperatures increase rates of microbial methane oxidation rates in cover materials	Minimal implications, Gas monitoring and control still required	Positive, Odour reduction (non-CH4 gases)	Positive, Job creation	Positive, Negative for improperly managed sites with air and water pollution	Use of cover soils and oxidation in cover soils reduce rate of CH4 and NMVOC emissions
Optimizing microbial methane oxidation in landfill cover soils ('bio covers')	Indirect low vulnerability or positive effects: Increased rates at higher temperatures	Minimal implications or positive effects	Positive, Odour reduction (non-CH4 gases)	Positive, Job creation	Positive, Negative for improperly designed or managed bio covers with, GHG emissions and NMVOC emissions	Important secondary control on landfill CH4 emissions and emissions of NMVOCs, Utilizes other secondary materials(compost, composted sludge's), Low-cost low-technology strategy for developing countries
Uncontrolled disposal (open dumping &	Highly vulnerable, Detrimental effects: warmer temp. promote	Exacerbates adaptation problems, Recommend	Negative	Negative	Negative	Consider alternative lower-cost medium technology solutions (e.g., landfill with controlled waste

burning)	pathogen growth and disease vectors	implementation of more controlled disposal and recycling practices				placement, compaction, and daily cover materials)
Thermal processes including incineration, industrial co-combustion, and more advanced processes for waste-to- energy (e.g., fluidized bed technology with advanced flue gas cleaning)	Low vulnerability	Minimal implications, Requires source control and emission controls to prevent emissions of heavy metals, acid gases, dioxins and other air toxics	Positive, Odour reduction (non-CH4 gases)	Positive, Job creation, Energy recovery potential	Positive, Negative for improperly designed or managed facilities without air pollution controls	Reduces GHG emissions relative to landfilling, Costly, but can provide significant mitigation potential for the waste sector, especially in the short term, Replaces fossil fuels
Aerobic biological treatment (composting) Also a component of mechanical biological treatment (MBT)	Indirect low vulnerability or positive effects: Higher temperatures increase rates of biological processes (Q10)	Minimal implications or positive effects, Produces CO_2 (biomass) and compost, Reduces volume, stabilizes organic C, and destroys pathogens	Positive, Odour reduction (non-CH4 gases)	Positive, Job creation, Use of compost products	Positive, Negative for improperly designed or managed facilities with odours, air and water pollution	Reduces GHG emissions, Can produce useful secondary materials (compost) provided there is quality control on material inputs and operations, Can emit N2O and CH4 under reduced aeration or anaerobic conditions

Anaerobic biological treatment (anaerobic digestion) Also a component of mechanical-biological treatment (MBT)	Indirect low vulnerability or positive effects: Higher temperatures increase rates of biological processes	Minimal implications, Produces CH_4, CO_2, and bio solids under highly controlled conditions, Bio solids require management	Positive, Odor reduction (non-CH_4 gases)	Positive, Job creation, Energy recovery potential, Use of residual bio solids	Positive, Negative for improperly designed or managed facilities with, odors, air and water pollution	Reduces GHG emissions, CH_4 in biogas can replace fossil fuels for process heat or electrical generation, Can emit minor quantities of CH_4 during start-ups, shutdowns and malfunctions
Wastewater control and treatment (aerobic or anaerobic)	Highly vulnerable Detrimental effects in absence of wastewater control and treatment: Warmer temperatures promote pathogen growth and poor public health	Large adaptation implications, High potential for reducing uncontrolled GHG emissions, Residuals (bio solids) from aerobic treatment may be anaerobically digested	Positive, Odor reduction (non-CH4 gases)	Positive, Job creation, Energy recovery potential from anaerobic processes Use of sludge's and other residual bio solids	Positive Negative for improperly designed or managed facilities with odors, air and water pollution and GHG emissions	Wide range of available technologies to collect, treat, recycle and re-use wastewater Wide range of costs CH4 from anaerobic processes replaces fossil fuels for process heat or electrical generation

						Need to design and operate to minimize N_2O and CH_4 emissions during transport and treatment

6.1.2 Method used for Waste management (landfill management),

$$\boldsymbol{ER_y = BE_y - (PE_y + LE_y)}$$

Where:

- ER_y= Emissiion reduction in the year Y(tCO_2e),
- BEy=Baseline emissions in the year y(tCO_2e),
- PEy= Mitigation action emissions in the year y(tCO_2e),
- Leakage emissions in yeary(tCO_2e)

Baseline emissions are calculated as follows:

$$BE_y = W_y \times FE_y$$

where:

- W_y is Total amount of waste disposed in the baseline in the year y (t),
- FE_y = Default value representing the emission reduction associated with the substitution of chemical fertilizer (tCO_2/ t)

$$Y_y \sum_{t=1}^{n} CT_{t,y}$$

Where:

- $CT_{t,}$ = Carrying capacity of truck t used in year y to deliver waste to the composting installation
- t = Waste deliveries in trucks to the composting installation in year y

Table 3: Summary of the GHG emission reductions from compost

City	**BEy** Baseline emissions (tCO_2e)	**ERy** Emission reduction in the year y (tCO_2e)
Adama	1,656 t $C0_2e$	1,656 t $C0_2e$
Bahirdar	937	937 t $C0_2e$

Bishoftu	731	731 t $C0_2e$
Hawassa	1585	1585 t $C0_2e$
Mekele	2136	2136 t $C0_2e$
		7,045tco_2eq or 0.007Mtco_2eq

6.2 Result Discussion on Light Railway Transit

Accordingly, methodologies and procedures used, source of activity data, emission factors used to calculate emission reduction, Quality Control and uncertainty management systems used during data collection are presented as follow;

6.2.1 Emission Removal (Reduction)

The estimation of emissions reduction was based on the modal shift from road transport to railway transport. The estimation is made by considering the business as usual scenario and project scenario. The business-as-usual scenario reflects the mode of transport that would have been used within the city of Addis Ababa and Ethio-Djibouti route in the absence of railway transport system. Therefore, the railway assumed to replace 3,107,182 minibuses in Addis Ababa; and 2,178 buses and 2,244 trucks in Ethio-Djibouti route based on number of passengers and cargo transported annually.

The replacement can save a total 4, 492,467 liter of gasoline and 532,541 liter of diesel by transporting 37,416,853 passengers and 897,900 tons of cargos. Emission reduction estimation is done using tier 1 approach and default emission factor for road transport. Therefore, the operation of Addis Ababa LRT and Ethio-Djibouti railway replaced transport system that would have been made by fuel based transport and can reduced 11,309 tCO_2e of emission in 2010 Eth.C.

