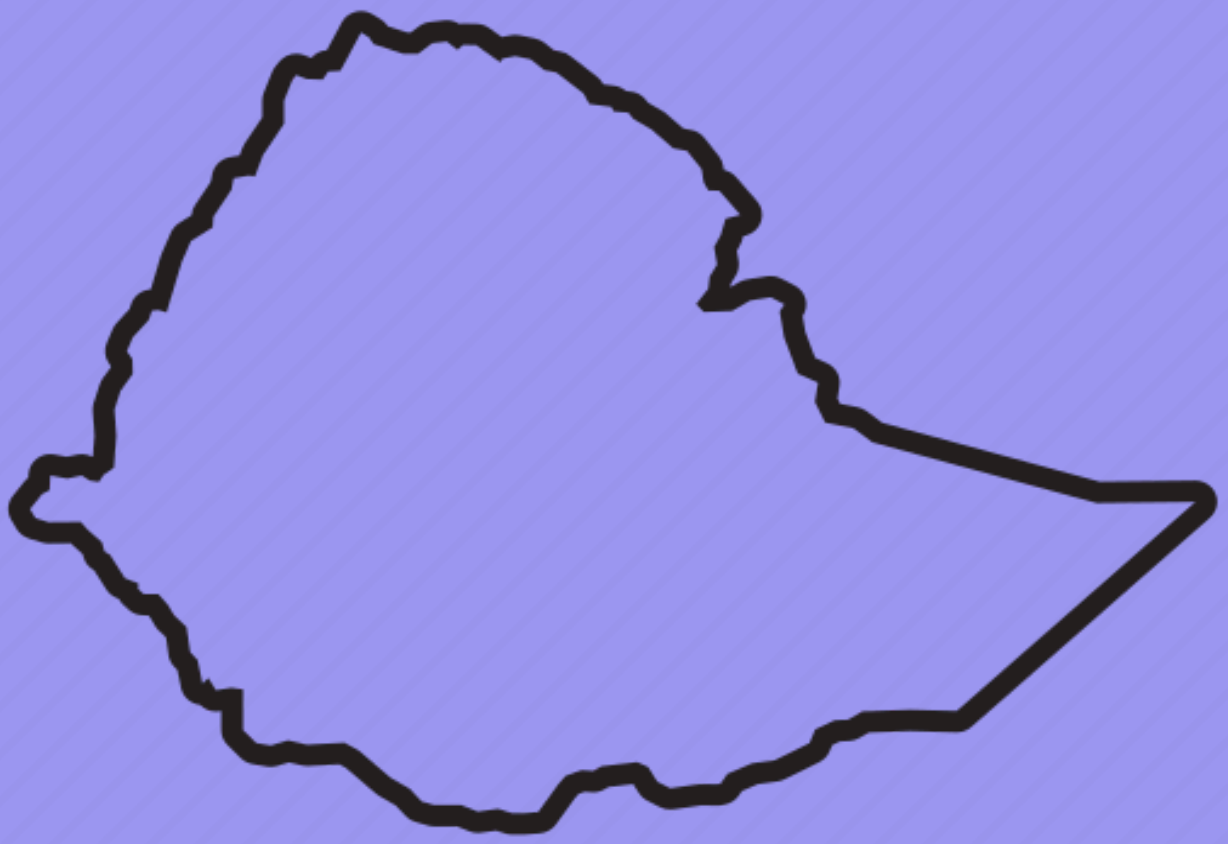
Ethiopia's Updated NDC Progress Tracking Framework Based on the GACMO Tool



Ethiopian NDC Progress Tracking Framework Based on the GACMO Tool

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Acronyms/abbreviations

10 YDP	Ten-year development plan
BAU	Business as Usual
CO_2e	Carbon dioxide equivalent
CRGE	Climate-Resilient Green Economy Strategy
FDRE EFCCC	Federal Democratic Republic of Ethiopia Environment, Forestry and Climate Change Commission
GACMO	Greenhouse Gas Abatement Cost Model
GES	Global Environmental Solution
GHG	Greenhouse gas
ICAT	Initiative for Climate Action Transparency
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use
ktoe	Killo ton oil equivalent
LUCF	Land use change and forestry
MARC	Marginal Abatement Revenue Curve
MRV	Measuring, Reporting and Verification
NDC	Nationally Determined Contributions
UNEP-CCC	UNEP Copenhagen Climate Centre
UNFCCC	United Nations Framework Convention on Climate Change
UNOPS	United Nations Office for Project Service

1. Executive summery

Ethiopia has set ambitious goals for climate change mitigation. In its updated NDC (2021), the country commits to several mitigation measures and adaptation actions to reduce the country's GHG emissions from a projected BAU of 403.5 Mt CO_2e to 277.7 Mt CO_2e by 2030. In its 2021 updated NDC, Ethiopia targets to achieve an emission reduction by 68.8% by employing both conditional and unconditional mitigation options. The country has put in place a tracking system on the progress and group GHG emission reduction impacts of various implemented mitigation policies. Yet it still faces some difficulties in monitoring and evaluating the efficiency of each mitigation actions. To address Ethiopia's needs for support on mitigation action monitoring and evaluation, the ICAT Secretariat, together with the UNEP-CCC, UNOPS and locally recruited national consulting firm (Global Environmental Solution, GES), has supported the country experts in developing the Greenhouse Gas Abatement Cost (GACMO) model as a tracking tool for Ethiopia's updated NDC. The tool helps to monitoring and collecting certain activity and energy balance data to get quite accurate estimates of the GHG mitigation effects including its projection by 2025 and 2030.

Procedurally, the team examined the compatibility of GACMO tool for tracking the mitigation options under Ethiopia's updated NDC. Then, the team identified 31 mitigation measures and organized it in GACMO tool to track its individual contributions for emission reduction, in particular and its cumulative effect on meeting the Ethiopia's Updated NDC targets, in general. The mitigation options were organized in GACMO tool as per their emission source sectors category. Their emission reduction potentials will be calculated by the model up on up updated activity data collection, approval and insertion into the model system. Finaly, the model provides the annual emission reduction potentials of an individual mitigation action for a given budget year. Sectors will compile all their individual mitigation actions activity and prepare their cumulative achievement report. Similarly, sectors take a corrective measure for weakly achieved mitigation options for future improvement. In general, the GACMO tool helps the country to track its mitigation actions achievement to reach its Updated NDC Targets.

