ETHIOPIA'S LONG-TERM LOW EMISSION AND CLIMATE RESILIENT DEVELOPMENT STRATEGY (2020-2050)

Foreword

The Federal Democratic Republic of Ethiopia remains committed to an ambitious contribution to the Paris Agreement goals of containing the global average temperature increase below 2^{o}C above preindustrial levels and pursuing efforts to limit temperature increases to 1.5^{o}C. Given the devastating impacts that climate change is already having on our people, environment, and economy, it is imperative that immediate global climate action is taken to increase climate resilience and reduce greenhouse gas (GHG) emissions. Recognizing Ethiopia's national circumstances and capabilities, this long-term low emissions development strategy (LT-LEDS) represents clear progress in ambition with net zero emissions reached by 2050, and also seeks to inspire others to increase their contribution to this collective effort.

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Ethiopia's LT-LEDS is built on its Climate Resilience and Green Economy strategy and the recently submitted Nationally Determined Contributions (NDCs) reported to the United Nations Framework Convention on Climate Change. The strategy will be a key tool, a guiding light, and a fundamental pillar for enhancing and raising ambition in our subsequent NDCs. We have undertaken economy-wide analysis and comprehensive stakeholder engagement to develop the LT-LEDS. These efforts generated a robust evidence base for identifying and prioritizing mitigation and adaptation contributions; establishing intermediate indicators to measure progress toward the targets; and strengthening measurement, reporting, and verification and monitoring and evaluation systems.

Our LT-LEDS has been fully aligned with the 10-Year Development Plan and the updated NDC and provides a suite of sectoral priority interventions that will guide sectors, development partners, development financing institutions, the private sector, and other stakeholders in implementing the activities set out in this document. Further, it has outlined long-term sustainable and resilient economy-wide mitigation pathways up to 2050. Its development was an inclusive process to ensure that the modeled pathways had credible mitigation and adaptation targets and provided synergies with sustainable economic growth.

To limit the global temperature rise to 1.5°C, it is crucial that commitment and action are taken on a global scale. We urge the global community to follow our path in creating a healthy and prosperous future for generations to come by reducing GHG emissions and aiming to achieve net zero emissions by 2050. Ethiopia can achieve this vision only in cooperation with our partners. Therefore, this is a call to action for all stakeholders to join hands and contribute to the realization of this ambitious LT-LEDS.

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Abbreviations

AD	Anaerobic digestion
AFD	French Development Agency
BAU	Business as usual
BRT	Carbon capture and storage
CCS	Bus rapid transit
CRGE	Climate Resilience Green Economy
EE	Executing entity
EFCCC	Environment, Forestry and Climate Change Commission
FIE	Federal implementing entity
FOLU	Forestry and other land use
GEM	Green Economy Model
GoE	Government of Ethiopia
GGSim	Green Growth Simulation Tool
IE	Implementing entity
IEA	International Energy Agency
IPPC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and product use
LDC	Least Developed Country
LFG	Landfill gas
LRT	Light rail transit
LT-LEDS	Long-term low emissions strategy
M&E	Monitoring and evaluation
MEFCC	Ministry of Environment, Forest and Climate Change
MoPD	Ministry of Planning and Development
MoWE	Ministry of Water and Energy
MRV	Measurement, reporting, and verification
MSW	Municipal solid waste
NAP-ETH	National Adaptation Plan
NFSDP	National Forest Sector Development Program
NMT	Nonmotorized transport
NZE	Net-zero emissions
NDC	Nationally Determined Contribution
ODF	Open-defecation free
O&M	Operation and maintenance
RDF	Refuse-derived fuel
RIE	Regional implementing entity
SCC	Social cost of carbon
SDG	Sustainable Development Goal
10YDP	10-Year Development Plan
WWTP	Wastewater treatment plant
W2E	Waste to energy

Executive Summary

Background

As part of the Paris Agreement, countries are encouraged to produce a long-term low emissions development strategy (LT-LEDS) to provide a roadmap for long-term decarbonization and climate resilience, which is particularly useful in the context of Nationally Determined Contributions (NDCs), since these trajectories can then be used as a benchmark for revised and updated NDCs. Underpinning the interim and long-run targets of the LT-LEDS with scientifically sound modeling demonstrates the feasibility of the targets and, in turn, enhances the credibility of the whole LT-LEDS. Using recognized, sector-specific, and open-access models help to build national capacity and expertise needed for updating the LT-LEDS in a transparent and participatory way. Against this background, the current summary note aims to present the main outcomes of the development of the LT-LEDS for Ethiopia.

Ethiopia LT-LEDS process and main activities

The LT-LEDS development process was led by the Ministry of Planning and Development (MoPD), with Global Green Growth Institute (GGGI) providing technical assistance and the AFD providing financial support. The MoPD established an LT-LEDS Steering Committee to provide overall guidance and endorse the process and development of the LT-LEDS. In addition, to ensure that the LT-LEDS enhances ownership, promotes knowledge sharing, and ensures data flow from key stakeholders, seven technical sectoral working groups were established. The working groups consisted of government experts from different line ministries and the Climate Resilience Green Economy (CRGE) Facility, as well as GGGI technical experts, and covered the following sectoral and cross-sectoral thematic areas: energy and transport, forestry, agriculture, waste, industry, macroeconomy, and adaptation.

A series of workshops were also organized as key milestones of the project to engage with stakeholders on the LT-LEDS development process and to solicit feedback to incorporate into the LT-LEDS. Furthermore, the MoPD with the support of GGGI, ensured a wider stakeholder engagement through six national stakeholder consultation and validation workshops and five training and capacity building events.

BAU and national pathways for Ethiopia's net-zero and climate-resilient transition

The development of Ethiopia's net-zero and climate-resilient pathways is based on a series of consultations with the sectoral working groups and MoPD and engagement with relevant stakeholders during the second national stakeholders' consultation and validation workshop. A business-as-usual (BAU) scenario and three net-zero emissions (NZE) scenarios were developed. The BAU scenario constitutes the baseline against which the performance of the NZE scenarios is compared and costs (and benefits) are assessed. The economic growth forecast is aligned with the 10-year economic transformation plan and the longer-term growth strategy. The three decarbonization scenarios show a range of possible trajectories for choosing a pathway for Ethiopia.

In the NDC-aligned scenario, ambition is phased in to achieve the NDC emissions target in 2030, after which ambition is increased by 2035 to achieve NZE by 2050. The maximum ambition scenario envisages the maximum ambition early on, leading to NZE reached around 2032 and remaining below zero after that. In the late action scenario, ambitions are reduced, compared to the other scenarios, and most ambition is implemented in 2040–2050; the NDC 2030 emissions target is missed, but if high ambition is implemented during the last years, the scenario can reach NZE by 2050.

Cost-benefit analysis of the NZE pathways

The implementation of LT-LEDS gives way to many costs and benefits that should be considered in exploring the appropriate pathways towards decarbonizing and climate proofing Ethiopia's economy. Benefits significantly exceed the costs in all scenarios, whereas an overall judgment sees advantages in favor of the NDC-aligned scenario. Avoided costs and added benefits are the main drivers of the net benefits derived from the implementation of low-emission development. In terms of avoided costs, the energy bill is the main contributor. The main added benefits derived from the decarbonization of Ethiopia's economy are total real GDP and additional discretionary spending in the economy generated through job creation. Comparing the cost-benefit analysis of the three scenarios as compared to the BAU scenario, the differences are larger or smaller depending on the metric considered. The maximum ambition scenario yields the highest benefits but also the highest investment and costs. This can be explained by the expectation that technologies mature over time such that decarbonization actions become cheaper over time, thus making early action more expensive. In line with this, the late action scenario is the least cost scenario but also leads to fewer benefits.

Ensuring gender and social inclusion outcomes in LT-LEDS implementation

The LT-LEDS recognizes the role that women, youth, and vulnerable communities play in climate action, and in alignment with national sustainable development policies, LT-LEDS implementation will maximize opportunities for gender and social inclusion outcomes. The LT-LEDS proposes an economic transformation that leads to the creation of economic opportunities and green jobs though paid employment and entrepreneurship. The LT-LEDS acknowledges the principles of just transition to a decarbonized, resilient economy and proposes measures to ensure a more inclusive labor market through establishing a Women and Youth in Green Jobs Program that addresses barriers to accessing economic opportunities. The program will also address the challenges workers face in vulnerable employment and enterprises in informal sectors.

Financing the net-zero and climate-resilient transition

The LT-LEDS presents estimates of investments needed to achieve NZE by mid-century under the three selected scenarios. It estimates the gap between the needed and available investments to meet the net-zero targets and provides recommendations to close the financial gap by describing the financing options associated with costs estimates derived from the Cost Benefit Analysis.


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1. Introduction

1.1 DEFINING THE LONG-TERM LOW EMISSION DEVELOPMENT STRATEGY

Parties to the Paris Agreement have agreed to "strive to formulate and communicate long-term low greenhouse gas emission development strategies," including the long-term goal of limiting global temperature rise to well below 2°C and pursuing efforts to limit warming to 1.5°C.

The 2050 Pathways Platform defines a long-term low emissions development strategy (LT-LEDS) as a pathway "that will help to envision the transition to low carbon economic development integrating the needed institutional, economic, technological and social changes, and the phases to achieve them." As part of the Paris Agreement, countries are encouraged to produce an LT-LEDS to provide a roadmap for long-term decarbonization, which is particularly useful in the context of Nationally Determined Contributions (NDCs), since these trajectories can be used as a benchmark for revised and new NDCs. In addition, in the context of Ethiopia, a highly vulnerable country to climate change and climate variability and impacts, the issue of climate resilience should be part of the long term strategy and planning of the country. Therefore, the LT-LEDS of Ethiopia incorporates climate resilience issues throughout the process and strategy development.

Underpinning the interim and long-run targets of the LT-LEDS with scientifically sound modeling demonstrates the feasibility of the targets and, in turn, enhances the credibility of the whole LT-LEDS. Using recognized, sector-specific, and open-access models helps to build the national capacity and expertise needed for updating the LT-LEDS or for developing long-term strategies for other purposes. At the same time, involving external experts and research institutes to use their know-how and expertise ensures the use of scientifically sound, state-of-the-art-methods. Modeling the impact of the targets in the LT-LEDS on other policy dimensions—including employment, competitiveness, distributional consequences, and air pollution—helps to demonstrate synergies between climate mitigation and adaptation and other policy priorities.