Table 4: Railway Emission Removal Activity Data for the year 2010 Ethiopian Calendar

S.N	Railway Route	Number of Passengers /Amount of Goods in Tonne/Transported Annually	Total Annual Kilometer Travel	Number of Vehicles Replaced	Fuel Type	Amount of Fuel Saved	Emission Factors (Kg/TJ)			Reduced Emission in Kg			
						TJ	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2e
A	Passenger	37,416,853	2,584,129.00	3109360						10273620	4626.223	478.449	10519090
1	Addis Ababa Light Transit Railway (AA-LRT)	37,286,183	2,308,189	3107182	Gasoline	139.1871	69,300	33	3.2	9645663	4593.173	445.3986	9880193
1.1	East-West	20,984,446	1,347,801	1748704	Gasoline	78.33367	69,300	33	3.2	5428523	2585.011	250.6677	5560516
1.2	North-South	16,301,737	960,388	1358478	Gasoline	60.85339	69,300	33	3.2	4217140	2008.162	194.7308	4319678

2	Ethio - Djibouti Railway (EDR)	130,670	275,940.0 0	2178	Diesel	8.4744 52	74,100	3.9	3.9	627956 .9	33.05036	33.05036	638896.5
B	**Freight**	897,900.00	551,880.0 0	2244	Diesel	10.477 5	74,100	3.9	3.9	776383	40.86226	40.86226	789908.4
1	Ethio - Djibouti Railway (EDR)	897,900.00	551,880.0 0	2244	Diesel	10.477 5	74,100	3.9	3.9	776383	40.86226	40.86226	789908.4
Total			3,136,009. 00	3,111,6 04	Diesel					11,050, 003	4,667.086	519.3112	11,308,998

Source: GHG inventor report of Ethiopia 2010 E.C

6.3 Result Discussion on Biofuel

6.3.1 Biofuel Development Strategy (2007)

The biofuel strategy was developed during a period of high international interest in biofuels due to record high petroleum prices. Ethiopia, as a land locked country which imports all its petroleum requirements and which allocates the largest share of its export income on petroleum imports saw this as an opportunity for reducing its dependence on imports, improving energy security, attracting investment and creating jobs. Very high hopes were placed on biofuels where the policy indicated potential to produce 1 billion liters of ethanol annually (7 times petroleum consumption levels at that time) and similar levels of biodiesel production.

The goal of the biofuel strategy is to produce biofuels for the domestic market and for export. Specific objectives include substituting petroleum fuels with biofuels; creating jobs and raising incomes through biofuel feedstock production, processing, and distribution; and greenhouse gas emission reduction from replacement of petroleum by biofuels. Key strategies for meeting objectives include technology transfer and R&D, promoting production of ethanol from sugarcane molasses and biodiesel from Jatropha, castor oil and palm oil; increasing biofuels use for transport and for cooking; regulations in support of transition to biofuels including standards and blending mandates for transport.

Cross-sectorial issues addressed include strong stakeholder engagement, international cooperation, efficient coordination and leadership (including a biofuel forum), and increasing finance for biofuel development.

Following the approval of the strategy, the government created a biofuel unit within the Ministry of Water and Energy to coordinate biofuel development activities. This unit is now housed under the Ministry of Mines, Petroleum and Natural Gas. A national biofuel forum was also set up to coordinate activities across government ministries and among government and other stakeholders. – Biofuel sappeared relevant for Ethiopia at the time when there was great international interest for biofuels due to high prices and supply uncertainties for petroleum. Investors and the government showed great interest to develop biofuels in Ethiopia for both the domestic and export markets – more than fifty international investors were registered to develop biofuel feedstock in Ethiopia at the height of the biofuel boom around 2007.

- Very little of what was envisaged in the strategy has been realized,
- Including investment from the government. Although production targets stated in strategic plans

(e.g. GTP 2) continue to be very ambitious production and use have not risen as expected,

- Ethanol production is still limited to 2 state owned sugar estates and there is no production of biodiesel. - Key measures that were put forward in the strategy have not been implemented,
- E.g. increasing ethanol production from state sugar factories. As a result strategies for utilization (e.g. increasing ethanol blending levels for transport, expanding use in cooking) have not happened. Also some of the measures proposed, such as use of bio or vegetable oils for cooking could not be realized due to availability of the fuel as well as availability of appropriate cook stoves for the fuel

Table 5: shows activity, description and status of implementation

Activity	Description	Status
Ethanol – benzene blending facilities	• Planned to be finalized in 4 years, • Being constructed by public finance and a capacity of 100,000 litters each	• Nile Petroleum p.l.c Oromia Regional State at Sululta, • NOC- Oromia Regional State at Dukem, • Total- Oromia Regional State at Dukem, • Oil Libya- Addis Ababa City Administration at Gotera
bio-diesel production plants construction	• Planned to be finalized by 2021 not yet finalized, • Being constructed by public finance and a capacity of 1000 litters each	• Southern Regional State, Hawassa, • Amhara Regional State, Bahirdar, • Addis Ababa City Administration, Addis Ababa
Bio-fuel development proclamation	• Proclamation on the production and utilization of bio-fuel	• Public consultation is done and it is almost in the final stage

Source: Ministry Mines and Petroleum

In light of this, environmental impact study on 68 projects will be conducted and necessary mitigation measures, especially, water and soil conservation, CO_2 emission reduction and improved waste collection and disposal systems will be implemented. Moreover, rehabilitation work on 1,485 hectares of land, which is affected by mining activities, will be undertaken.

Table 6: Show the target and achievement of the plan

NO	Target	Planed	Implemented	Remarks
1	Rehabilitation of abandoned area	14.1 million hectares of land for Jatropha plantation	around one million hectares of land planted for bio-fuel	Jatrofa for bio-diesel production
		on 1,485 hectares of land from mining	312 hectares of land	Rehabilitation of mine abounded area
2	Blending of ethanol with benzene to reduce co2 emission and to save foreign currency	Produce 1,288 million liters ethanol and 212 million liters of bio-diesel	5.127 million liters ethanol produced	
3	Ethanol use cook stove distribution	No plan	1304 ethanol cook stoves distributed to users	

Source: Ministry of Mines and Petroleum

7. CHALLENGES

We used desk review, KII and Focus group discussion as the main too for data collection and preparation of this guideline. However, lack of appropriate data as per the format required is the main challenge in each sector. Therefore, we focused on desk review of documents such as *2006 IPCC Guidelines (tire 1 approach)*, Ethiopia's Climate Resilient Green Economy (CRGE) strategy, , Nationally Appropriate Mitigation Actions (NAMA) 2010, Climate Resilient and Green Economy Strategy (CRGE) 2011, and sector specific strategic interventions such as Climate Resilience Strategy Agriculture and Forestry 2015, Climate, Resilience Strategy: Energy & Water 2015, Climate Resilient Transport Sector Strategy 2015, National Health Adaptation Plan to Climate Change (H-NAP) 2017.