2. Introduction

Climate change poses a global challenge with profound impacts on diverse aspects of the environment and human society. Ethiopia has encountered both climate variability and change, evident in an average annual temperature increase of about 1.3 °C since 1960, with a corresponding rise of 0.28 °C per decade[1]. Spatial and temporal variations in precipitation have also been intensified, highlighting the country's exposure to climate fluctuations. To address these challenges, the Ethiopian government has implemented various policies, strategies and programs aimed at enhancing the country's adaptation capacity and minimizing the impacts of climate variability and change. To fight against climate change, the country has developed a Climate Resilient Green Economy (CRGE) strategy on four pillars such as agriculture, forestry, renewable energy and advanced technologies. The country has been trying to integrate climate change adaptation and mitigation actions into its development plans and strategies. Accordingly, the government has passed multiple legislation and decisions on cooperating with the international community in climate actions and signed the Paris Agreement in 2015 to take actions to for the global target of controlling the global average temperature rise to less than 2 °C.

[1] *Kobe, F. T. (2024). UNDERSTANDING CLIMATE CHANGE IN ETHIOPIA : IMPACTS AND. January. https://doi.org/10.1142/S2630534823300014*

After signing the Paris Agreement[2], Ethiopia submitted its Intended Nationally Determined Contribution (INDC) in 2015 and first NDC in 2017. The NDC focused on four pillars to mitigate GHG emissions: (1) improving crop and livestock production practices for higher food security and farmer income while reducing emissions; (2) protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks; (3) expanding electricity generation from renewable sources of energy for domestic and regional markets; and (4) leapfrogging to modern and energy-efficient technologies in transport, industrial sectors, and buildings. In July 2021, Ethiopia submitted an updated NDC, raising its mitigation target for 2030 from 64% to 64.8%[3]. The updated NDC is integrated in Ethiopia's Ten-Year Development Plan published in June 2020, and forms the basis of updating its core climate strategy (CRGE) from 2011. The update NDC includes conditional and unconditional mitigation activities with its specific actions. In addition, it contains cost-benefit analysis of specific actions. Many of the initiatives offer positive returns on investments, thus directly promoting the development of a climate change resilient green economy (CRGE). The update NDC includes quantitative targets of the potential emissions of individual actions from all sectors.

Despite of all these efforts to comply with the Paris Agreement, Ethiopia has not identified and developed methods and tools to systematically track the achievement of its emission reduction targets at a given period. The country lacks a tool to properly measure its achievement of each mitigation action target in its NDC. Hence, the Ethiopia government in collaboration with the Initiative for Climate Action Transparency (ICAT) has developed this GACMO tool enhanced tracking framework.

3. Objectives

The aim of this tracking document is to develop a new robust, more accurate and reliable mitigation actions progress tracking system based of Greenhouse Gas Abatement Cost (GACMO) model.

4. Methodology

The team applied the following approaches and methodologies in the work. The first approach is reviewing published articles, strategic and online documentations. They collected secondary data pertaining strategic documents of various ministries from the official sectoral databases, international organization data platforms and from articles. They also did primary data collection through key informant interview, online Google forms survey and focus group discussion with the sector experts from line ministries. They also performed consultations with such stakeholders as Environmental Protection authority and related line ministries responsible for emission report writing. The national information was collected and provided to the international experts of UNEP-CCC for further analysis on their suitability as inputs to the GACMO tool for NDC tracking. Then in consultation with the UNEP - CCC, the national team developed the initial NDC tracking framework for Ethiopia based on the GACMO. Finally, the UNEP-CCC team gave an in-person capacity building workshop to the national MRV experts of Ethiopia in applying the indicator sets for NDC tracking. This report described the process and results of applying the GACMO tool for assessing and tracking the GHG emission reduction impacts of eighteen mitigation options in Ethiopia's updated NDC and another thirteen options that Ethiopia is implementing but not included in its updated NDC.

[2] The Paris Agreement | UNFCCC

[3] *FDRE EFCCC. (2021). Updated NDC of Ethiopia. Submitted to UNFCCC, 1–48.*

5. Emission reduction targets of Ethiopia's updated NDC

The economic development of Ethiopia will undergo structural change in the coming years. According to the 10YDP of Ethiopia, the base of the economy will be anchored in the manufacturing sector. In addition to this, there will be a high pace of urbanization. Thus, emissions from industry and energy are expected to increase much faster than other sectors (Table 1). Nevertheless, the agricultural sector, particularly livestock, will remain the main contributor to GHG emissions in the coming years, followed by the land use change and forestry (LUCF) sectors. The sectors together will represent 83% (LUCF 35% and livestock 48%) of total BAU emissions in 2030. It is noteworthy that LUCF accounts for emissions from biomass use, e.g., for cooking and baking, which is the single largest driver of LUCF-related emissions. The 2021 updated NDC[4] includes three different GHG reduction scenarios: the business-as-usual (BAU) pathway, unconditional, conditional contributions. Accordingly, the 2030 absolute emission level under the unconditional approach will be 347.3 Mt CO2e, with a reduction of 68.8% (-277.7 Mt CO2e) in the combined impacts of the unconditional and conditional pathways. While GHG emission projections in BAU will be 403.5 Mt CO2e in 2030.