The LT-LEDS are based on a contrast between business-as-usual (BAU) and climate action scenarios with different levels of ambition to indicate which goals Ethiopia can reach by 2050.

1.2 PURPOSE OF THE LT-LEDS FOR ETHIOPIA

The LT-LEDS communicated under the Paris Agreement should aim to provide both a vision and a pathway to guide countries' transitions to a decarbonized, 1.5°C compatible economy, consistent with the achievement of net-zero emissions (NZE) by mid-century and considering national circumstances (2050 Pathways Platform). This vision and pathway can help formulate Ethiopia's aspirations by identifying critical issues, challenges, and opportunities at the intersection of climate action and socioeconomic development objectives.

The LT-LEDS for Ethiopia will serve a critical role in implementing the common objectives under the United Nations Framework Convention on Climate Change (UNFCCC) guidelines and the Paris Agreement. Given Ethiopia's position as a "green champion" and a "green model" country in Africa, building on the pioneering Climate Resilience Green Economy (CRGE) strategy developed in 2011 and the recent launch of the Green Legacy Initiative, an impactful and transformational LT-LEDS will further demonstrate Ethiopia's global leadership in climate action.

The Ethiopia LT-LEDS will play an important role in driving the alignment of Ethiopia's NDC and near-term actions with longer-term Paris Agreement goals. The LT-LEDS also provides a structure for establishing milestones in Ethiopia's NDC. Developing and updating the NDC with an aim to meet the LT-LEDS targets will help distinguish the short-term and long-term measures that Ethiopia can use to achieve its climate ambition and to help direct successive NDCs in being more ambitious.

The LT-LEDS could be a key tool in bridging Ethiopia's sustainable development and climate mitigation and adaptation objectives, following a wholistic long-term planning approach. Furthermore, given that Ethiopia is highly vulnerable to climate change impacts the Ethiopia LT-LEDS can raise the climate adaptation policy agenda and strengthen climate resilience and low emission growth by assessing cost-effective climate mitigation and adaptation measures in an integrated manner. The long-term planning horizon of the LT-LEDS provides an opportunity to consider interactions, synergies, and trade-offs between different sectoral goals, mitigation and adaptation objectives, and national development priorities to ensure that any transformational changes scheduled for implementation will promote sustainable development.

The LT-LEDS outlines the priorities for attracting international and private-sector financing for green, low-carbon, and climate-resilient projects over the near and long term. Further, the LT-LEDS could provide country program guidelines for pipeline development priorities and for the utilization of innovative financial mechanisms for transformational investment identification. The completion of the Ethiopia LT-LEDS could help identify funding sources and innovative financing mechanisms and accelerate the process toward tapping international climate and private finance for the implementation of prioritized climate actions that generate significant development benefits.

The LT-LEDS is an inclusive process that requires coordination among ministries, agencies, and departments to ensure policy harmonization and alignment while considering interactions, synergies, and trade-offs. A fully participatory, cross-sectoral process that engages a broad range of stakeholders at different levels provides the basis and inputs for exploring and developing the most appropriate pathways for each sector and the economy as a whole, boosting understanding between the Government of Ethiopia (GoE) and other stakeholders while enhancing the political and social buy-in needed for implementation and a shared vision. In addition, the LT-LEDS process—through its various stages, including the modeling of different pathways and analysis of relevant sectors—is the right vehicle for enhancing the capacity of government staff and relevant stakeholders and for ensuring wider acceptance and continuity.

Importantly, the longer-term perspective of the LT-LEDS allows for discussions beyond incremental technological substitutions and innovations and considers larger-scale transformational changes. The LT-LEDS could provide evidence-based, long-term planning for decarbonizing, climate proofing, and modernizing key Ethiopian economic sectors while ensuring a just transition and the creation of economic and decent job opportunities.

2. Process and Methodology of Developing Ethiopia's Long-Term Low Emission and Climate Resilient Development Strategy

2.1 PROCESS OF DEVELOPING THE LT-LEDS IN ETHIOPIA

The GoE, through the former Environment, Forestry and Climate Change Commission (EFCCC) and the Ministry of Planning and Development (MoPD), engaged with GGGI and the French Development Agency (AFD) in early 2020 to request support for the development of the LT-LEDS for Ethiopia. The GoE and GGGI jointly developed a timeline and a detailed work plan for the development and completion of the LT-LEDS by COP27 in Sharm El Sheikh, Egypt. The LT-LEDS work plan also included a comprehensive process for engaging with a range of key stakeholders through regular national workshops and consultations, preparing the economy-wide low-emission scenarios, and identifying priority mitigation and adaptation actions and potential financing mechanisms.

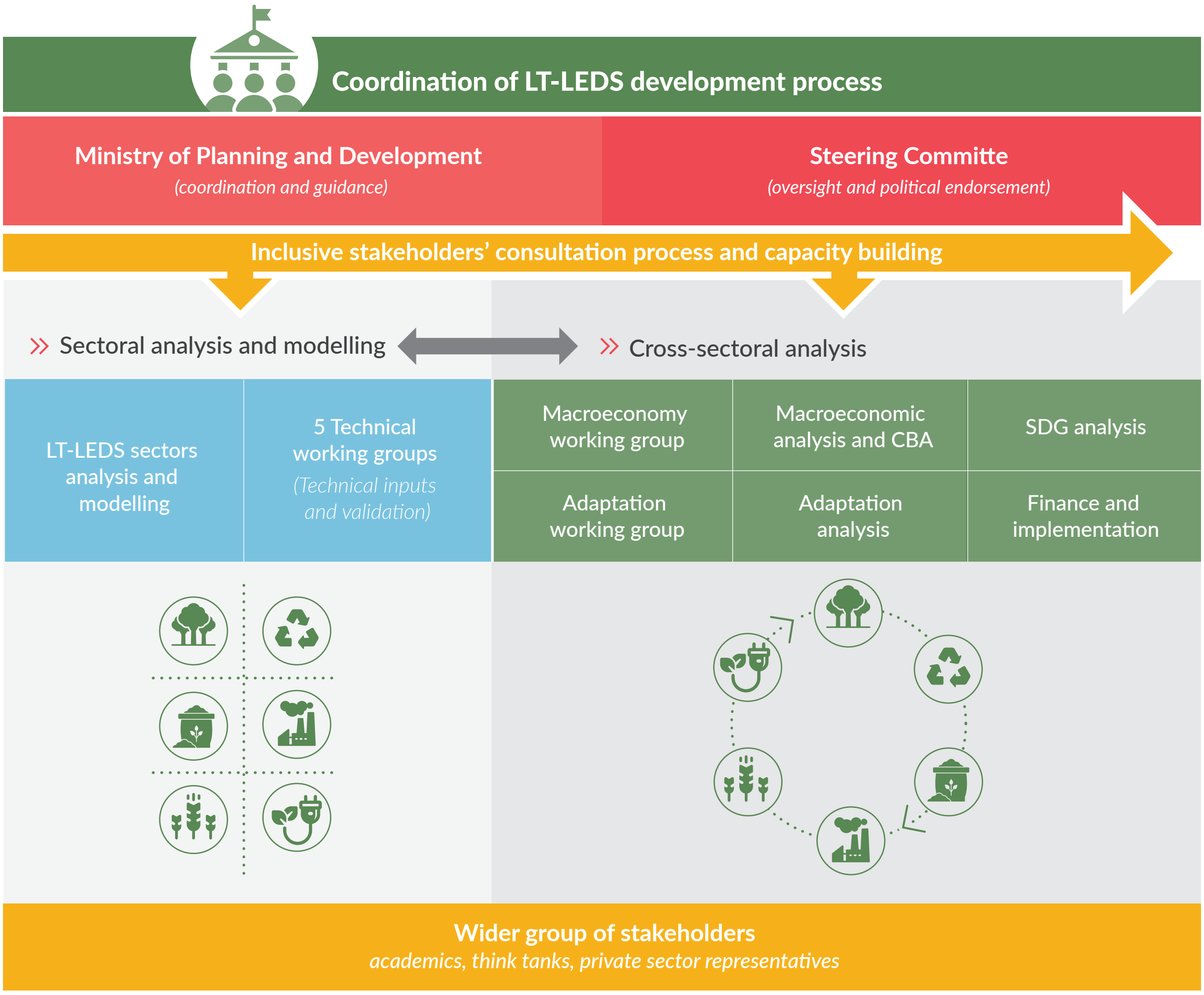
The entire LT-LEDS development process was led by the MoPD, with GGGI providing technical assistance and the AFD providing financial support. The MoPD established an LT-LEDS Steering Committee to provide overall guidance and endorse the process and development of the LT-LEDS. In addition, to ensure that the LT-LEDS enhances ownership, promotes knowledge sharing, and ensures data flow from key stakeholders, eight technical sectoral working groups were established. The working groups consisted of government experts from different line ministries and the CRGE Facility—related to the LT-LEDS sectors and thematic areas—and GGGI technical experts.

The Ethiopia LT-LEDS work plan developed five major activities to guide the development process:

- Activity 1: Organize the LEDS Process: Institutional Arrangements, Coordination, and Multi-Stakeholder Engagement Process (conducted during the entire LT-LEDS development process)
- Activity 2: Assess the Current Situation: Strategies, Policies, Practices, and Capacities (conducted June to December 2021
- Activity 3: Analyze Scenarios – Identify and Analyze BAU and Low Emission Development Scenarios (conducted September 2021 to July 2022)
- Activity 4: Prioritize Actions: Identify Financing and Other Implementation Options and Priorities (conducted May to July 2022)
- Activity 5: Prepare the Ethiopia LT-LEDS Document (conducted June to October 2022)

FIGURE 2.1

Process of developing the LT-LEDS for Ethiopia



The LT-LEDS Steering Committee was established in March 2021 and comprises actors from the former EFCCC, the AFD, GGGI, high-level officials from the CRGE implementing line ministries, the MoPD, academia, and other relevant institutions. Chaired by the MoPD, the committee serves as a high-level advisory group with the objective of guiding the LT-LEDS process and development.