The other challenges that encounter during the preparation of this document are lack of policy implementation monitoring and evaluation, lack of technical capacity building for calculation of GHG mitigation policy and lack of a management system (ICT) gaps related to climate/GHG mitigation actions, law enforcement, and Resource mobilization.

8. SUMMARY AND CONCLUSIONS

Based on the FGDs and KIIs responses obtained from the target sectors, the below are summarized results which the GHG Mitigation Guideline and further formulation processes need to consider.

Sectoral and Institutional level gaps

- The outcomes of the CRGE implementation in the last 10 years (2010-2019) are not known,
- Short institutional memory,
- Data from CSA (Central Statistics Agency) has fallacy,
- No institutional arrangement for MRV,
- No transparency in data collection and reporting,
- No quality control and quality assurance (QC and QA) mechanism, and
- Gap on the data flow between line ministries and MRV directorate.

Federal Level Gaps

- Unavailability/inadequate tools to measure GHG emission,
- Inadequate budget,
- Limited capacity to implementation,
- Less attention,
- Lack of improved/modern working systems,
- Inadequate personnel,
- Weak monitoring and evaluation system, and
- Lack of well-developed GHG mitigation system by linking pollution-health matters.

Regional, Zonal and Wereda level gaps

- No policy and strategy,
- No CRGE structure in the sector,
- The organizational structure is poor,
- Short institutional memory,
- The sector is overlooked on the CRGE and GHG,
- CRGE focal person not synonymous to federal position,
- No sectoral GHG analysis on CRGE in the sector,

- No CRGE team, and
- Knowledge/Skill gap.

9. RECOMMENDATION

Establishment of data management system as a national will be the main issue the government should take in to consideration giving technical capacity building for the national expert on how to make an assessment of GHG mitigation policy will be the one bottleneck that the government should plan to do.

Monitoring and evaluation of the developed policy to check the implementation status of the policy will be take in to consideration.

EFCCC should provide training on national greenhouse gas (GHG) mitigation assessment modes for each IPCC pilar sectors that intends to provide the sectors with the best possible synthesis of all the Intergovernmental Panel on Climate Change IPCC methodologies and tools available which could be of use for non-Annex I Parties and experts in the process of preparation of their national GHG inventories.

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ANNEX I: LIST OF DATA REQUIREMENT

Table 7: List of Data requirement

Step/treatment	Type of data required	Unit
Transportation	Amount of waste transported diesel-fueled trucks	Tons/month
	Monthly diesel requirement	L/Month
	Amount of waste transported by natural gas-fueled trucks	Tons/Month
	Monthly natural gas requirement	Kg/Month
Mix waste landfilling	Amount of mix waste landfilling per month	Tons/month
	Amount of diesel fuel use for operation of machineries at the landfill	L/Month
	Composition of waste	%
Composting	Amount of food waste and garden waste use for composting	Tons/Month
	Amount of fossil-fuel use for operational activities	L/Month
	Total amount of compost production	Tons/Month
	Percentage of compost use for the agricultural and gardening purposes	**%**
Anaerobic digestion	Amount of food waste and garden waste use for anaerobic digestion	Tons/Month
	Amount of fossil diesel use for operational activities	L/Month
	Amount of electricity use for operational activities	kWh/month
	Approximate water content of the influent (mixture of waste and water)	%
Mechanical Biological Treatment (MBT)	Amount of waste use for MBT.	Tons/month
	Amount of fossil fuel require for operational activities	L/Month
	Amount of electricity require for operational activities	kWh/month
	Amount of compost-like material production capacity	Tonnes/Month

	Approximate percentage of produced compost-like material used for soil amendment	%
Recycling	Amount of separated recyclables	Tonnes/Month
	Composition of the recyclable mix	%
Incineration	Amount of total waste use for incineration	Tonnes/Month
	Amount of fossil fuel use for the operation activities	L/Month
	Amount of grid electricity use for the operation activities	kWh/Month
	Composition of combustibles	%
	Amount of electricity produced	kWh/Month
	Percentage of electricity use for on-site activities	%
	Amount of heat recovered	MJ/Month
	Percentage of recovered heat use for onsite activities	%
Open Burning	Amount of waste open burned	Tons/month
	Composition of waste	%

ANNEX II: FGDS AND KIIS RESULTS: IMPACT OF GHG MITIGATION POLICY

1. FGDS results: impact of GHG mitigation policy

1.1 Environment Forest Climate Change Commission (EFCCC)

Position: Climate change planning, implementation and verification coordination directorate staffs

General

- Under EFCCC there are 4 directorates *disclaim*
    - Measuring, Reporting and Verification Directorate (MRV),
    - Climate Change Planning, Implementation and Verification Coordination Directorate (CCPIV),
    - Negotiation Directorate,
    - Technology Directorate
- It is also known as CRGE mainstreaming directorate
    - Main function is follow up that the sectors mainstream CRGE/NDC strategy starting from planning,
    - There are 8 pillar sectors and 4 other sectors involved in NDC implementation,
    - EFCCC and MoF (Ministry of Finance) are responsible to follow up the sectors implementation,
    - EFCCC is responsible for technical support and MOF is responsible for financial (budget) support,
    - CRGE organized at Bureau level in Somali, Benishangul Gumuz and Gambela regions,
    - CRGE organized at Agency level in Tigray and Afar Regions,
    - CRGE organized at Authority level in Amhara, Oromia, SNNPR, Harari and Dire Dawa.
  - CRGE organized at Commission level in Addis Ababa.