Table 1 GHG emission projections in BAU, unconditional and conditional pathways

Sector	BAU emission projection (Mt CO_2e)			Unconditional emission projection (Mt CO_2e)		Conditional emission projection (incl. unconditional) (Mt CO_2e)	
	2020	2025	2030	2025	2030	2025	2030
Industry	5.9	12.7	26.1	12.9	27.3	10.2	22.6
Energy	10.7	14.4	20.0	12.7	14.9	10.4	9.5
LUCF	125.0	133.8	140.2	112.6	91.8	21.4	-99.9
Livestock	146.4	169.5	194.8	168.7	192.9	162.8	180.0
Managed Soils	5.8	8.1	11.0	8.0	10.9	8.0	10.6
Waste	9.1	10.3	11.5	9.4	9.5	6.0	2.9
TOTAL (Mt CO_2e)	302.9	348.8	403.5	324.3	347.3	218.8	125.8

The mitigation potentials are represented at sector level considering all sector-relevant policies and variables as underlying interlinked drivers of emissions, activity level emission reductions are monitored and verified through sectoral MRV systems upon implementation of each activity in the context of the 10YDP. The projected emission reduction potential estimates by sector and pathways are described in detail in Table 2. For example, Emissions in LUCF originate from net changes in the stock of carbon in the country, largely emanated from land conversion and emissions from biomass energy use. The result has shown that Land Use Change and Forestry (LUCF) have the largest mitigation potential as a result of highly ambitious reforestation and forest restoration targets (Table 2). At the same time, LUCF is the second most important driver of emissions under BAU assumptions (Table 1). Policy interventions reduce the emission level in 2030 to -99.9 Mt CO_2e (under the conditional pathway) which turns the entire sector into a significant GHG sink (Table 1). This equals a relative reduction of emissions of 171% (-240.1 Mt CO_2e) compared to BAU emissions in LUCF by 2030. The unconditional pathway foresees a reduction of emission levels to 91.8 Mt CO_2e, which represents a relative reduction of 34.6% of sectoral BAU emissions in 2030 (-48.4 Mt CO_2e) (Table 2). Moreover, the livestock sector exhibits the second most important mitigation abatements. It is also one of the most significant contributors to emission source under BAU assumptions contributing nearly 45% of total base year emissions in 2020 and almost half of the total BAU emissions in 2030. Policy interventions in

[4] *FDRE EFCCC. (2021). Updated NDC of Ethiopia. Submitted to UNFCCC, 1–48*

this sector will reduce the emission level in 2030 to 180 Mt CO_2e in the conditional pathway. The sector has relative reduction of emissions of 7.6% (-14.8 Mt CO_2e) compared to BAU emissions in 2030. The unconditional pathway foresees a reduction of emission levels to 193 Mt CO_2e, which represents a relative reduction of 0.92% of sectoral BAU emissions in 2030 (-1/8 Mt CO_2e) (Table 2).

Table 2 Mitigation potentials by sector and conditionality

Sector	BAU Emission Projection (Without Mitigation options) (Mt CO_2e)		Unconditional Emission Reduction Projection (Mt CO_2e)		Conditional Emission Reduction Projection (incl. unconditional) (Mt CO_2e)	
	2025	2030	2025	2030	2025	2030
Industry	12.7	26.1	-0.2	-1.2	2.5	3.5
Energy	14.4	20.0	1.7	5.1	4.0	10.5
LUCF	133.8	140.2	21.2	48.4	112.3	240.1
Livestock	169.5	194.8	0.8	1.8	6.7	14.8
Managed Soils	8.1	11.0	0.0	0.1	0.1	0.3
Waste	10.3	11.5	0.9	2.0	4.3	8.6
TOTAL (Mt CO2e)	348.8	403.5	24.5	56.2	129.9	277.7

6. Model Inputs in Ethiopia's updated NDC tracking system

6.1 Assumption

Basic country information such as existing USD exchange rate to local currency and discount rate was considered to 55.5 ETB and 7.0%, respectively. Baseline data of the country was taken from a 2020 GC country emission and other supplementary information. A start year baseline ppopulation (in thousands) of 120300 and GDP (Current Million USD) of 107660 were considered. In addition, the Ethiopian energy outlook data such as the price of Crude oil, LNG and Coal, respectively to 77.9 US$/bbl, 3.3 US$/MBTU and 147 US$/ton were collected from international Energy agency[5]. In addition, an electricity price of 0.01 US$/kWh was used, and a grid electricity loss was assumed to 37.4%. GACMO tool has used these energy data and generated the Fuel prices for the entire future period & fuel physical-chemical properties (Table 8). A CO_2 mission factor (kg GHG/GJ) utilized for a specific sector of Fuel oil, Diesel oil, Gasoline, Jet fuel, Kerosene, LPG, Natural gas, Coal and Lignite, respectively was about 77.4 ,74.1, 69.3, 71.5, 71.9, 63.1, 56.1, 94.6 and 101.2. In addition, a methene emission factor (kg GHG/GJ) of 0.003 was used for Fuel oil, Diesel oil, Gasoline, Jet fuel and Kerosene, and 0.001 for LPG, Natural gas, Coal and Lignite. Nitrous oxide emission factor from 0.0001 to 0.0006 kg GHG/GJ was utilized to generate the emission data of BAU and mitigation scenario. Moreover, AR4 report (25 Ton CO_2/1 Ton CH_4, 298 Ton CO_2/1 Ton N_2O) global warming potentials of methane and nitrous oxide were used to convert the emission quantity in CO_2eq (Table 3).

[5] https://www.iea.org/articles/ethiopia-energy-outlook

Table 3 Fuel prices for the entire period - GACMO tool output

	LPG	Gasoline	Bioethanol	Jet Fuel	Diesel oil	Biodiesel	Heavy Fuel Oil	Kerosene	Coal	Coke	Petroleum coke	Lignite	Natural Gas
Distillate price/crude oil price (litre/litre)	0.90	1.40		1.40	1.20		0.80	1.40					
Fuel price (US$/litter)	0.44	0.69	0.83	0.69	0.59	1.20	0.39	0.69					
Fuel price (US$/GJ)	17.3	20.4		19.2	16.2		10.0	19.2	5.9	5.9	5.9		3.1
Fuel density (t/m3)	0.54	0.75	0.76	0.80	0.84	0.88	0.98	0.80					(MJ/Nm3)
Fuel calorific value (GJ/t)	47.3	44.8	26.8	44.6	43.3	26.8	40.2	44.8	25.0	28.0	31.0	18.3	39.0

6.2 Growth factors

Ethiopia is one of the Least Developed Countries in the world and is the second-most populous country in Africa with a population of more than 100 million (CSA, 2013). The country has endorsed a climate resilient green economic path since 2010 and has registered dramatic economic growth, with a growth rate averaging 9.2% a year from 2010/11 to 2019/20. This growth rate is high when it is compared to a regional average of 5.4% (PDC, 2021). Also, the high growth rates have been accompanied by structural transformation. This is evidenced by the fact the share of the agricultural sector to GDP decreased to 32.7% in 2019/20 from 45.7 in 2010/11 while the construction and services sectors made up the majority of the growth. The share of the constructions and the service sectors from the total GDP reached as high as 21.1 and 39.5, respectively, in 2019/20. Accordingly, the rate of poverty has declined from 29.6% in 2010/11 to 23.5% in 2019/20[6]. Ethiopia has heavily invested in road and railway infrastructure, industrial parks, universities, and the energy sector over the last decades. The 10YDP aims to build on the enhanced physical infrastructure to promote the industrial sector and achieve successful economic transformation. It envisions increasing the share of the manufacturing from the total GDP from the current level of 6.9% to 17.2% by 2030. The plan also aims to achieve an average economic growth of 10% in the coming ten years.