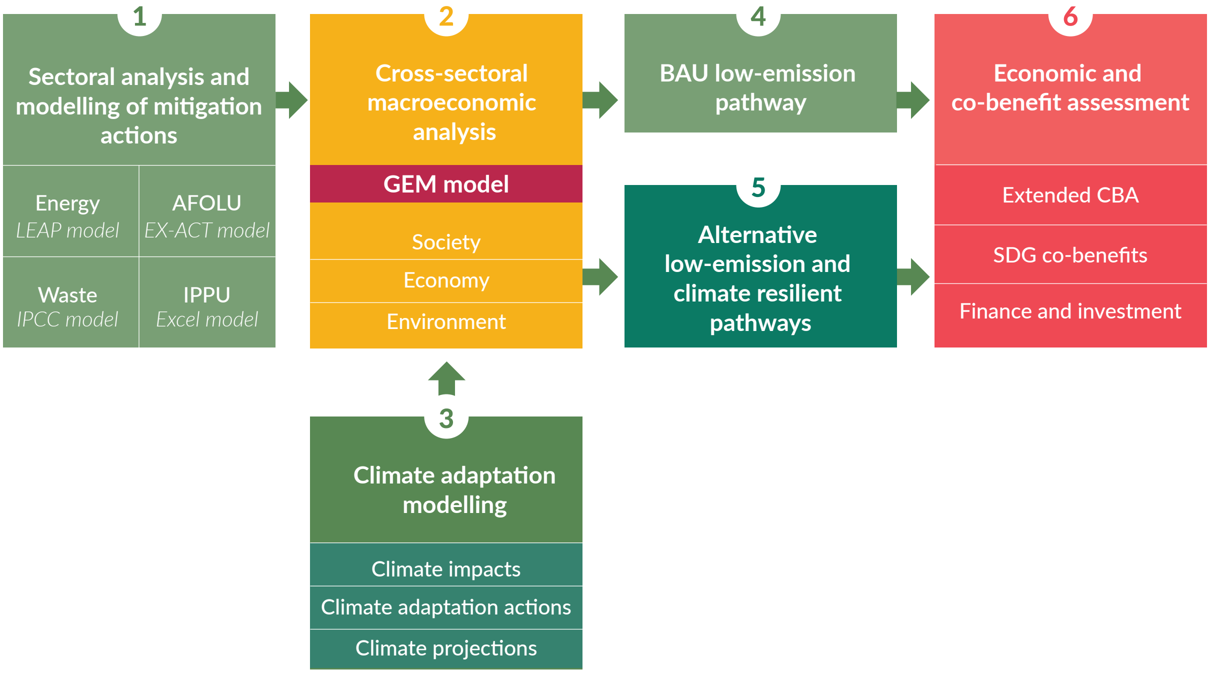
During the kick-off meeting of the Ethiopia LT-LEDS, the MoPD established five sectoral and two cross-sectoral technical working groups to conduct the modeling and analysis of the national and sectoral socioeconomic and emissions pathways while also providing inputs on the level of ambition of the sectoral interventions and technical validation. A total of 32 technical government experts were nominated to work closely with GGGI experts in the seven established working groups that cover the sectors of energy, waste, forestry, agriculture, and industrial processes and product use (IPPU) as well as the cross-sectoral themes of macroeconomy and climate adaptation. The cross-sectoral working groups conducted the analysis and modeling of the national pathways and the climate adaptation analysis, modeling, and integration across the LT-LEDS sectors.

A series of workshops were also organized as key milestones of the project to engage with stakeholders on the development process and to solicit feedback to incorporate into the LT-LEDS. Furthermore, with the support of GGGI, the MoPD ensured a wider stakeholder engagement—including regional bureaus, academia, women, youth, and civil society organizations—through six national stakeholder consultation and validation workshops and five training and capacity-building events. Lastly a wider sectoral stakeholders' "circle" was established, including academia, think tanks, and other relevant government agencies, where regular meetings and calls provided additional feedback and guidance on the development of the sectoral and economy-wide emission pathways while enhancing awareness of the LT-LEDS process. Figure 2.1 illustrates diagrammatically the process for developing the Ethiopia LEDS.

2.2 THE APPROACH AND METHODOLOGY OF DEVELOPING ETHIOPIA'S LT-LEDS

FIGURE 2.2

Integrated methodology of long term pathway analysis



The first step in the analytical approach involves a sectoral analysis facilitated by a set of bottom-up models that consider primary sources and carbon sinks. These models are selected by the working groups based on the understanding of the priority sectors and compatibility with the models already used by the government. The exact bottom-up models used for each sector were the Stockholm Environment Institute's LEAP model and the Green Economy Model (GEM) for the energy sector; the Ex-ACT and NEXT models, both developed by the Food and Agriculture Organization, for the AFOLU sectors; the IPCC Waste Model for the waste sector; and an in-house MS Excel tool for the IPPU sector.

These models are used to derive sectoral BAU trajectories that consider only the current policies, programs, and plans of the government, its partners, civil society, and the private sector as well as the most likely trends for technologies and energy consumption if no external mitigation programs or measures are adopted and applied to reduce GHG emissions. In applying these models, it is ensured that sectoral scenarios are consistent with national development objectives and fully aligned with other processes, such as the NDC and the 10-Year Development Plan (10YDP). Once the sectoral BAU pathways were established, the sectoral working groups identified mitigation and adaptation interventions and their long-term ambition levels, which were then considered in the sectoral models to determine the sectoral low-carbon and climate-resilient development pathway to 2050.

To analyze the achievement of NZE in 2050 and conduct the corresponding environmental, climatic, social, and macroeconomic assessment, GEM was applied. GEM for Ethiopia was originally developed to support the EFCCC and the Planning and Development Commission for the NDC revision process and the development of the 10YDP. As the core model for the assessment of Ethiopia's LT-LEDS, GEM is an integrated assessment model that goes beyond a linear representation of emission changes and incorporates socioeconomic and environmental trends based on system dynamics models to enable simulation of the whole Ethiopian economy and its interactions in terms of emissions. Due to the modular nature of GEM, it can be adjusted to changes in policy and to external shocks, such as the Covid-19 crisis, which strongly influence sectoral growth rates in Ethiopia. the results of the individual sectoral models are input in GEM, in which the sectoral BAU trajectories are replicated and calibrated. In this way, a holistic cross-sectoral macroeconomic assessment can be carried out for the BAU scenario established in the sectoral models.

In a further step, climate data is then introduced into GEM. Using historical data, such as spatially disaggregated precipitation and temperature data, past impacts of climate change on sectoral outcomes are identified and serve as the basis for estimating future impacts in the model. Future climate projections as per the RCP 4.5 and RCP 8.2 scenarios[1] are then incorporated into the model. In the scenarios, climate change impacts are modeled only for the energy and agriculture sectors. The exact approach to modeling climate change impacts in these sectors is explained in more detail in sections 4.2 (energy) and 4.4 (agriculture), whereas all technical specifications of the models used are included in the technical annex.

Once GEM has been calibrated with the sectoral BAU projections, the selected mitigation and adaptation measures are modeled, along with their targets, to derive the low-emission and climate-resilient scenario. For all scenarios, further assessments in terms of an extended cost-benefit analysis and co-benefits of achieving the UN's Sustainable Development Goals (SDGs) are conducted. In addition, thorough finance and investment plans are also derived for all scenarios, emphasizing the conditionality and differentiation of public and private funding.

The approach shown in Figure 2.2 makes Ethiopia's LT-LEDS among the first to fully integrate impacts of climate change in its long-term scenarios. This is an important milestone as climate change adaptation is a critical component of national priority in Ethiopia. The GoE also intends to combine the long-term mitigation and adaptation strategies to better understand the strong synergies and take advantage of them in national planning processes.

Identifying adaptation co-benefits of climate mitigation actions and incorporating this information in the prioritization process is highly valuable, as actions that may have small abatement potential but generate high adaptation benefits can be mainstreamed, which would not have been prioritized otherwise. Furthermore, by identifying adaptation co-benefits of mitigation actions, the chances of maximizing and mobilizing multiple funding opportunities for implementation of these actions are enhanced. In this LT-LEDS, both synergies and trade-offs of mitigation and adaptation actions are identified and validated by each sectoral working group.

1 The applied future climate projects are statistically downscaled from the second-generation Canadian Earth System Model (CanESM2), which was used in CMIP5. Source: https://doi.org/10.1038/s41597-019-0038-1

3.

National Context

3.1 ETHIOPIA'S VISION FOR A LOW-CARBON AND CLIMATE-RESILIENT FUTURE

Ethiopia's commitment to advancing its climate mitigation and adaptation actions has made the country a recognized leader in the low-carbon and climate-resilient development landscape. The GoE has developed the CRGE strategy, which is the backbone of the country's climate policy efforts. The CRGE is an ambitious national blueprint that intends to reduce Ethiopia's GHG emissions by 64%, compared to the BAU scenario, by 2030. The country has also signed the Paris Agreement and is among the first Least Developed Countries (LDCs) to submit an ambitious NDC to the UNFCCC.

Following the call from the Paris Agreement for parties to submit their LT-LEDS, Ethiopia has developed its long-term net-zero and climate-resilient 2050 strategy using a participatory approach. The LT-LEDS will enhance the Ethiopian government's ability to plan for the decarbonization of its economy by providing a framework and pathway for a progressive revision and enhancement of targets under its NDC to reduce CO_2 emissions and enhance climate resilience. The LT-LEDS outlines ambitious scenarios to decarbonize seven priority sectors of Ethiopia's economy by 2050. The scenarios will contribute to making the country's economy more innovative, sustainable, and resilient by leveraging various sustainable development and adaptation co-benefits of mitigation actions. The LT-LEDS is constructed as a living document that evolves with national circumstances, as new or improved data become available, and as improved decarbonization and climate-resilient options emerge.

A'S BRIEF PROFILE

Demography and economy

Ethiopia is the second most populous country in Africa, with a current population of approximately 104.1 million, in 2022, which is expected to surpass 200 million by 2050. Ethiopia has a population growth of about 2.4% annually and is expected to continue growing in the coming decades without reaching a peak. Ethiopia is the fastest-growing economy in the region, with 6.3% growth in 2020. However, it is also one of the poorest, with a per capita gross national income of USD 1218, in 2022. Ethiopia aims to reach lower-middle-income status by 2025.