GHG Mitigation Gaps Identified during the Discussion

- There is mandate fallacy between EFCCC and MoF. MoF is directly involved on technical support; it is even giving technical training without its mandate,
- The organizational structure at federal and regional level is liquid,
- There were various structural changes without assessing the pros and cons of the existing structure,
- EFCCC is undermined by stakeholders since it is commission and the pillar sectors are organized at Minister Level,

- Regions have a complain about EFCCC being lowered to commission level since its power will be limited to coordinate other ministries,
- Poor communication among stakeholders in the country,
- Poor organizational structure starting from the Federal-Regions-Zone-Woread,
- Different organizational structure in regions with various names. Since the regions have their mandate to correct the structure it is difficult to enforce them,
- No structure at woreda level in all regions,
- Weak structure at Zonal level in all regions,
- In Amhara region it was Bureau but now it is Authority and in many regions it is tied with other sectors. And this shows how liquid the organizational structure is at Regional Level. Oromia, Diredawa, SNNPR, Harar, Tigray had changed their organizational structure to Authority (Environment Protection Authority, EPA),
- Oromia, SNNPR and Dire Dawa have structures up to woreda level. But there is still a gap on the structure,
- The agriculture sector has shaded it and there is competition on the Forest sector,
- The structural gap is an old issue which is not solved still now. EPA-MEF-EFCC-EFCCC-EPA,
- At pillar sectors the CRGE is organized at directorate level and yet the synergy among the sectors and EFCCC is not as per the requirement,
- In Ministry of Mines and Petroleum (MoMP) the CRGE structure is there but there is internal gap in implementing CRGE/NDC,
- The pillar sectors did not give job description for their staff working on CRGE/NDC,
- There is a question on the qualification of the professionals involved on CRGE/NDC implementation,
- There are no focal persons for CRGE/NDC on cross cutting ministries like Ministry of Education, Ministry of women affairs etc,
- Better interaction with donors but the synergy is a gap,
- CRGE/NDC is considered by many regions as a project. But it should be mainstreamed. Awareness gap,
- No direct engagement mechanism with the private sector,
- Lack of regulation for private sector engagement on new technology.

GHG Mitigation Actions: The following Actions are identified during the focus group discussion for better implementation of CRGE/NDC

- The presence of CRGE directorate in all the pillar sectors at Federal Level,

- Better commitment on EFCCC side,
- The updated NDC is approved.
- CRGE is one of the 10 pillars of the Perspective Development Plan (PDP10),
- PDP10 is approved by the pillar sectors and is under implementation.

1. The problems are identified, there is a plan and the outcomes are clearly known on the PDP10,
2. The directorate is supporting on organizing the pillar sectors, assist on planning and coordination on implementation of CRGE/NDC.

Suggestions by the participants: The country need to focus on the following in order to achieve its commitment for GHG emission reduction:

- It is better to have solid organizational structure at federal level and the EFCCC should be organized at Minister Level to empower the sector,
- Similar organizational structure and name should be adopted in all regions for better performance,
- The organizational structure at regions should be present up to woreda level,
- GHG Mitigation building should focus on Technical, Financial and Technology,
- GHG Mitigation building should be planned based on the Paris Agreement on GHG Mitigation building.

1.2 Ministry of Agriculture (MoA)

Position: CRGE Directorate

General

- Organizational relation is led through the signed memorandum of understanding with EFCCC,
- Since the signed MOU, the team develops proposals for GIZ and GHG intervention.,
- Delivered GHG Mitigation capacity building to Regions,
- Supervise physical activities,
- Conduct experience sharing,
- Give feedback based on the report submitted from regions,
- Works with CSA, data mainstreaming

GHG Mitigation Gaps Identified During the Discussion

- Gaps on measuring, reporting and verification of GHG ,

- Limitation on mitigation,
- Limitation on setting target for GHG 2030,
- Perform process oriented rather than strategy focused,
- Lack of GHG Mitigation to measure the amount of GHG emission in the sector,
- MRV is a main challenge,
- Scarcity of quantitative data,
- Weak data management (ICT-database system),
- Project beneficiaries from GHG Mitigation project are not figured out,
- Awareness gap on the updated GHG/CRGE,
- No strong supervision and coordination from EFCCC,
- System gap, IPCC software and climate/GHG Data integration,
- Use government budget but the financial system is rigid,
- Limited man power, machinery and technology on project sites, 28 in number,
- Implementation capacity gap,
- Legal framework gap, organization structure and arrangement,
- Planning gap, the amount of GHG emission reduction is not quantified and indicated on the DP-10,
- Budget limitation,
- Technology limitation.

GHG Mitigation Actions: The following Actions are identified during the focus group discussion for better implementation of CRGE/NDC

- CRGE is established at Bureau level at Federal, but focal persons at regional organizational structure,
- The Bureau has been directly working on GHG emission reduction, MRV and greenery (park development) and compost production,
- The federal level experts well committed to implement GHG Mitigation,
- The directorate had participated on DP10 preparation,
- The day to day activity of the sector is related to GHG emission reduction,
- GHG emission report is being delivered to EFCCC,
- Training was conducted on IPCC software utilization,
- With GIZ, Research is being conducted on measuring the GHG emission,
- EFCCC had also organized some GHG Mitigation building trainings,
- The down ward and upward relation is now better,
- The GHG mitigation policy/plan is under revision but it is still ok,

- Weak linkage with MoUDC, e.g. NAMA COMPOST project give support on solid waste and urban greenery sites, to make uses of compost products for agricultural crop production.

Suggestions by the interviewee: The sector needs to focus on the following in order to achieve its commitment for GHG emission reduction:

- CRGE directorate should be established under the regional bureau,
- MRV directorate shall be established for better performance on measuring and reporting,
- Need national dialog on environmental/climate issues to achieve the green legacy,
- The commitment has to be raised as it was during the CRGE implementation,
- Awareness should be created at all levels on the updated \NDC and DP10, and
- Motivation mechanism should be developed to enhance experts' performance.

1.3 Ministry of Mines and Petroleum (MoMP)

Position: Director, Environment and Community Development Directorate

General

- The mines and petroleum Policy is sent to the Prime minister office and not yet approved.
- Good relation with petroleum suppliers but we do not have the mandate to communicate with them.
- Quality control on sulfuric acid content is done by our sector with petroleum suppliers.
- We give more focus on our day to day activity not on CRGE and NDC.

GHG Mitigation gaps identified during the discussion

- No GHG Mitigation policy and strategy,
- No CRGE structure in the sector,
- The organizational structure is poor,
- Short institutional memory,
- MoMP was not a pillar sector on CRGE,
- The sector is overlooked on the CRGE and NDC,
- No CRGE focal person at Regional level,
- No sectoral analysis on CRGE in the sector,
- No CRGE team,
- Knowledge gap,
- Roles and responsibilities of the staff for NDC implementation is not prepared,
- Lack of consistent and uniform organizational structure in all regions,
- Awareness gap at Regional and Woreda levels, and
- The updated NDC is not mainstreamed at minister level.