6.3 Baseline (2020) energy balance for Ethiopia

A total of 328,789 Tera Joule (TJ) fossil fuel energy consumption in Ethiopia was considered in 2020 while projecting the BAU and Mitigation scenario until 2030. The majority of the emission was Transport - domestic air which is about 172,705 TJ. The emission from the household was observed the list among the other energy consuming utilities 3,643 JU. The remaining energy (152,441 TJ) are consumed by a miscellaneous activity of various industries (Table 4).

[6] FDRE Minsitry of Planning and Development. (2021). Ten Years Development Plan: A Pathway to Prosperity. *Ten Years Development Plan: A Pathway to Prosperity*, *2*(ten years d velopment plan.), 86.

Table 4 Ethiopia's Fossil fuel energy balance in TJ, 2020.

Fossil fuel energy balance in TJ	LPG	Gasoline	Jet Fuel	Diesel	HFO	Kerosene and other	Total oil products	Coal	Total energy (fossil)
Unit	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ	TJ
Fossil power plants	-	-	-	-	-	-	-	-	-
Industry - miscellaneous		2,135		9,211	2,512		13,858	138,58	152,441
Transport - road		28,135			109,066		137,201		137,201
Transport - domestic air		35,504					35,504		35,504
Households	377	3,266					3,643		3,643
Total all energy consumption									328,789

6.4 Projected (2030) energy balance for Ethiopia

As summarised in Table 5, by 2030, about 27,435.84 ktoe of energy are expected to be utilized from various sources. The Biggest energy shares will be taken by coal and total oil products 13,984.52 and 13,451.32 ktoe to be utilized by miscellaneous industries and transport sectors. Whereas, LPG and diesel fuel have remained at lowest utilization rate at the 2030. The projected BAU GHG emissions from fuel combustion sectors will be determined accordingly. Whereas, in the projected BAU energy balance, about 16619.24 GWh of electric city energy options are expected to be utilized by various sectors in Ethiopia.

Table 5 BAU projected Fossil fuel energy balance - 2030

ktoe units	Industry - miscellaneous	Transport - road	Transport domestic air	Households	FINAL CONSUMPTION
LPG	-	-	-	13.20	13.20
Gasoline	215.44	1,942.73	2,451.56	114.36	4,724.10
Diesel	929.49	-	-	-	929.49
Fueloil	253.49	7,531.04	-	-	7,784.53
Total oil products	1,398.42	9,473.77	2,451.56	127.57	13,451.32
Coal	13,984.52	-	-	-	13,984.52
Total	15,382.94	9,473.77	2,451.56	127.57	27,435.84

6.5 GHG balances (Baseline, inventory year 2020)

Totally 299,327 $ktCO_2$-equivalents of emission from a fuel combustion and non – fuel combustion sectors in 2020 was considered as baseline. A total emission of 27,232.85 $ktCO_2$-equivalents were recorded in Ethiopia by 2020 and it was utilized as a baseline information to BAU and Mitigation scenario development for 2030. Coal and total oil products have shown the highest GHG emission in 13,109.95 and 14,122.89 $ktCO_2$-equivalents, respectively and will be considered as major emitter in the scenario projected years. Whereas, LPG and diesel fuel has shown the lowest rated GHG emitter in the energy options that have been considered in GACMO tool GHG balance sheet. Whereas 272,094 of $ktCO_2e$ of emission were recorded from various sectors of

non-fuel fuel combustion sources. The total Agriculture (including other land) has taken the biggest of the non-fuel combustion sources which accounts 294,487 $ktCO_2e$ of emissions (Table 07). As a general view, the non-fuel combustion sources contribute the majority of GHG emissions in Ethiopia and this fact is reflected in the GHG and mitigation scenario developments. Forestry reports has shown a net carbon sequestration (Table 7).

Table 6 Baseline GHG balance (ktCO2-equivalents), Inventory Year: 2020

Emitting energy options	**Ton CO_2/Toe (IPCC):**	**Industry - miscellaneous**	**Transport - road**	**Transport - domestic air**	**Households**	**FINAL emission**
LPG	2.64	0	0	0	23.78	23.78
Gasoline	2.90	147.96	1,949.76	2,460.43	226.33	4,784.47
Jet Fuel	2.99	0	0	0	0	0
Diesel	3.10	682.23	0	0	0	682.23
HFO	3.24	194.35	8,438.07	-	-	8,632.42
Kerosene and other	3.01	0	0	0	0	0
Total oil products	-	1,024.53	10,387.83	2,460.43	250.11	14,122.89
Coal	3.96	13,109.95	-	-	-	13,109.95
Lignite	4.24	0	0	0	0	0
Natural Gas	2.35	0	0	0	0	0
Coke	4.53	0	0	0	0	0
Petro-coke	4.20	0	0	0	0	0
Total		14,134.48	10,387.83	2,460.43	250.11	27,232.85

Table 7 non-CO_2 – non fuel combustion source of emission in ktCO2e

Non-CO_2 emissions, non-fuel combustion sectors	**ktCO2e**
CH_4 from energy combustion	10,691
N_2O from energy combustion	2,207
Total Agriculture (including other land)	294,487
Fugitive (CH_4)	1
Forestry	-50,155
Waste - solid	6,387
Waste - liquid	3,949
Industrial processes	4,527
Total non-CO_2 emissions, non-fuel combustion sectors	272,094

6.6 BAU projected GHG balance

In 2030, about 97,228.20 $ktCO_2$ are expected to be emitted in the form of CO_2 from the fuel combustion sectors. The emission of energy options has been characterised by its increase in utilization projected in the BAU energy balances. The emission from the coal and total oil energy options have been shown highest in its $ktCO_2e$ and the least in LPG and diesel energy sources (Table 8). Whereas, about 461,032 $ktCO_2e$ will be emitted from the non-CO_2-non-fuel combustion sectors (Table 9). About 558260.3 $ktCO_2$ emission are to be generated from Ethiopia by 2030.