Over the past 15 years, Ethiopia's economy has been among the fastest growing worldwide, at an average of 9.5% per year. Among other factors, growth was led by capital accumulation, particularly through public infrastructure investments. Ethiopia's real GDP growth decreased in 2020 and further in 2021 due to COVID-19, particularly in industries and services that were mainly affected by the pandemic. However, agriculture, where over 70% of the population is employed, was not significantly affected by the pandemic, and its contribution to growth slightly improved in 2021 compared to the previous year. The government has recently launched a new 10-Year Development Plan (10YDP) that aims to sustain the remarkable economic growth of the previous decade while facilitating the shift toward a more private-sector-driven, competitive, and resource-efficient economy.

Key challenges for development

Ethiopia faces several key challenges that hinder its economic development. The incidence of conflict has increased, particularly in the north since November 2020, leading to substantial impacts on lives, livelihoods, and infrastructure. Additionally, Ethiopia's Human Development Index is at a low 0.38, indicating that special attention and investments are needed to boost education and health services to an adequate level and tap the full potential of the Ethiopian people. Further, the country's young and growing workforce (at around 2 million per year) presents an opportunity but also strains the absorption capacity of the labor market, necessitating the creation of sufficient new and decent jobs to capitalize on its potential. Lastly, frequent extreme weather events, alongside long-term impacts of climate change, undermine agriculture and pastoral livelihoods and food security. The 2022 drought was the worst in 40 years, severely affecting 7 million people in southern and eastern parts of the country—disproportionally impacting women, who are mainly responsible for food production and domestic care roles.

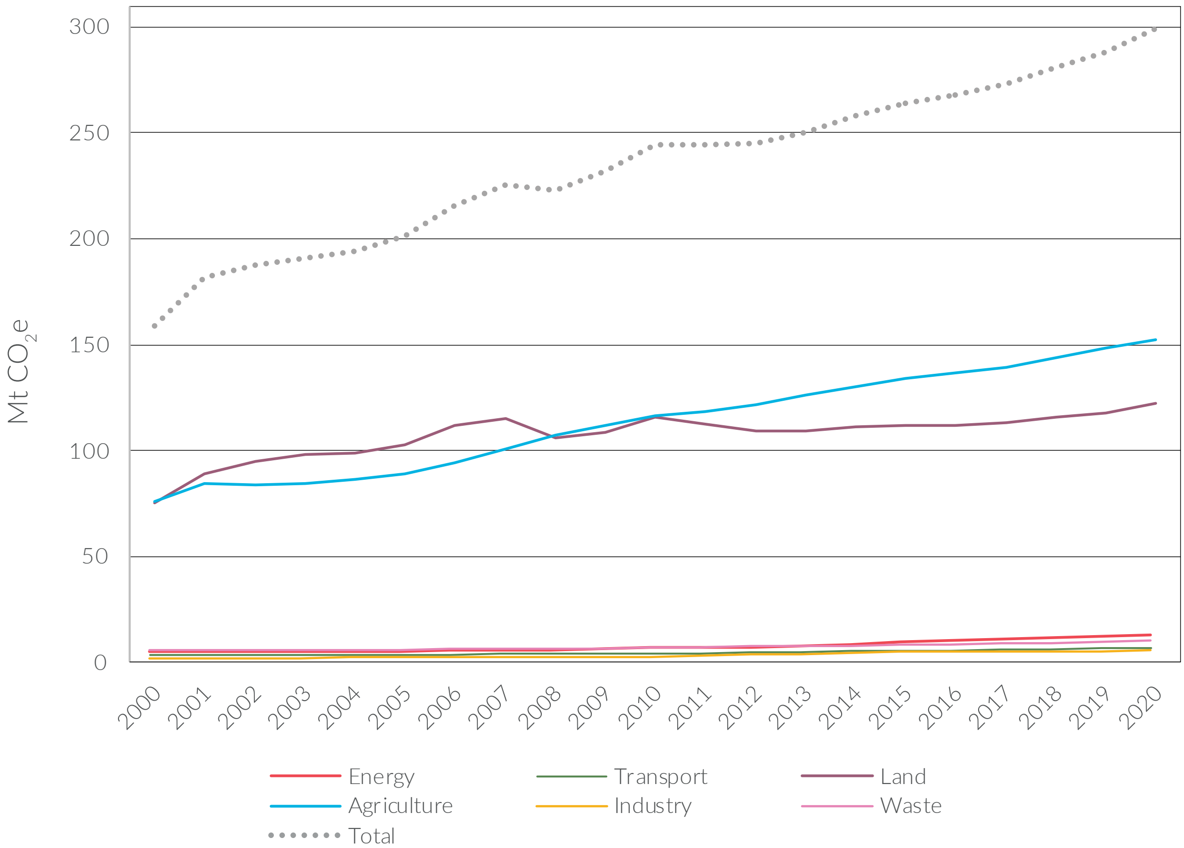
Main climate impacts

Ethiopia is one of the most vulnerable countries to climate variability and climate change due to its high dependence on rainfed agriculture and natural resources and its relatively low adaptive capacity to deal with these expected changes. Challenges include the underdevelopment of water resources, low health service coverage, a high population growth rate, low economic development, inadequate road infrastructure in drought-prone areas, weak institutional structures, and a lack of awareness. Ethiopia has frequently experienced extreme events, like droughts and floods, in addition to rainfall variability and increasing temperatures, which contribute to adverse impacts on livelihoods. Primary environmental problems are soil erosion, deforestation, recurrent droughts, desertification, land degradation, and loss of biodiversity and wildlife. Given the nation's vulnerability to climate change impacts, there is a pressing need for climate change adaptation across all sectors.

3.3 ETHIOPIA'S GHG INVENTORY

FIGURE 3.1

Total and sectoral annual emissions in Mt CO_2e, 2000–2020



Ethiopia has had two decades of strong growth in carbon emissions. As Figure 3.1 and Table 3.1 show, since the beginning of the century, emissions have nearly doubled from 160 Mt CO_2e to 300 Mt CO_2e in 2020. If unabated, the steep rise is expected to continue as the GoE seeks to maintain the country's impressive economic growth performance while the population is expected to increase to about 200 million people in 2050, according to the UN (CITE).

The agriculture sector, including emissions from livestock and managed soils, has the highest emissions (Figure 3.1), contributing about half of all emissions in 2020. Ethiopia's strong reliance on agriculture features a steady increase of livestock in line with population growth, notably since a significant share of the population lives in pastoralist communities. Land use, particularly deforestation and land degradation, is responsible for almost all remaining emissions beyond agriculture. Although emission growth from lands has slowed significantly since about 2007, there is a constant annual loss of carbon stock in the form of biomass, hence the continued deforestation and land degradation.

The remaining sectors—energy, transport (being a subsector of energy), IPPU, and waste—together only contribute about 8% of total emissions. This can be partly explained by the fact that emissions from burning biomass, as a category of energy consumption, are attributed to emissions from land. Moreover, with the transformation of Ethiopia's economy envisaged by the 10YDP, until 2030 and also beyond, emissions in the IPPU sector are expected to substantially increase as economic activity shifts from agriculture and land-based activities to manufacturing.

TABLE 3.1
Total and sectoral annual emissions in Mt CO_2e, 2000–2020

	2000		2005		2010		2015		2020	
Total	159	100%	201	100%	244	100%	264	100%	299	100%
Energy	4	3%	4	2%	5	2%	8	3%	11	4%
Transport	2	1%	2	1%	3	1%	4	2%	5	2%
Energy w/o transport	2	1%	2	1%	2	1%	4	2%	6	2%
Land	75	47%	103	51%	116	48%	112	42%	122	41%
Agriculture	76	48%	89	44%	116	48%	134	51%	152	51%
Industry	0	0%	1	0%	1	0%	3	1%	4	1%
Waste	4	3%	5	2%	5	2%	7	3%	9	3%

3.4 DESCRIPTION OF RELEVANT CLIMATE POLICY, LEGAL AND INSTITUTIONAL FRAMEWORKS

Ethiopia's economic and climate policies are based on several strategy documents and institutional frameworks at the national level as well as, in more detail, in each sector.

The **Ten-Year Development Plan: A Pathway to Prosperity 2021–2030 (10YDP)** sets a long-term vision of making Ethiopia an "African Beacon of Prosperity," which will be brought about through the following objectives:

> Building a prosperous country by creating a pragmatic market-based economic system and enhancing the role and participation of the private sectors.

> Maintaining macroeconomic stability, ensuring rapid and sustainable economic growth, and creating decent jobs.

> Ensuring structural economic transformation by promoting overall productivity and competitiveness.

> Creating an enabling environment where every citizen will become an owner and beneficiary of the development endeavor by ensuring the quality and accessibility of basic social services and the provision of infrastructure.

> Ensuring a competent, independent, and quality civil service system by building the capacity of the government and establishing good governance.

> Building strong and inclusive institutions to ensure a peaceful society and access to justice and to uphold the rule of law and human rights.

The 10YDP inevitably concerns all sectors where the LT-LEDS sets emission reduction targets. For instance, the plan focuses on the fight against land degradation, pollution reduction, forest protection, and green urban development. Likewise, by increasing the economy's productivity, it aims at increasing the policy space to make GHG emission reductions affordable. However, the plan's targets have significant implications for climate change, such as the intended increase in fertilizer application in agriculture.

The **Climate Resilient Green Economy (CRGE) strategy** was launched in 2011 to foster a climate-resilient and middle-income green economy by 2025. It demonstrates Ethiopia's commitment to bypassing a conventional economic development approach by creating a green economy where economic development goals are met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in a sustainable way (SDG Knowledge Platform, 2011). The strategy identifies four pillars of development in the green economic action plan:

- Improve crop and livestock production practices for higher food security and farmer income while reducing emissions.
- Protect and reestablish forests for their economic and ecosystem services, including as carbon stocks.
- Expand electricity generation from renewable energy sources for domestic and regional markets.
- Leapfrog to modern and energy-efficient technologies in transport, industrial sectors, and buildings.

In 2017, the launch of Ethiopia's National Adaptation Plan (NAP-ETH) provided an overarching framework to minimize the vulnerability of key economic sectors—agriculture, forestry, health, transport, energy (power), industry, water, and urban—to the impacts of climate change by developing adaptive capacity and resilience.