GHG Mitigation Actions: The following GHG Mitigation assets for CRGE/NDC and DP10 implementation are identified during the discussion.

- Petroleum directorate is established,
- Coal production is stopped,
- NDC is mainstreamed on the directorates DP10,
- Mining is not the main GHG gas emitting sector since it is on the infant stage,
- Planned to plant trees to rehabilitate abandoned mine sites,
- Good commitment on experts' side for NDC and DP10 implementation,
- Organized and submitted the 6 month progress report based on DP-10.

Suggestions by the participants: The country need to focus on the following in order to achieve its commitment for GHG emission reduction:

- Awareness should be created at all levels in the sector,
- GHG Mitigation building should be system based,
- The policy should be approved ASAP,
- The revised organizational structure shall be approved,
- EFCCC, MoF and Planning Commission should support the sector for increased performance,
- Since the ministry is focusing on petroleum systematic approach should be designed and focus should be given for the sector for better implementation of the updated NDC and DP-10,
- NDC should be mainstreamed at ministerial level too,
- The directorate should be supported technically and financially.

1.4 Ministry of Transport (MoT)

Position: CRGE Directorate

General

- The directorate is under GHG Mitigation policy development
- Regional level structure, focal persons run the GHG Mitigation/MRV
- Updating CRGE/MRV Platforms for better performance
- EFCC/MoF and others assist coordination and facilitation
- Awareness created at town level for waste management and greenery
- Supervision work

- The main aim is to give support, coordination and GHG Mitigation building for towns

GHG Mitigation gaps identified during the discussion

- Legal framework under development for low GHG emission,
- Human resource gap at lower structure,
- Limited implementation capacity for most towns,
- High/congested trafficking areas/zones under revision for GHG Mitigation,
- Logistics shortage,
- Maintenance gap for vehicles used for solid waste transport,
- No MRV system, poor technical support on MRV,
- No strong technical support,
- Knowledge gap to calculate GHG emission,
- Gap to implement Environmental Impact Assessment report,
- Awareness gap on the updated NDC and DP-10,
- No MRV unit,
- Lack of awareness on railway transit, SWM,
- No incentive mechanism,
- Budget limitation,
- No hands on training other than IPCC software,
- No GHG Mitigation to support associations, bus-terminal stations,
- The federal work on disposal coverage without the sector`s consent/knowledge
- Difficulty to measure and quantify GHG leakages, water transport,
- No planned and continues supervision,
- Experience sharing is only conducted by higher officials not professionals and
- Planned for MRV with EFCCC to include GHG Mitigation cost, Air transport-air ticket.

GHG Mitigation Actions: The following Actions are identified during the focus group discussion for better implementation of CRGE/NDC

- DP-10 for 2020-2030 is prepared in view of the NDC direction,
- One year operational plan for GHG Mitigation is also under preparation,
- Legal framework for waste management is prepared,
- Waste management proclamation, regulation and guideline are prepared and approved,
- The structure is to be aligned up to Wereda level,
- Public terminals managed by cooperatives (WM-income generation),
- Road separator greenery is being conducted,
- GHG Mitigation building training to continue be given for Weredas,
- QA and QC for vehicles, updated,

- Awareness creation for transits to reduce GHG emission,
- Standards for GHG quality monitoring and evaluation,

Suggestions by the participants: The country need to focus on the following in order to achieve its commitment for GHG emission reduction:

- Separate MRV team is needed for land, water and air transport to GHG mitigation,
- Cities and Towns should have their own MRV unit,
- The regional CRGE Focal persons Need technical training to calculate GHG/IPCC Software,
- Technical training is needed on ESIA for effective GHG Mitigation,
- Need technical support on MRV,
- Need-based training is needed for professionals, and
- Monitoring and evaluation of GHG Mitigation Need to be result focused.

1.5 Ministry of Trade and Industry (MoTI)

Position: Environment Protection and Climate Change Directorate

General

- CRGE implementation at good status.
- Still working on CRGE
- Required staffs exist
- Coordination and controlling is being done

GHG Mitigation Gaps Identified during the Discussion

- GHG Mitigation plan is not yet approved by the regional government,
- Structural gap, No CRGE unit in the sectors,
- Limitation on MRV,
- Budget shortage allocated for GHG Mitigation,
- No regional plan for the DP-10,
- Knowledge and skill gap,
- Technology and ICT-System gap,
- Gap on synergy and alignment,
- Limited capacity to manipulate the IPCC Software,
- Gap on monitoring and evaluation

GHG Mitigation Actions: The following GHG Mitigation assets for CRGE/NDC and PDP10 implementation are identified during the discussion.

- The GHG Mitigation plan was prepared with the sectors involvement
- The GHG Mitigation plan is sent to the regional government for approval

- The GHG mitigation implementation guideline is developed
- Awareness is created on technology and ICT-System utilization
- Early warning is being given for GHG risk areas
- Training conducted on MRV
- The NDC is mainstreamed on the DP-10 at federal level, regions to continue
- Awareness on the updated NDC and DP-10 created
- GHG Mitigation, climate change issues with low carbon emission trade/investment
- GHG Mitigation and its linkage with economic growth under plan of study/research

Suggestions by the participants: The country need to focus on the following in order to achieve its commitment for GHG emission reduction:

- The Impact of climate change, GHG Mitigation, various across regions,
- Sectoral institutional capacity building under planning,
- GHG Mitigation-Trade/investment linkage,
- GHG mitigation cost,
- Budget support from stakeholders is needed,
- The monitoring and evaluation at all levels to start-up,
- Mainstreaming the CRGE/MRV unit is the sectors mandate up to Wereda level,
- Checklists and IPCC Software under revision and approval,
- Regional focal persons in the regions, need-based training on MRV,
- The ministry is looking for local and international partnership to address GHG

1.6 Ministry of Urban Development and Construction (MoUDC)

Position: CRGE Directorate

General

- Organizational relation is led through the signed memorandum of understanding with EFCCC,
- We give GHG Mitigation building to Regions,
- We supervise physical activities,
- We conduct experience sharing,
- We give feedback based on the report submitted from regions,
- CRGE bureau is established at federal level. It has two directorates. Greenery directorate and sanitation directorate,
- NAMA Compost project is under the bureau. It is working on GHG emission reduction, Urban Greenery and Solid waste management to build urban resilience, Job creation,