Table 8 BAU projected GHG emission balances from fuel combustion sector

$ktCO_2$	Industry - miscellaneous	Transport - road	Transport - domestic air	Households	Total emission
LPG	-	-	-	34.86	34.86
Gasoline	625.10	5,636.74	7,113.09	331.82	13,706.76
Jet Fuel	-	-	-	-	-
Diesel	2,882.37	-	-	-	2,882.37
Fuel oil	821.09	24,394.46	-	-	25,215.55
Kerosene and other	-	-	-	-	-
Total oil products	4,328.56	30,031.20	7,113.09	366.68	41,839.53
Coal	55,388.67	-	-	-	55,388.67
Total	**59,717.24**	**30,031.20**	**7,113.09**	**366.68**	**97,228.20**

Table 9 BAU projected GHG emission balances from non-CO2 - non- fuel combustion sector

Non-CO_2 emissions, non-fuel combustion sectors	**$ktCO_2e$**
CH4 from energy combustion	38169.6
N_2O from energy combustion	7879.553
Total Agriculture	415328.2
Enteric fermentation	415328.2
Forestry	-36985.7
Waste - solid	10704.42
Waste - liquid	6809.67
Industrial processes	19126.27
Total non-CO2 emissions, non-fuel combustion sectors	461032.1
Total GHG emission	558260.3

7. Result

7.1 BAU and Mitigation Scenario Emission projections

As summarized in Table 10, the total BAU GHG emissions ($ktCO_2e$) and Total emissions in Mitigation scenario ($ktCO_2e$) are about 404,955 and 375,61, respectively. About 29,344 $ktCO_2e$ of emissions Reduction is achieved from the mitigation Scenario in Table 10. Whereas the emission reduction in the mitigation scenarios were increased with projection years. An increase action of mitigation options will increase the degree of emission reduction with time. In addition, total tCO_2e/capita and tCO_2e/US$ in the BAU scenario were found to 3.2 and 3, respectively. In Table 17, The sectoral contribution to the BAU scenario emissions has shown that industry, power, and transport contributes the greatest shares. Whereas the forestry sector has negative emissions and has net carbon sequestration. It was also observed that the increasing emission trends indicated the increasing emission contribution of all sectors over time.

Table 10 Sectoral split of BAU scenario emissions

$ktCO_2e$/year	2020	2025	2030	2035	2050	% of emission contribution

Total	**299,327**	**404,955**	**558,260**	**711,969**	**1,491,908**	
Power	12,898	24,250	46,049	64,486	179,714	257%
Industry	18,662	38,358	78,844	114,778	354,112	322%
Transport	12,848	21,846	37,144	48,777	110,451	189%
Households	250	303	367	444	788	47%
Agriculture & Fishery	294,487	349,695	415,328	493,280	826,415	41%
Forestry	-50,155	-43,070	-36,986	-31,761	-20,113	-26%
Waste	10,336	13,573	17,514	21,966	40,539	69%

As illustrated in Figure 1, agriculture sector of Ethiopia has shown the highest emission trends from the base year (2020) to 2050. Many of the activities in agriculture sector emits higher amount of greenhouse gasses. In the NDC update, the application of reduced tillage form of agricultural practices and soil management have been selected as mitigation options to reduce the emission from the sector however, in the BAU Scenario there was no specifically applied mitigation actions utilized to reduce the emissions. Hence, by 2030, the emissions share of agriculture reaches to 415,328.00 kt CO_2 eq./year and to 826, 415.00 ktCO_2 eq. /year by 2050.

In BAU mode, industry such as heavy energy intensive industries have shown the second emission potentials. In Ethiopia, especially energy intensive industries such as cement, ceramic and metal industries have shown higher emission potentials. By 2030, these industries reach emissions of 114,778.00 kt CO_2 eq./year. Power and transport sectors share medium emission potentials at BAU conditions. By 2030, the emission potential of power sector reaches to 64,486 kt CO_2 eq. /year. Whereas, the transport sector BAU emission level was projected to 17,514.00 ktCO2eq./year. Service sector has shown the lowest emission profile at BAU conditions. Next to service sector, Waste sector in urban sectors has shown relatively the lowest emissions profiles. Potential mitigations measures have been identified and implemented to reduce the emission levels of individual sectors (Figure 1).