Furthermore, the NAP Implementation Roadmap of 2019 expanded the options outlined in NAP-ETH with actions, which were categorized into short-term priorities (e.g., capacity building, strengthening the enabling environment, and promoting research) for 2020–2022, and long-term priorities (with sector-specific activities) for 2025–2030. For effective implementation of NAP-ETH, the government developed further strategies, including gender analyses for NAP-ETH, the NAP-ETH Resource Mobilization Strategy, and the M&E technical working paper for NAP. A full list of climate- and environment-related strategies, policies, and programs, including the national communications, are provided in the technical annex.

In 2015, as a signatory to the Paris Agreement, Ethiopia formulated an NDC, which was updated in 2021 through improved modeling and new data. Ethiopia pledged to limit its annual net emissions to 126 Mt CO_2e or lower by 2030, which would constitute a 278 Mt CO_2e (or 69%) reduction from the BAU scenario of 403 Mt CO_2e. The country has committed to achieving 20% of this scenario out of its own financial resources (unconditional scenario), whereas it requests international financial support to achieve the other 80% (conditional scenario). Table 3.2 gives an overview of the emission reduction ambitions and the policy actions in each sector.

TABLE 3.2
Ambitions and policy actions in the updated NDC 2021

Sector	Unconditional	Conditional	Actions
LUCF	-48.4 Mt CO_2e (-35%)	-240.1 Mt CO_2e (-171%)	> Sustainable agricultural land management practices > Reduction in preharvest losses > Carbon sequestration in grasslands > Lowlands Livelihood Resilience Project > Fuel switch and biomass efficiency (improved cookstoves) > Reforestation > Landscape restoration
Livestock	-1.9 Mt CO_2e (-1%)	-14.8 Mt CO_2e (-8%)	> Enhancement of livestock productivity > Agricultural mechanization > Increase in the share of poultry > Oilseed feeding to reduce emissions from enteric fermentation
Energy	-5.1 Mt CO_2e (-26%)	-10.5 Mt CO_2e (-53%)	> Energy efficiency > Transport electrification > Public transport expansion > Industry fuel switch
Managed soils	-0.1 Mt CO_2e (-1%)	-0.4 Mt CO_2e (-4%)	> Use of organic fertilizer and crop residues
Industry	1.2 Mt CO_2e (+5%)	-3.5 Mt CO_2e (-13%)	> Clinker substitution in cement
Waste	-2 Mt CO_2e (-17%)	-8.6 Mt CO_2e (-75%)	> Reduction of waste per capita > Waste separation and composting > Wastewater management
Total	**-56.2 Mt CO_2e (-14%)**	**-277.7 Mt CO_2e (-69%)**	

Source: FDRE (2021), Updated NDC

While the first NDC incorporated only a few climate adaptation interventions under three pillars (i.e., drought, flood, and cross-cutting interventions), the updated NDC included a selection of over 50 climate adaptation actions from the NAP Implementation Roadmap, which were prioritized by cross-referencing the 10YDP, the NAP-ETH, and other relevant sectoral climate resilience or adaptation strategies.

3.5 MAIN DEVELOPMENT OBJECTIVES

The following table gives an overview of Ethiopia's main economic development objective as well as strategic objectives relevant for LT-LEDS.

TABLE 3.3
Ethiopia's main development objectives

Area	Target						Source
Economy							
Economic growth until 2030		Total GDP	Agriculture	Industry	Manufacturing	Services	10YDP
	Annual growth	10%	6.2%	13%	20.6%	10.6%	
	Targeted share in GDP		22%	35.9%	17.2%	42.1%	
Per capita income by 2030	USD 2,220 (+8.5% annually)						10YDP
Forestry							
Prevention of forest degradation	USD 2,220 (+8.5% annually) Use of efficient cooking technologies (total abatement potential 50 Mt CO_2e)						CRGE
Carbon sequestration by 2030	Afforestation and management of 7 million ha (total abatement potential 42 Mt CO_2e)						CRGE
Forest cover by 2030	From 15.5% to 30% of country area						10YDP
Wildlife habitats	From 8.6% to 14% of country area						10YDP
Timber production	Private and community plantations on 15 million ha of degraded land to reduce pressure on nature forest						REDD+ Strategy

TABLE 3.3

Ethiopia's main development objectives (cont.)

Area	Target	Source
	Agriculture	
Output targets by 2030	> Crop production: 92.5 million tons/year (+70%) > Milk production: 11.8 billion liters/year (+170%) > Chicken meat production: 0.1 million tons/year (+121%) > Egg production: 5.5 billion tons/year (+96%) > Pesticide use: 5.5 million liters/year (+12%) > Fertilizer use: 3.3 million tons/year (+106%)	10YDP
Output targets by 2030	> Expand irrigation-based agriculture > Promote nutrition-sensitive agriculture > Foster adoption of integrated soil fertility management practices > Enhance the productivity of livestock > Widely promote perennial crops, such as fruits and coffee > Promote research-based food security systems > Enhance agricultural production to boost agricultural export revenues and substitute imports > Improve private sector participation > Promote restoration of degraded agricultural land > Improve the supply of agricultural inputs and finance > Expand agricultural mechanization	10YDP and MoA

TABLE 3.3
Ethiopia's main development objectives (cont.)

Area	Target	Source
Energy		
Electricity shares by 2040	> 55% hydropower > 45% solar PV, geothermal, and others	NEP
Citizens' electricity access	> 2025: 65% on-grid and 35% off-grid > 2030: 96% on-grid and 4% off-grid	NEP
Electricity targets by 2030	> Electricity generation capacity: 19,900 MW (+344%) > Electricity transmission lines: 29,900 km (+62%) > Energy exports: 7,184 GWh (+156%) > Electricity customers: 24.3 million (+319%) > Grid-connected customers: 96% (+191%) > Off-grid customers: 4% (-64%) > Energy loss: 12.5% (-36%)	10YDP
Transport		
Railway network by 2030	+3,297 km (+366%)	10YDP
Transport service coverage by 2030	> Increase rural transport service coverage from 67% to 100% > Increase urban mass transport services from 34% to 70%	10YDP
Bus transport by 2035	Expand bus routes and increase the number of buses by 89,680	NTP
Electrification of vehicle fleet by 2030	Increase electric vehicle infrastructure by 10%	
Vehicle efficiency	Ban on import of used vehicles by 2030	

TABLE 3.3

Ethiopia's main development objectives (cont.)

Area	Target	Source
	IPPU	
Manufacturing industry targets by 2030	> Increase the average manufacturing industry capacity utilization from 50% to 85% > Raise the domestic market share of locally manufactured industrial products from 30% to 60% > Raise the competitiveness of the manufacturing industry > Raise the number of small- and medium-scale manufacturing enterprises from 2,000 to 11,000 > Create 5 million new jobs in the manufacturing industry	10YDP
	Waste	
Waste management in urban areas by 2030	> Raise the coverage of liquid waste removal from 1% to 50% > Raise dry waste removal from 30% to 80%	10YDP

4.

Ethiopia's Long-Term Net-Zero Emission and Climate-Resilient Development Pathways

4.1 NATIONAL NET-ZERO AND CLIMATE-RESILIENT DEVELOPMENT PATHWAYS

The development of Ethiopia's net-zero and climate-resilient pathways is based on a series of consultations with the sectoral working groups and MoPD and engagement with wider stakeholders during the second national stakeholders' consultation and validation workshop. The BAU scenario and three NZE scenarios were selected.

In the LT-LEDS model, the total population is calibrated according to the UN population forecast for Ethiopia. The economic growth forecast is aligned with the 10YDP and the longer-term growth targets. All technical specifications of the GEM model are presented in the technical annex.

Using scenario analysis, the BAU scenario constitutes the baseline against which the performance of the decarbonization scenarios is compared and costs (and benefits) are assessed. In addition to the BAU scenario, three decarbonization scenarios are simulated: the maximum ambition scenario, the NDC-aligned scenario, and the late action scenario. The three net-zero scenarios presented in this chapter provide a variety of decarbonization pathways (early action, medium term, and late action) for the Ethiopian economy.

In the NDC-aligned scenario, ambition is phased in to achieve the NDC emissions target in 2030, after which ambition is increased by 2035 to achieve NZE by 2050. Strengthening the NDC-aligned scenario seems to be the most plausible future in which Ethiopia realizes its NDC pledges and works toward achieving NZE by 2050. The benefit-to-cost ratio projected for this scenario is the highest among the three scenarios assessed, indicating the best proportion of costs to avoided costs and added benefits.

The maximum ambition scenario envisages the maximum ambition early on, leading to NZE around 2035 and remaining below zero after that. The maximum ambition scenario should be regarded as the maximum hypothetical potential for emission reductions if strong ambitions are implemented early on. However, the Cost Benefit Analysis (CBA) presented shows that the implementation of the ambitions envisaged requires much financing for which funding is not secured.

In the late action scenario, ambitions are reduced, compared to the other scenarios, and most ambition is implemented during 2040–2050. In this scenario, the NDC 2030 emissions target is missed, but high ambition implemented during the final years allows the scenario to reach NZE by 2050. The late action scenario analyzes how the trajectory of key indicators changes if the NDC targets cannot be achieved due to global increasing energy prices and inflation induced by the COVID-19 pandemic. Therefore, this scenario illustrates how NZE could be achieved if the fiscal space for early action is not available.

In the BAU scenario, total country CO_2e emissions are projected to increase from 299 Mt in 2020 to around 558.7 Mt by 2050. The BAU scenario hereby does not envisage any additional mitigation or adaptation actions. The development of total country CO_2e emissions is presented in Figure 4.1 for all four scenarios presented.

For the NZE scenarios, the most important actions for reaching the net-zero target while delivering numerous additional socioeconomic benefits are:

I. The creation of a carbon sink in the **land use sector,** particularly through reforestation, afforestation, forest restoration, and reduced deforestation.

II. The **electrification of end-use sectors**—such as transport, residential, commercial, and industry—and replacing fossil fuels combined with expanding renewable power production.

III. The reduction of **livestock**-related emissions using a range of interventions, such as increased productivity of livestock.