- National Implementation Modality (NIM) is available,
- Intervention in 6 towns, Bishoftu, Adama, Hawassa, Mekelle, Bahir Dar, Diredawa and in Jimma minimum intervention,
- The implementer is MoUDC,
- NAMA does the coordination,
- More focus is given to GTPII and CRGE,
- The targets are taken from GTPII and CRGE,
- The sector is key for NDC implementation,
- CRGE Committee is available,
- Available staff is 10, 2 on MSc education

GHG Mitigation gaps identified during the discussion

- Poor on measuring, reporting and verification,
- Not working on mainstreaming,
- No MRV expert,
- No MRV section,
- The sectoral plans are not in line with GHG emission reduction,
- The plan is not aligned with NDC,
- The report is not aligned with NDC,
- No alignment was done for CRGE,
- No focus on NDC,
- Gap on alignment,
- Work on cascading,
- No system,
- All the gaps identified during the CRGE period persist. No intervention,
- Some gap on the structure,
- Gap on planning and reporting,
- The sector is not aligned with NDC,
- The sectoral plan has a gap on NDC mainstreaming,
- The report is not verified,
- There is no verifier,
- Draft plan has been prepared on selecting verifier but it has to be aligned with EFCCC policy,
- GHG Mitigation gap on MRV,
- More focus on greenery and less focus on GHG emission measuring,
- No MRV plan indicated on the annual plan,

- Poor financial management system, 40,000,000 USD is returned,
- Technology gap ,
- Gap on information communication technology (ICT),
- Baseline data gap on sectoral GHG emission,
- Poor market for compost

GHG Mitigation Actions: The following Actions are identified during the focus group discussion for better implementation of CRGE/NDC

- Good organization structure. CRGE is established at bureau level at Federal and regions have similar organizational structure,
- NAMA COMPOST project funded by UNDP is under the bureau and is directly working on GHG emission reduction, MRV and greenery (park development) and compost production,
- Good commitment,
- IPCC training was given,
- Good relation with stakeholders,
- Better on policy, strategy and standard,
- Good support from the ministry,
- Compost is being utilized for urban greenery,
- Working on Plastic waste reduction,
- NAMA Compost project created job opportunity,
- Turner machine and thermometer is supplied to Adama Compost project,
- Ethiopia Forest Research is our customer for compost

Good Practice: Adama greenery project which is funded by UNDP NAMA COMPOST project is the best experience in our country. The consultant is advised to visit the project.

Suggestions by the participants: The sector needs to focus on the following in order to achieve its commitment for GHG emission reduction:

- CRGE directorate should be established under the bureau,
- MRV directorate shall be established for better performance on measuring and reporting,
- System should be established,
- EFCCC has to do more on GHG Mitigation building,
- The main goal of this sector has to be GHG emission reduction,
- Regional structures should be aligned with CRGE facility,
- The organizational structure should be similar all over the country,
- Good vertical relation up to town level,
- We have to build a system,

- EFCCC should build web based system for NDC,
- Public private partnership should be a focus- Urban agriculture and Waste recycle

1.7 Ministry of Water, Irrigation and Energy (MoWIE)

Position: CRGE Directorate

General

- More focus is given on GHG emission reduction on Donor side,
- More focus is given on Adaptation and Mitigation on our side,
- GHG emission reduction through initiating CRGE in 2015,
- Additional fund from UNDP and World Research Institute (WRI), SNV,
- Coordination through negotiation with CRGE Steering committee and stakeholders,
- Communication taskforce established for negotiation,
- MEAs and protocols, Kyoto, Paris Agreement, and
- Mainstreaming and alignment with the CRGE pillar sectors.

GHG Mitigation gaps identified during the discussion

- Limited GHG Mitigation, MRV, for large-scale irrigation dams/reservoirs,
- Limited GHG Mitigation, inaccessibility and high costs technologies,
- Government policy shift now calls for sectoral policy adjustment, energy,
- Gap on creating international negotiators,
- Gap on technologies and ICT-Systems,
- Gap on manipulating IPCC Software at regional and Wereda level,
- Limited capacity to GHG Mitigation, and
- Government structure for climate change, GHG.

GHG Mitigation Actions: The following GHG Mitigation assets for CRGE/NDC and PDP10 implementation are identified during the discussion.

- Good will since the sector is one of the pioneers,
- GHG Mitigation building works are being done to empower negotiators,
- Good experience in clean development mechanisms, GHG,
- Conditional target project area planning, as pilots, for GHG Mitigation,
- NDC partnership, CRGE forum and LIMA partnership are potential resources,
- Paris agreement, GHG Mitigation building now under formulation and development,
- Ministry of Finance is the key sector at national level for negotiation and resource mobilization,
- Encouraging the private sector to support the updated NDC-DP-10, GHG Mitigation,

- Planning technologies and ICT-Systems for NDC implementation, GHG Mitigation,
- Daily monitoring system is designed COP26,
- For knowledge management experience sharing workshops have been organized.

Suggestions by the participants: The country need to focus on the following in order to achieve its commitment for GHG emission reduction:

- Sustainable and planned GHG Mitigation building is needed,
- Build GHG Mitigation on negotiation,
- Work starting from grassroots levels up to the higher levels, and
- Monitoring and evaluation of GHG Mitigation, result-based assessment.

1.8 Response Summary of FGDs

- CRGE directorate should be established within sectors,
- MRV directorate shall be established for better performance on measuring and reporting,
- National dialogue on environmental issues to achieve the green legacy and initiation has to start sooner,
- The commitment has to be raised as it was during the CRGE implementation,
- The internal relation has to be addressed and enhanced,
- Awareness should be created at all levels on the updated GHG Mitigation policy, and
- Need-based training, GIS-RS

2. KIIs Results: Impact of GHG Mitigation Policy

Here, the FGDs and KIIs response rates are addressed and discussed in accordance to the target sectors. The main concerns are availability of GHG mitigation polices and strategies, practices of GHG mitigation policies, amount of sector`s GHG emission, applied technologies and software, coordination and synergy, constraints and challenges and, constraints of GHG mitigation policy.