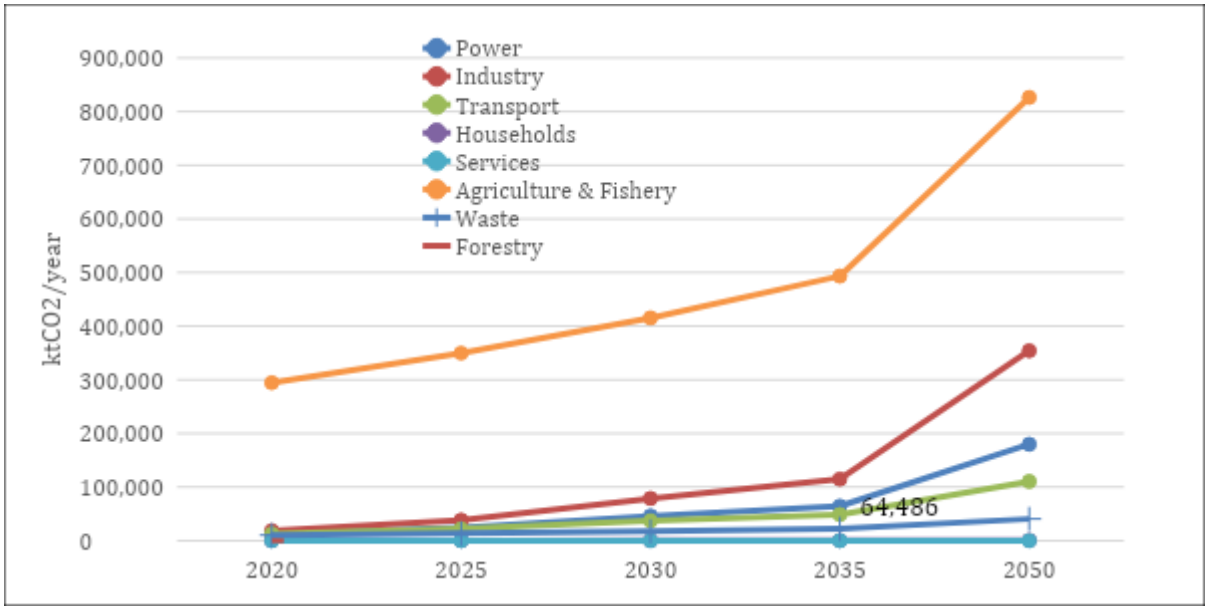

Figure 1 BAU emission from the sectors

Furthermore, the mitigation scenario emissions across sectors are summarised in Table 11. As summarised in Table 10, the BAU scenario emission was about 404,955 and increased to 558,260

(2030), 711,969 (2035) and 1,491,908 (2050). This BAU scenario emission ($ktCO_2$) has been decreased by applying the mitigation actions to 375,611 (2025), 491,707 (2030), 648,482 (2035) and 1,428,422 (2050). In households, highest reduction of emission was observed. Similar to the BAU scenario, forestry sector has shown a sequestration actions.

Table 11 Sectoral split of mitigation scenario emissions

ktCO2e/year	2020	2025	2030	2035	2050
Total	**299,327**	**375,611**	**491,707**	**648,482**	**1,428,422**
Power	12,898	15,252	-160	21,343	136,572
Industry	18,662	38,358	78,844	114,778	354,112
Transport	12,848	17,527	32,827	44,459	106,134
Households	250	-1,080	-1,016	-939	-595
Services	0	0	0	0	0
Agriculture & Fishery	294,487	349,695	415,328	493,280	826,415
Forestry	-50,155	-47,323	-41,239	-36,014	-24,366
Waste	10,336	3,182	7,124	11,575	30,149

7.2 Mitigation Scenario emission reduction

In Table 12, the reduction potentials of mitigation actions from different sectors are summarized. The total emission reduction potential increases from 29,344 ktCO2e in 2025 to 63,553 $ktCO_2e$ in 2030. Sector wise, the biggest reduction potentials are observed power sector rating from 8,999 to 43,143 $ktCO_2e$. Energy or power sectors have employed green energy sources such as hydropower, solar and wind so that it has reduced highest number of emissions from the sources. Whereas household sector's emission reduction projections are smaller than those of the other mitigation actions. The waste sector implements methane collection, flaring, and incineration activities to reduce GHG emissions and has the second biggest annual GHG emission reductions among all sectors.

Table 12 Sectorial split of GHG reduction potential

GHG reduction ($ktCO_2e$/year)	**2020**	**2025**	**2030**	**2035**	**2050**
Total	**0**	**29,344**	**66,553**	**63,487**	**63,487**
Power	0	8,999	46,209	43,143	43,143
Industry	0	0	0	0	0
Transport	0	4,318	4,317	4,317	4,317
Households	0	1,383	1,383	1,383	1,383
Services	0	0	0	0	0
Agriculture & Fishery	0	0	0	0	0
Forestry	0	4,253	4,253	4,253	4,253
Waste	0	10,390	10,390	10,390	10,390

As shown in Figure 2, the Ethiopia's Updated NDC has no potentially implementable mitigation actions in agriculture sector. With implemented mitigation actions the agricultural sector shows the highest emission. Industry has taken the second emitter next to agriculture sector. Whereas, services, waste, transport and power has shown a remarkable emission reduction through its mitigation actions.

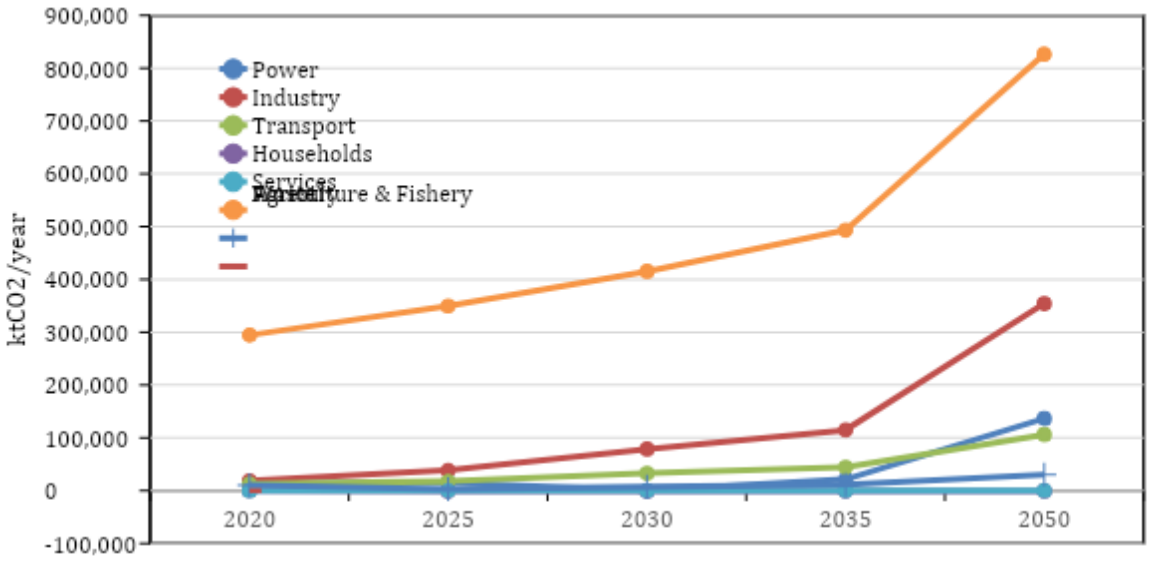

Figure 2 Sectoral splits of mitigation scenario emissions

The implemented mitigation measures in agriculture sectors are weak so that the emission reduction potentials in the sector have become lowest. The emission reduction potentials in power sector and waste sector by 2030 have reached to 46,209 and 10,390.00 ktCO2eq./year, respectively. Many potential mitigation schemes have been employed in these sectors. Whereas, sectors such as households, forestry and services have identified and implemented their own mitigation measures and reduced reasonably (Figure 3).