In particular, the **energy sector interventions** create synergies in the short, medium, and long run, given that they reduce emissions, unlock additional growth, and create employment at the same time as well as contribute to the achievement of SDGs 7 (affordable clean energy), 8 (decent work and economic growth), and 13 (climate action). Furthermore, **land-based interventions** are highly needed as they create a significant number of green jobs, thus contributing to enhanced reforestation and carbon sinks, an increased provision of ecosystem services, and the achievement of SDGs 8, 13, and 15 (life on land).

Furthermore, additional actions should be implemented in other sectors with high ambition targets constant in all net-zero scenarios:

IV. **Agriculture**-related interventions—such as enhancing sustainable agriculture practices, reducing preharvested losses, expanding perennial crops, and increasing areas under irrigation schemes—modernize Ethiopia's agriculture systems, maintain and increase the number of jobs, provide opportunities for the young rural labor force, and potentially boost agriculture exports.

V. **Waste sector** interventions—such as reducing waste per capita, waste at source, and wastewater emissions as well as significantly increasing the waste collection and recycling rates—provide a better quality of life for the people of Ethiopia, create more local businesses and jobs compared to the BAU scenario, improve the quality of urban areas, and reduce increased flood risk from clogged drainage systems.

VI. **IPPU-related interventions**, such as improving the efficiency of product use and utilizing advanced technologies like carbon capture and storage (CCS).

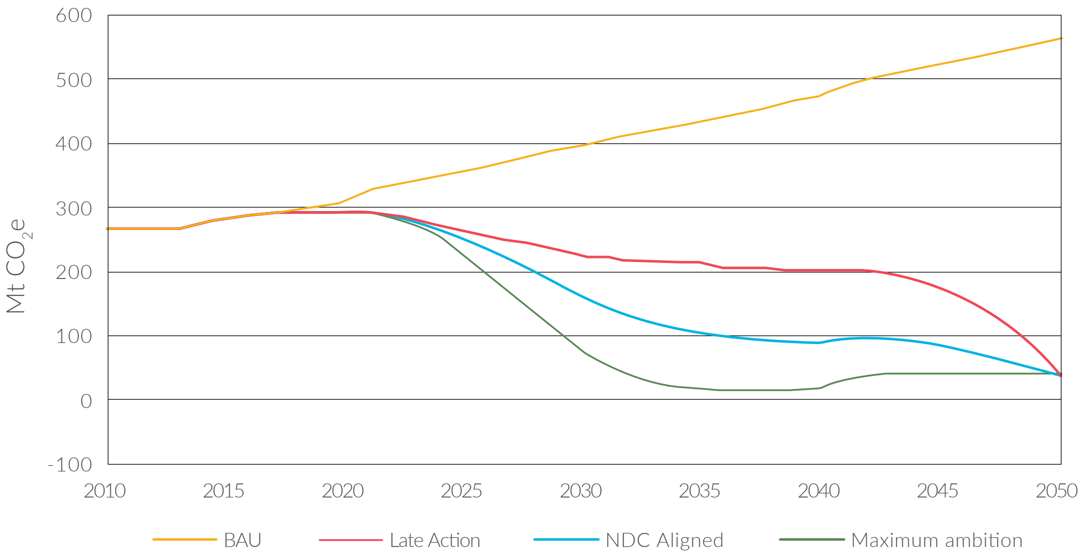
In the NDC-aligned scenario, total CO_2e emissions reach around 118.5 Mt by 2030 before declining to 61.9 Mt per year in 2040 and –1.2 Mt per year by 2050. The cumulative avoided emissions relative to the BAU scenario total 10,018 Mt for 2020–2050, or 332.5 Mt per year on average over 30 years. This scenario constitutes medium-term action, with ambitions being spread out during 2030–2040. This scenario reaches net-zero in 2050 but emits fewer emissions in the medium and longer term.

In the late action scenario, total CO_2e emissions are projected to reach around 176.7 Mt per year in 2040 before declining to –1.5 Mt per year in 2050. Cumulatively, the reduction in emissions achieved in the late action scenario, compared to the BAU, totals 7,911 Mt for 2020–2050. The cumulative reduction reflects the late phase in the decarbonization ambitions, as well as establishment of the land sink, leading to lower cumulative reductions relative to the other two scenarios.

Lastly, in the maximum ambition scenario, total emissions reach NZE around 2035 and remain below zero due to the continued implementation of ambitions. The cumulative avoided CO_2e emissions in the maximum ambition scenario, compared to the BAU, total 11,709 Mt, equivalent to 390.3 Mt in avoided emissions per year for 2020–2050. This scenario represents the early action scenario in which NZE is reached by 2035, after which additional ambition is only required to ensure that net zero is maintained.

FIGURE 4.1

Total annual CO_2e emissions



GDP outcomes of the different pathways for reaching NZE

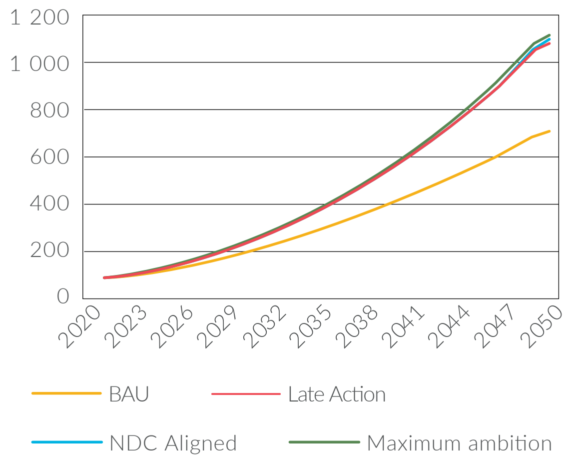
In the BAU scenario, the total real GDP is expected to reach around USD 606 billion in 2050 with an average annual growth rate of around 7.3% for 2020–2050. In the NDC-aligned scenario, total real GDP is projected to increase to approximately USD 1.01 trillion by 2050, which is 66.1% higher compared to the BAU scenario. The average real GDP growth for 2020–2050 is indicated at 9.05% per year.

For the late action scenario, the results indicate an average annual growth rate of 9.02% for 2020–2050, resulting in a total real GDP of USD 996 billion in 2050, which is an increase of 64.4% relative to the BAU scenario. The maximum ambition scenario projects an average real GDP growth rate of 9.07% per year for 2020–2050, with total real GDP reaching USD 1.013 trillion in 2050 (+67.2% vs. BAU scenario), indicating that early action for decarbonization benefits overall economic growth.

Total real GDP and real GDP growth in the BAU scenario and all NZE scenarios is presented in Figure 4.2, and an overview of the average real GDP growth rate for selected periods is provided in Table 4.1.

FIGURE 4.2

Total real GDP in bn USD (left) and real GDP growth rate (right)



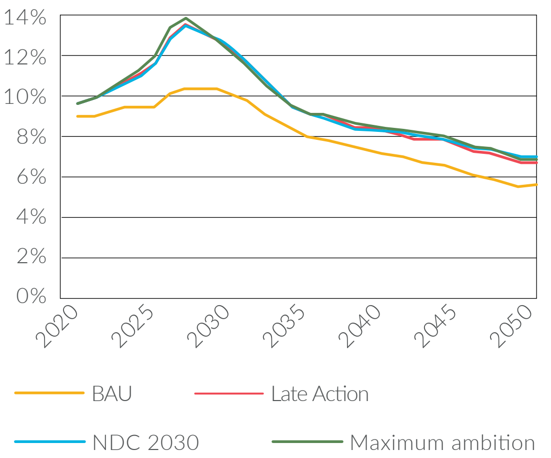


TABLE 4.1

Average real GDP growth rate for selected periods

Real GDP growth	Unit	2020–2030	2030–2040	2040–2050	2020–2050
Late action	%/year	11.34%	9.09%	6.76%	9.02%
NDC aligned	%/year	11.29%	9.09%	6.91%	9.05%
Maximum ambition	%/year	11.26%	9.11%	6.97%	9.07%
BAU	%/year	9.16%	7.52%	5.30%	7.30%

The additional growth induced in the decarbonization scenarios is the result of various feedback loops in GEM that capture the beneficial impacts of decarbonization strategies and related interventions. Relevant feedback loops capture, for instance, the effect of energy costs or the impact of energy related GHG emissions on total factor productivity. Energy costs are related to the competitiveness of the economy, whereas energy related GHG impacts capture productivity impacts from air pollution.

Employment implications of the NZE pathways

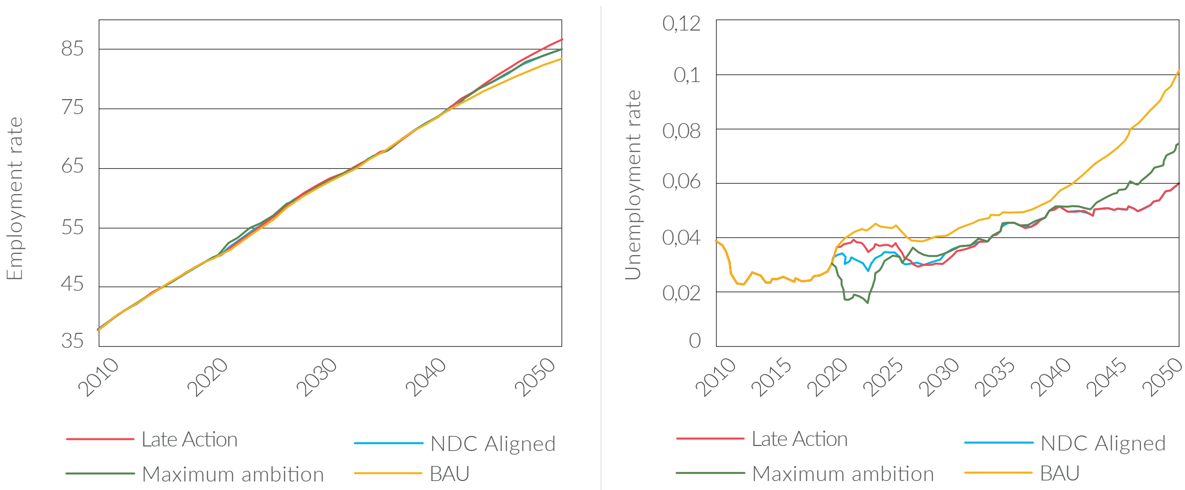
Along with the additional real GDP, the ambitions envisaged for the decarbonization scenarios generate additional jobs relative to the BAU scenario. Total employment and the unemployment rate in the BAU and NZE scenarios are presented in Figure 4.3.