Table 8: Summary of KII Response Rate from Target Sectors

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
1	Did your organization develop a climate change mitigation policy or GHG mitigation policy? (Yes; No)	Yes, GHG emission standard guidelines/procedures; National and sector GHG emission MRV Guidelines	Yes	Yes, Developed inddor air pollution measurement policy/guideline	Yes, Railway transit safety policy/guideline	Yes, Policy shift towards low carbon emission investment, GHG Pollution control strategies/directives	Yes	• The mines and petroleum Policy is sent to the Prime minister office and not yet approved.	Yes, Policy shift towards alternative energy sources, HEPP & Solar energy	Data Source, Harmonizes national level datasets	Research, Technical assistance like capacity building

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
1.1	Lists of policies and strategies	There are three setups for GHG inventory – Official setup (MoU is signed) -Institutional setup -Procedural setup	Climate Resilient Green Economy Strategy (CRGE), Agricultural Mechanization strategy, Livestock Master Plan, Ethiopia's Agricultural Sector Policy and Investment Framework, Climate Resilience Strategy:	Waste reduction/minimization strategy, Indoor pollution, via incineration technology	To mitigate GHG emission our organization have developed CRGE transport strategy decumbent	Yes	Yes	Planned to plant trees to rehabilitate abandoned mine sites.	Yes	Collect and report Yearly GHG emissions/removals by sectors.	Conduct research in Natural Resources Management; Environmental Pollution; Climate Change and Energy.

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
			Agriculture and Forestry(this is more of adaptation), Rural Development Policy and Strategy (RDPS), Rural Land and Administration and Use proclamation								

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
2	Did your institution/directorate develop GHG emission mitigation/climate change mitigation policy?	Yes	Yes, the directorate developed also Climate smart Agriculture rod map and Climate Smart Agriculture field manual for extension worker are some of them.	No, ongoing stage	Yes	Yes	Yes			Developed Sector GHG inventory/assessment, verification and validation guidelines/protocols	Develops fast measurement and tracking methods for GHG inventory and assessment.

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
3	Do you have any procedure or guideline how to monitor, evaluate and assess this mitigation action policy intervention?	Yes	Yes we do have guidelines to monitor, evaluate and assess the mitigation; The guidelines are; •GHG Emission Assessment Guideline Volume I: Soil Carbon and Nitrogen Stock Assessment	No	Yes	Yes	Yes				Applies various toolkits, software and hand`s-on-Applications to measure and estimate pollution loads from different activities.

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
			in agricultural land and agroforestry systems • GHG Emission Assessment Guideline Volume II: Aboveground Biomass Field Guide for baseline survey •GHG Emission Assessment Guideline Volume III:								

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
			Guideline on data collection and estimation of GHG emission from Livestock and Manure Management • Conservation agriculture guideline								
4	What are the types of the fund initiate? (Mitigation,	All	The types of fund depend on the donor interest.		Government budget	Government budget	All				

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
	adaptation, capacity building, technology support, or all)		Even though there is no clear bounders between Mitigation and adaptation the fund is for all								
5	What other co-benefits has the mitigation action policy interventions in addition to reducing GHG? (Health impact reduction,	All	The co-benefits of mitigation action is to reducing air pollution from emissions of fossil fuels and the		Finance sector, health sector, tourism sector		All				

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
	environmental pollution reduction impact etc.)		accompanying health and environmental impacts is the most obvious co-benefit, but there are many other areas, including resource efficiency, economic security, sustainability of ecosystems or increased								

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
			economic dynamism where positive impacts can be expected ..								
6	Which GHG types were targeted to reduce after the implementation of mitigation action policy? CO2, CH4, N2O, etc.	CO2, CH4 and N2O are some the GHG gases that given priority to reduce as per the source of GHG but it reported in the carbon dioxide equivalent	CO2, CH4 and N2O are some the GHG gases that given priority to reduce as per the source of GHG but it reported in the carbon		CO2, CH4, N2O,		Landfill GHG Emission				

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
			dioxide equivalent								
7	What tools were used to monitor and evaluate the implementation performance of the mitigation action policy? (A. Checklist developed, B. minutes developed C. any other)	A and IPCC M&E Tracking	To monitor and evaluate the implementation of the mitigation action we used Checklist by the Directorate and we use minutes by steering committee		IPCC 2006 software	IPCC 2006 software	IPCC 2006 software	IPCC 2006 software			

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
			the led by his excellency Ministry of agriculture								
8	Who financed the developed mitigation action policy implementation? (Government, NGOs, other donor)	All	The mitigation action financed by Government and Development partners		Government	All					
9	How many community members are benefited from this mitigation	Tens of thousands	It needs further investigation per intervention		Both of them, but not identified in	Both of them, but not identified in	Both of them, but not identified	Both of them, but not identified in figure	Both of them, but not identified		

No.	Description	Response									
		EFCCC	MoA	MoH	MoT	MoTI	MoUDC	MoMP	MoWIE	CSA	AAU
	action policy intervention? (Male and female)?		so there is no clear number mentioned here		figure	figure	in figure		in figure		
10	What are the types of the budget support approved? (Grant, loan budget support, etc)	All	The approved budget support are both grant and loan		Budget	All	All	All	All	All	All

2.1 Response Summary of the KIIs

- Need for hands on training on IPCC software
- The policy should be approved as soon as possible
- The updated organizational structure shall be approved and implemented to strengthen the sector
- More focus should be given to the sector on GHG since we are focusing on petroleum exploration and extraction and this will increase the sectors contribution of GHG emission
- Direct intervention on GHG is vital in all sector.
- Need for strong and solid organizational structure
- The updated GHG should be discussed among the staffs and officials of the sector
- Capacity building plan should be developed and the capacity building should be system driven and need base
- Awareness should be created at all levels of the sector for GHG implementation by EFCCC,
- The staff should be strengthened on human resource
- The MRV system should be strengthened in each sector

3 Qualitative Results

Table 9: SWOT Analysis Result

Strengths (S)	**Weaknesses (W)**
10-year plan for GHG emission at sector level	Low awareness on environmental issues
Some capacity building trainings conducted, Trainings given on CRGE overview and environment and social development, Online training given for selected staff on IPCC software by GEF	MRV (Measuring, Reporting and verification)
Raw data on GHG emission is being submitted for EFCCC, MRV directorate	Law enforcement
Communication with EFCCC, MoF and planning commission	Human resource
Staff involvement during the preparation of DP-10	No strong data base management system
IPCC software use and application	Lack of base line data for GHG emission

Checklist-based GHG assessment/inventory practices	Knowledge management
Readiness to implement GHG Mitigation actions	Limitation on climate change adaptation and mitigation
Coordination and alignment to mainstream MRV	No need based capacity building system
Opportunities (O)	**Threats (T)**
Organizational relation is led through the signed memorandum of understanding with EFCCC	Limited support from development partners
Focus given for the sector GHG mitigation	Limited coordination and synergy among stakeholders to implement GHG Mitigation
Existence of global climate finance	Financial resource limitation for GHG implementation
Stakeholder involvement in climate change issues	Increasing demand for coal and petroleum will increase the GHG emission