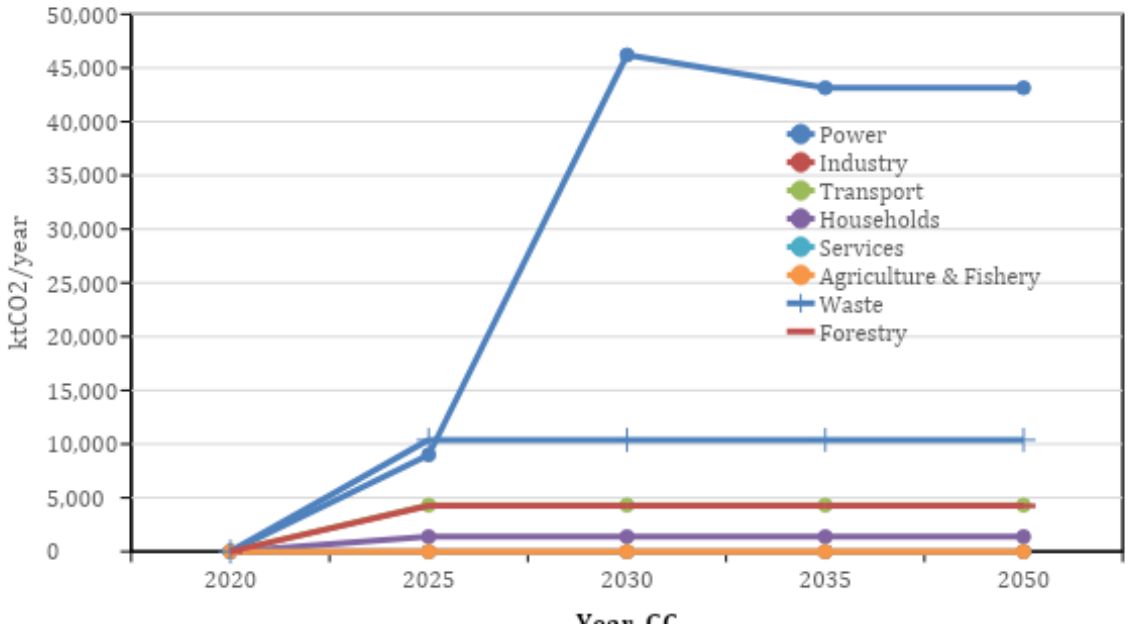

Figure 3 Sectoral split GHG reduction potentials of mitigation actions

7.3 Tracking Progress

The potential mitigation actions considered in Ethiopia's updated NDC are summarised in Table 13. Reduced tillage agricultural practices are being used in the Ethiopian agricultural policy. Upon availability of data the reduced tillage mitigation options implementation and its carbon reduction status will be tracked. Emission management in households is tracked by mitigation

options such as Efficient lighting with CFLs, Efficient wood stoves, Efficient charcoal stoves, LPG stoves replacing wood stoves and Efficient electric stoves. The activity data for this mitigation's actions are provided by the Ministry of Water and Energy especially energy utilization activity data for the households. Similarly, the energy options that serves as baseline and projected scenarios both at business as usual and mitigation options are being provided by the Ministry of Water and energy, coincided with the international energy agency Ethiopian Energy outlook. The diverse energy sources from solar, offshore wind, geothermal and hydropower sources with various quantities are considered. In the forestry sector, both Reforestation and REDD: Avoided deforestation mitigation options are considered in the Ethiopia's updated NDC and are also available in GACMO. The input activity data are enquired from the Ministry of Agriculture and Ethiopian Forestry Development. Global forest watch online platform has also providing such activity data. In the Transport sector, electrification of fossil fuel cars and utilization or shift of mass transport to train are major mitigation options are utilized as mitigation options. Ministry of transport has provided the baseline data for the projection and will provide the activity data for the future tracking duties. In the landfill gas management, composting, biogas recovery, flaring and incineration plays a major role in GHG reductions. The Ministry of Urban and Infrastructure has compiled the information on amount methane collected and flared, amount of compost produced, incinerated and disposed. The activity data to be collected from the ministry of urban and infrastructure will help to track the achievement of these landfill gas management mitigation actions.

Table 13 Tracking system of the Ethiopian NDC Update (2024 -2030)

Type	Reduction option	Sub-type unit	2025 plan	2030 plan	2035 plan	2050 plan	Total planned by 2030	2020 Base year	2021 Actual	2022 Actual	2023 Actual	2024 Actual	2025 Actual	2026 Actual	2027 Actual	2028 Actual	2029 Actual	2030 Actual	2031 Actual	2032 Actual	2033 Actual	2034 Actual	2035 Actual	Accumulated	Progression towards 2030	kt/CO2e/yr.	Million US$	Comments
Agriculture	Zero tillage	1000 ha	0	0	0	0	0																	0		0			
EE households	Efficient residential air-conditioning	1000 Air conditioners	0	0	0	0	0																	0		0			
	Efficient lighting with CFLs	1000 Bulps	350	350	350	350	350																	0	0%	0			
	Efficient lighting with LEDs	1000 Bulps	0	0	0	0	0																	0		0			
	Efficient lighting with LEDs replacing CFL	1000 Bulps	0	0	0	0	0																	0		0			
	Efficient wood stoves	1000 stoves	1,000	1,000	1,000	1,000	1,000																	0	0%	0			
	Efficient charcoal stoves	1000 stoves	14	14	14	14	14																	0	0%	0			
	LPG stoves replacing wood stoves	1000 stoves	5	5	5	5	5																	0	0%	0			
	Efficient electric stoves	1000 stoves	65	65	65	65	65																	0	0%	0			
	Induction based cooking	1000 stoves	0	0	0	0	0																	0		0			
Forestry	Reforestation	Reforestation of 1000 ha	500	500	500	500	500																	0	0%	0			
	REDD: Avoided deforestation	Avoided deforestation 1000 ha	660	660	660	660	660																	0	0%	0			
	Assisted forest regeneration	Reforestation of 1000 ha	0	0	0	0	0																	0		0			