In the BAU scenario, total employment is projected to increase from 50.4 million jobs in 2020 to around 83.3 million jobs by 2050. In the NZE scenarios, total employment in 2050 is projected to reach 85.4 million jobs (maximum ambition, +2.5% vs. BAU), 85.3 million jobs (NDC 2030, +2.4% vs. BAU), and 86.7 million jobs (late action, +4% vs. BAU). The difference in job figures between the NZE scenarios derives from the phase in of assumptions related to decarbonization, with increased effort affecting the total number of jobs provided in 2050.

Furthermore, while the unemployment rate in the BAU scenario averages 5.66% for 2020–2050, average unemployment during the same period is 1.2% (NDC aligned), 1.3% (maximum ambition), and 1.4% (late action) lower relative to the baseline. The results show that the maximum ambition scenario has significant short-term employment benefits relative to the other two scenarios, whereas the late action scenario reduces unemployment during 2040–2050.

FIGURE 4.3

Total employment and unemployment rate



4.2 ENERGY TRANSITION TOWARDS NET-ZERO AND CLIMATE-RESILIENT PATHWAY

Sectoral background

Energy Policy Frameworks

The GoE formulated its new **National Electrification Plan (NEP and NEP II)** in 2017 and 2019, which strives for universal electrification by 2025 through a mix of on- and off-grid electrification (MoWIE a, 2019). Already today, the grid covers a significant share of the country. Moreover, via its **National Energy Policy** and the **Energy Efficiency Strategies** for various sectors, the government is committed to building a climate-resilient green economy by expanding electricity generation from renewable sources and leapfrogging to energy-efficient technologies. This is to be achieved through a) increasing the use of clean/renewable power in all sectors, including fuel switching to clean and modern energy in all economic sectors, and b) improving energy efficiency and maximizing benefits by utilizing clean energy efficiently in the residential, industrial, and transportation sectors. The measures specific to the energy sector include development of hydropower plants, production and integration of variable renewable energy into power systems, electrification of the residential sector in urban areas and beyond, adoption of clean and efficient cooking technologies in rural areas, electrification of industrial processes with clean energy, electrification of agricultural machinery, and irrigation with clean energy.

Business-as-usual scenario

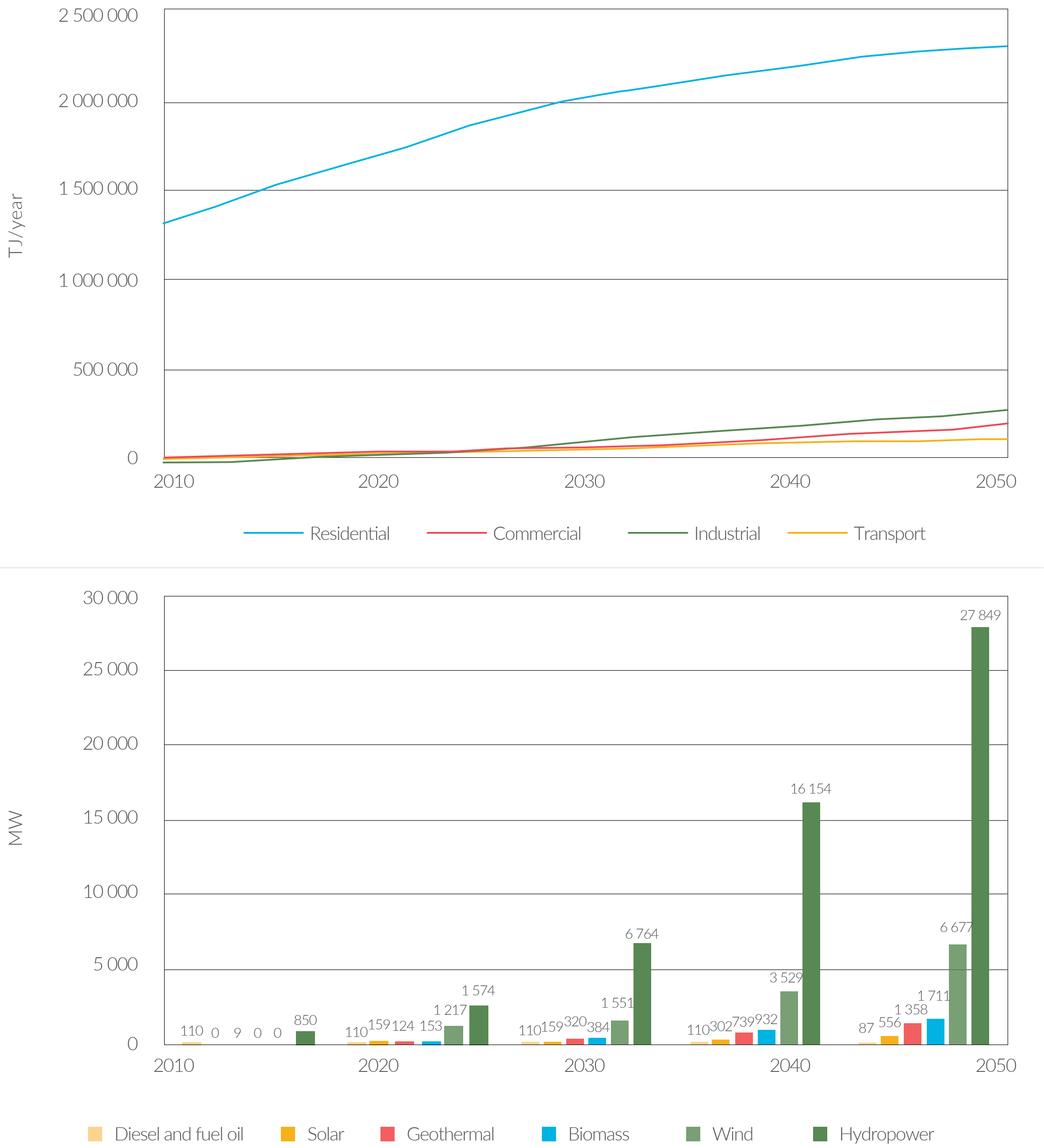
Energy is used in Ethiopia's agriculture, transportation, industry, commerce, and household sectors, all of which significantly contribute to national-level emissions. The energy BAU scenario is mainly driven by expected GDP growth as a driver for energy demand. Moreover, the following assumptions apply:

- Ethiopia would face no pressure to reduce CO_2 emissions during 2020–2050. The country's current annual per capita CO_2 emissions is less than 0.2 tons, which is low. But according to Ethiopia's updated NDC report (July 2021), the country's GHG emissions will double from 247 million tons of CO_2 in 2010 to 403.5 million tons of CO_2 by 2030 in the BAU scenario.
- A rapid rise in energy demand for solid fossil fuels in industry, particularly for the cement and metal industries.
- Increased use of petroleum in the agriculture sector. Energy requirements (mainly for diesel) for irrigation, cultivation, and other farm activities will rise due to an expansion of large commercial farms.
- Requirements for commercial energy will rise. Indigenous energy resources would be developed at an accelerated rate, and the balance would need to be met by imports.
- To pursue the goal of energy security, the extraction of gas and coal reserves will be prioritized.
- Biomass energy consumption remains an important source of energy in both rural and urban areas and is expected to grow as fast as the population, increasing pressure on natural resources.

Energy demand: the results obtained for 2010–2050 show that the primary energy requirement in the Ethiopia BAU scenario is expected to increase to 2 million TJ per year (Figure 4.4). Increased economic activities, population growth, and transport needs are the major contributors to such an increase. In the BAU scenario, the total power generation capacity will reach 38 GW by 2050, with around 28 GW being from hydropower.

FIGURE 4.4

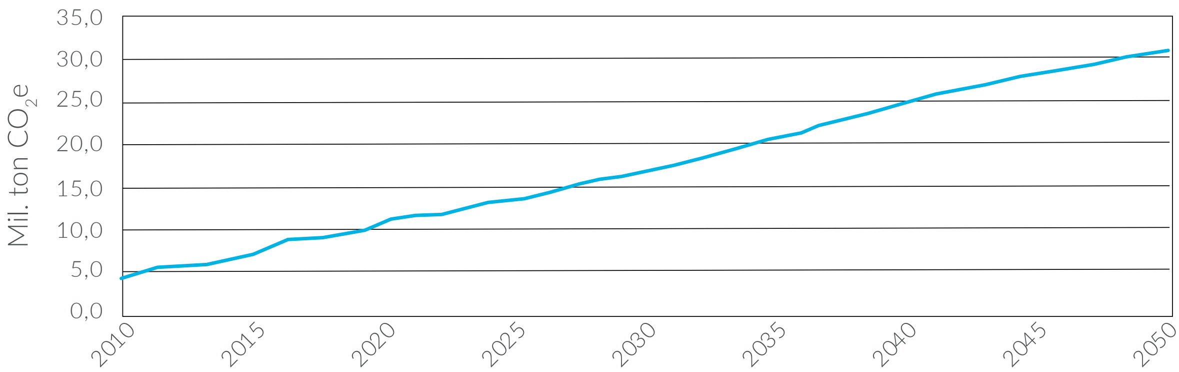
BAU projections of total energy demand by sector (upper), and total power generation capacity (lower)



CO_2e emissions: energy-related CO_2e emissions are expected to increase throughout 2010–2050 due to increased use of fossil energy resources. The total emissions in 2020 from the energy sector (including transport) were 11.9 Mt. This is expected to increase to around 31 Mt in absolute terms, resulting in an average increment of 3.24% per annum until 2050. The transport sector is the major contributor (to be emphasized in section 4.3). Figure 4.5. Total CO_2e emissions under BAU scenario from the below shows the emissions from the energy sector in Ethiopia under the BAU scenario.