Table 10: FGDs in Response to Role and Function and Mandates of Target Sectors

No.	**Sectors**	**Experts/Officials/Managers**	**Role & Function**	**Mandates**
FGD-1	MoUI	3% GHG contribution, 3 MtCo2E; Greenery and urban sanitation directorate	NAMA Compost project is assisting the greenery and solid waste	The directorate prepares guidelines, build bilateral relationship, monitoring and evaluation, Capacity building, experience sharing
FGD-2	MoH	Indoor air pollution control	Management staff	(Bio) fuel switching technology for energy efficiency, CDM Practices
FGD-3	EPA	Mainstream CRGE/GHG strategy from planning	Climate change planning, implementation and verification coordination directorate staffs	Measuring, Reporting and Verification Directorate (MRV), Climate Change Planning, Implementation and Verification Coordination Directorate (CCPIV), Negotiation Directorate

No.	Sectors	Experts/Officials/Managers	Role & Function	Mandates
				&Technology Directorate
FGD-4	MoTL	Railway transit	In line with the federal structure & Work on coordination and follow-up	Updated & modern technology to mitigate GHG
FGD-5	MoMP	Coal production banned	Environment and Community Development Directorate staffs	Sign MOU, review EIA documents, Organizational structure, CRGE implementation & Prepare and report DP-10
FGD-6	MoA	90% GHG contribution, 9 MtCO2E; Reduce GHG through R/A.	Greenery Directorate staff and NAMA project manager	Give capacity building to Regions, Supervise physical activities, Conduct experience sharing & Give feedback
FGD-7	MoWE	Switching to Alternative energy supply sources	CRGE Directorate staffs	Give capacity building to Regions, Supervise physical activities, Conduct experience sharing & Give feedback
FGD-8	CSA	Data and/or information sources	Hub of GHG data banks	Capacity Building, Team for Waste management and Greenery, Zonal and Town level structure, Establishing associations, Waste management, Recycling,

No.	Sectors	Experts/Officials/Managers	Role & Function	Mandates
				Awareness created at town level for waste management and greenery & Supervision work
FGD-9	AAU	CRGE support units, GHG research and dissemination	Research for GHG Mitigation	Work on institutional capacity building, pollution loads assessment, tracking tools and etc

Table 11: KII in Response to Position and Responsibility in the Target Sectors

No.	Sector	Position	Responsibility
1	EFCCC	Director, GHG Emission Reduction Verification Directorate	Work on mitigation, adaptation, Gives technical support & Technical wing (directorate) for MRV
		Technical Assistant assigned by EU, GHG Measuring, Reporting and Verification Directorate	Inventory, Mitigation & Support (from developed nations)
		Director, Resource Mobilization Directorate	GCF and Adaptation fund mobilization, Nationally Designated Authority (NDA) & Clean Development Mechanism
4	MoTI	LE-Carbon Market/Investment	Source of finance- GCF, GEF (multilateral), Carbon market, Bilateral (REDD+) & DFID)
5	CSA	GHG Measuring, Reporting and Verification	Steering committee and facilitating staffs & Technical wing (EFCCC) and Financial wing (MoF)

No.	Sector	Position	Responsibility
6	MoMP	Director, Mines resource Study and Administration Directorate	Focal person working with delegation, with CRGE & Directly staff of the Energy sector
7	AAU/CES	Environmental Science	Support CRGE and GHG & Works with CRGE as focal person
8	MoT	Environment and Community Development	Policy, Communication, Quality control on sulfuric acid content is done by our sector with petroleum suppliers & Follows up CRGE and GHG activities
9	MoUDC	Climate Change Negotiation and Coordination Directorate	GHG emission reduction,Adaptation and Mitigation, Coordinates the negotiation and Cooperates with the pillar sectors
10	MoA	Climate Change, Planning, Implementation and Verification Coordination Directorate	CRGE progress report & Capacity gap assessment for Adaptation
14	MoWIE	CRGE Focal person, Alternative Energy Technology Development Transformation Directorate	Focal person working with delegation
15	Forest and other land uses	Environment Protection and Climate Change	CRGE implementation, working on CRGE, & Coordination and controlling of staffs
17	Waste sector	Climate Change and Biodiversity Conservation	Support assessment & Responsible/Commitments to take adaptation &/or mitigation actions

ANNEXES III: FGD AND KII CHECKLISTS FOR GHG MITIGATION POLICY ASSESSMENT

Table 12: FGD Checklist for GHG Mitigation Policy Assessment

No.	**Description**
1	What mitigation action was implemented by your institution for the intervention of developed mitigation policy?
2	Where this mitigation action was implemented sofar?
3	Which key category/sector were mainly targeted to consider for implementation of this mitigation action?
4	What is the implementation status of the developed mitigation action policy?
5	What is the amount budget needed for full implementation of this mitigation policy?
6	Amount of budget used till now (in %)
7	What types and amount of technology support were received for the implementation of this mitigation action policy?
8	What do the identified indicators and implementation report look like?
9	Number of indicator set and which of them achieved
10	What are the challenges and gap faced in the implementation process of mitigation action policy?

Table 13: KII Checklist for GHG Mitigation Policy Assessment

No.	Description
1	Did your organization develop a climate change mitigation policy or GHG mitigation policy? (Yes; No)
1.1	Lists of policies and strategies
2	Did your institution/directorate develop GHG emission mitigation/climate change mitigation policy?
3	Do you have any procedure or guideline how to monitor, evaluate and assess this mitigation action policy intervention?

No.	Description
4	What are the types of the fund initiate? (Mitigation, adaptation, capacity building, technology support, or all)
5	What other co-benefits has the mitigation action policy interventions in addition to reducing GHG? (Health impact reduction, environmental pollution reduction impact etc.)
6	Which GHG types were targeted to reduce after the implementation of mitigation action policy? CO2, CH4, N2O, etc.
7	What tools were used to monitor and evaluate the implementation performance of the mitigation action policy? (A. Checklist developed, B. minutes developed C. any other)
8	Who financed the developed mitigation action policy implementation? (Government, NGOs, other donor)
9	How many community members are benefited from this mitigation action policy intervention? (Male and female)?
10	What are the types of the budget support approved? (Grant, loan budget support, etc)