Type	Reduction option	Sub-type unit	2025 plan	2030 plan	2035 plan	2050 plan	Total planned by 2030	2020 Base year	2021 Actual	2022 Actual	2023 Actual	2024 Actual	2025 Actual	2026 Actual	2027 Actual	2028 Actual	2029 Actual	2030 Actual	2031 Actual	2032 Actual	2033 Actual	2034 Actual	2035 Actual	Accumulated	Progression towards 2030	kt/CO2e/yr.	Million US$	Comments
Geothermal	Geothermal power	1 MW	228	1,000	0	0	1,000																	0	0%	0		
	Geothermal heat		0	0	0	0	0																	0		0		
Hydro	Hydro power connected to main grid	1 MW	3,881	22,000	22,000	22,000	22,000																	0	0%	0		
	Mini hydro power connected to main grid	1 MW	0	0	0	0	0																	0		0		
	Mini hydro power off grid	1 MW	0	0	0	0	0																	0		0		
Landfills	Landfill gas plant with power production	200 t/day plant	0	0	0	0	0																	0		0		
	Landfill gas flaring	200 t/day plant	11	11	11	11	11																	0	0%	0		
	Incineration plant	200 t/day plant	7	7	7	7	7																	0	0%	0		
	Recycling of plastics	1000 t/year plant	7	7	7	7	7																	0	0%	0		
	Refuse Derived Fule (RDF) from MSW	1000 t MSW/day	0	0	0	0	0																	0		0		
	Biogas from Municipal Solid Waste	200 t MSW/day plant	438	438	438	438	438																	0	0%	0		
	Composting of Municipal Solid Waste	1000 t/day plant	0	0	0	0	0																	0	0%	0		
Solar	Solar water heater, residential	1000 locations	0	0	0	0	0																	0		0		

Type	Reduction option	Sub-type unit	2025 plan	2030 plan	2035 plan	2050 plan	Total planned by 2030	2020 Base year	2021 Actual	2022 Actual	2023 Actual	2024 Actual	2025 Actual	2026 Actual	2027 Actual	2028 Actual	2029 Actual	2030 Actual	2031 Actual	2032 Actual	2033 Actual	2034 Actual	2035 Actual	Accumulated	Progression towards 2030	kt/CO2e/yr.	Million US$	Comments
	Solar water heater, large	1 unit	0	0	0	0	0																	0		0		
	Solar PVs, large grid	1 MW	342	342	342	342	342																	0	0%	0		
	Solar PVs, large grid with 24h storage	1 MW	0	0	0	0	0																	0		0		
	Solar LED lamps	1000 lamps	0	0	0	0	0																	0		0		
	Solar PVs, small isolated grid, 100% solar	2 MW					0																	0		0		
	Solar street lights	1000 locations (0.05 MW)	0	0	0	0	0																	0		0		
	Parabolic through CSP, no storage	1 MW	0	0	0	0	0																	0		0		
Transport	5%-20% Biodiesel blend in all diesel	5%-20% blend in transport	0	0	0	0	0																	0		0		
	15% Bioethanol blend in all gasoline	15% blend in transport	0	0	0	0	0																	0		0		
	Bus Rapid Transit (BRT)	1 km BRT line	32	32	32	32	32																	0	0%	0		
	More efficient gasoline cars	1000 cars	0	0	0	0	0																	0		0		
	More efficient diesel cars	1000 cars	0	0	0	0	0																	0		0		
	Natural Gas cars	1000 cars using natural gas	0	0	0	0	0																	0		0		
	Electric cars	1000 cars	17	17	17	17	17																	0	0%	0		
	Electric 18m buses	1000 buses	0	0	0	0	0																	0		0		

Type	Reduction option	Sub-type unit	2025 plan	2030 plan	2035 plan	2050 plan	Total planned by 2030	2020 Base year	2021 Actual	2022 Actual	2023 Actual	2024 Actual	2025 Actual	2026 Actual	2027 Actual	2028 Actual	2029 Actual	2030 Actual	2031 Actual	2032 Actual	2033 Actual	2034 Actual	2035 Actual	Accumulated	Progression towards 2030	kt/CO2e/yr.	Million US$	Comments
	Electric 12m buses	1000 buses	0	0	0	0	0																	0		0		
	Electric heavy trucks	1000 trucks	0	0	0	0	0																	0		0		
	Electric light trucks	1000 trucks	0	0	0	0	0																	0		0		
	Electric rail	1 million train/day	949	949	949	949	949																	0	0%	0		
	Shifting passengers from car to rail (1Mill. Person.km/day)	1 million person/day	0	0	0	0	0																	0		0		
	Shifting freight transport from road to rail (1000 tonkm/day)	1000 tonkm/day	3,843	3,843	3,843	3,843	3,843																	0	0%	0		
	Restriction on import of used cars	1000 cars	0	0	0	0	0																	0		0		
	New bicycle lanes	1 km bicycle lane	20	20	20	20	20																	0	0%	0		
	Electric three-wheelers	1000 three-wheelers	620	620	620	620	620																	0	0%	0		
	Electric two-wheelers	1000 three-wheelers	2	2	2	2	2																	0	0%	0		
	Better maintenance and use of motor bikes	1000 bikes	0	0	0	0	0																	0		0		
Wind	Wind turbines, off-shore	1 MW	342	342	342	342	342																	0	0%	0		

8. Conclusion

GACMO tool helps to track and assess the GHG emission reduction efficiency or performance of an individual mitigation options as per the set of monitoring time. About 31 mitigation options that serve as an emission reduction for Ethiopia are identified, organized and set in the model. The mitigation options were organized in GACMO tool as per their emission source sectors category. The performance or efficiency of an individually implemented mitigation option will be calculated by the model up on collection, approval and insertion of their activity data. The model provides the contribution of an individual mitigation option for meeting the Ethiopia's Updated NDC emission reduction targets. The cumulative effect of mitigation options in a similar sector expresses the reduction potentials in their sector. The model utilizes to evaluate the efficiencies of mitigation actions separately as well as the sectoral achievements to reach the Updated NDC targets. In general, the GACMO model set reported in this report helps Ethiopia to track its mitigation actions achievement to reach the Updated NDC Targets.