FIGURE 4.5

Total CO_2e emissions under BAU scenario from the energy sector



Low-emission scenarios

The measures chosen to achieve GHG emission reductions are consistent with Ethiopia's national development priorities, objectives, and circumstances. Ethiopia considers the updated emission reduction targets to reflect the highest possible ambition in light of national circumstances and as a fair contribution to the long-term global mitigation goal. The low-carbon emission pathways of Ethiopia's energy sector reflect a future in which explicit policies and measures are adopted to reduce the sources of GHGs. They should not simply reflect the current plans but assess what would be achievable based on the goals of the scenario.

The low-carbon emission scenarios take into account 1) specific national and regional development priorities, objectives, and circumstances and 2) the common but differentiated responsibilities of the parties of the Paris Agreement. The key inputs to mitigation targets were the validated sectoral targets of the GoE communicated through the Ministry of Water and Energy (MoWE).

To reduce carbon emissions, the MoWE considers the expansion of renewable energy (i.e., solar and wind) both off- and on-grid as a key factor for achieving the required electrification rate in Ethiopia. Therefore, in the power generation sector, all electricity will be generated from renewable sources, primarily hydropower plants, as well as solar PV. The use of energy-efficient technologies will also help reduce emissions in other sectors. In the household sector and industry, the use of liquified petroleum gas must be reduced by applying efficient cooking stoves and biogas, and the transportation sector will need to transition to zero emissions. Table 4.2 provides a high-level summary of the planned interventions per scenario, indicating the nature of the mitigation effect of Ethiopia's energy sector policy intervention and targets. The figures indicate that the highest net reduction in emissions and energy consumption revolve around mitigation interventions focused on improving energy efficiency, expanding the rail transport sector, and electrification of vehicles.

TABLE 4.2

List of mitigation measures for Ethiopia LT-LEDS in the energy sector

Energy: high-level interventions	2020	2030	2050
Electrification of households (petroleum demand reduction)			
Maximum ambition scenario	0%	15%	75%
NDC-aligned scenario	0%	10%	75%
Late action scenario	0%	7%	75%
Electrification of households (biomass demand reduction)	0%	14.5%	60%
Electrification of industry (petroleum demand reduction)			
Maximum ambition scenario	0%	30%	50%
NDC-aligned scenario	0%	20%	50%
Late action scenario	0%	14%	50%
Electrification of transport			
Maximum ambition scenario	0%	15%	75%
NDC-aligned scenario	0%	10%	75%
Late action scenario	0%	7%	75%
Energy			
Annual energy efficiency improvements	+8%	+8%	+8%
Sustainable biomass production	100%	100%	100%
Share of renewable energy in total capacity			
Maximum ambition scenario	86%	100%	100%
NDC-aligned scenario	86%	100%	100%
Late action scenario	86%	90%	100%
Transmission losses	19%		10%

Strategic actions for the energy sector

The energy uses in households, transport, industry, and commercial contribute to the total country's emissions. As per the 2021 updated NDC assessment, the below sectors contribute to emissions in ascending order.

In households, the changes include the electrification and promotion of efficient technologies in all end-use services in urban areas, the promotion of clean and efficient cooking stations with low emissions in rural areas, electrification in water heating, and lighting in rural areas.

In the agriculture sector, Ethiopia must increase electrification in farm machinery and water pumping and promote solar PV pumping.

The industry sector's actions include expansion of efficient and clean production technologies; electrification in process heat and boilers and in power in all industries (fuel switch from petroleum demand to electricity); the intervention of green fuels (waste, electricity, and hydrogen) for thermal processes in the industries; and the introduction of electric technology for process heat in heavy industries (cement and brick).

The transportation sector will need to transition to zero-emissions transportation for intracity, intercity, and freight travel across private and public modes. Specific actions include promotion of electric mass passenger transport, switching fuel to clean energy (electricity, biofuels in aviation), electrification in freight transport, and installation and expansion of charging stations (also see section 4.3).

Enhance and maximize power generation and usage in the industry, agriculture, and commercial sectors with renewable energy. In the power generation sector, all electricity will be generated from renewable sources, primarily hydropower plants (including the Grand Ethiopian Renaissance Dam and Koysha Hydro) with the appropriate generation mix as well as development and integration of renewable energy technologies, including mini- and micro-hydropower, solar (including the Metahara, Metema hurso, and Weranso), wind, bioenergy, and geothermal (including Tulu Moye and Corbetti Geothermal). This also requires the development of policy on regional power sector integration and grid flexibility, expansion of the high-capacity transmission lines, and maintenance and/or upgrading of the electricity distribution lines.

Figure 4.6 exhibits energy demand in the low-emission scenarios. It is similar across scenarios and projected to decline to 1.52 million TJ per year. As Figure 4.6. Total energy demand in LT-LEDS scenario reveals, while carbon intensity of energy production is expected to increase in the BAU scenario, it will fall in the low-emission scenarios. For the carbon intensity of GDP, there is a falling secular trend, even in the BAU scenario. The low-emission scenarios will bring down the intensities faster and to a lower level due to the planned interventions.

FIGURE 4.6

Total energy demand in LT-LEDS scenario

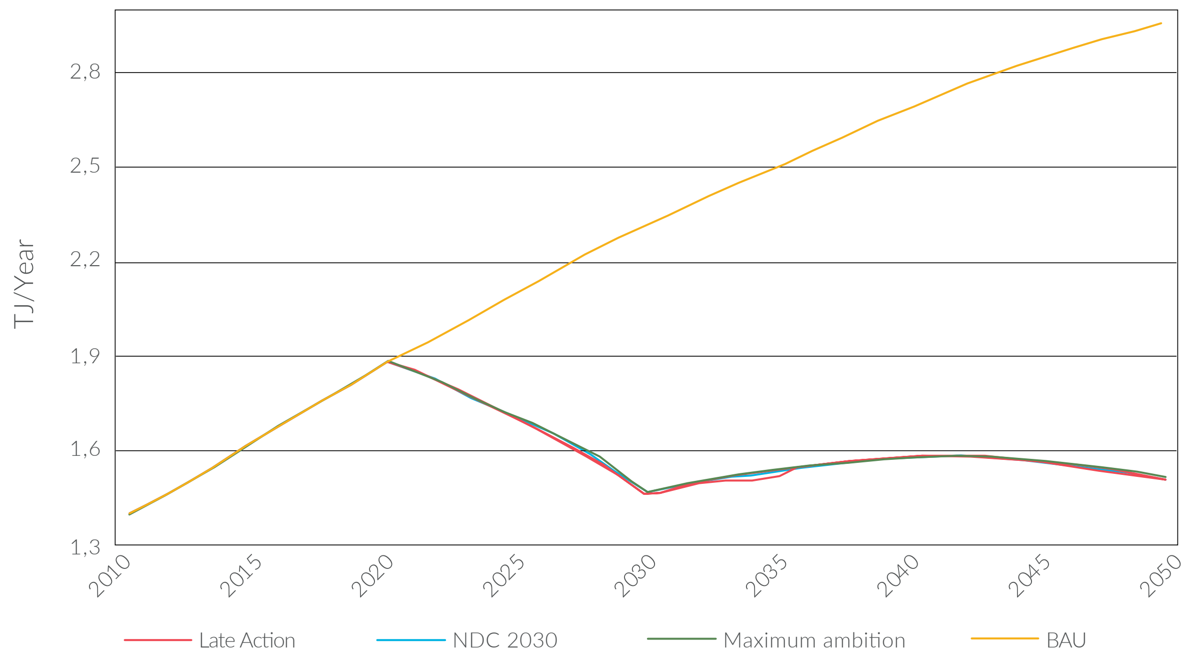
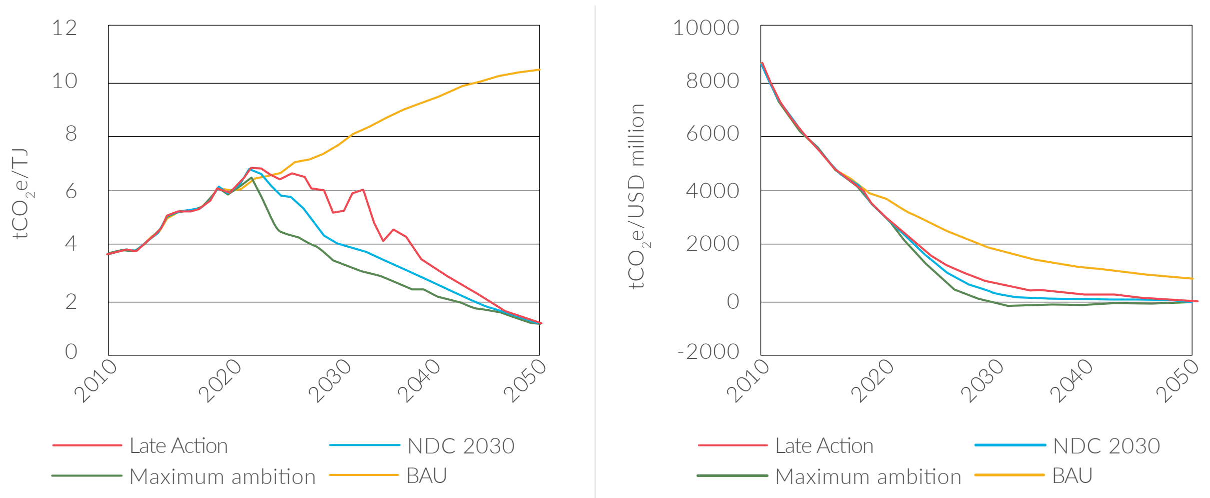


FIGURE 4.7

Carbon intensity of energy production in tCO_2e/TJ (left) and in tCO_2e/USD million (right)



Additional economic growth and the electrification ambitions assumed for the LT-LEDS scenario increase the required power generation capacity. By 2050, a total generation capacity of 116.3 GW is projected for the LTS-LEDS scenario, which is three times the amount projected for the BAU.

During the transition period toward full renewables, the additional electricity demand resulting from interventions temporarily reduces the share of renewable energy generation, assuming that fossil fuel generators are used to compensate until renewable capacity is fully established. The total emissions in 2020 were 11.9 Mt. By 2050, these are expected to increase to 31 Mt for the BAU scenario and decrease to around 3.1 Mt in the low-emission scenarios. The results show that the mitigation interventions identified by the GoE will play a critical role in achieving a low-carbon development pathway for the transport sector in Ethiopia.

FIGURE 4.8

Total power generation capacity under LT-LEDS scenario

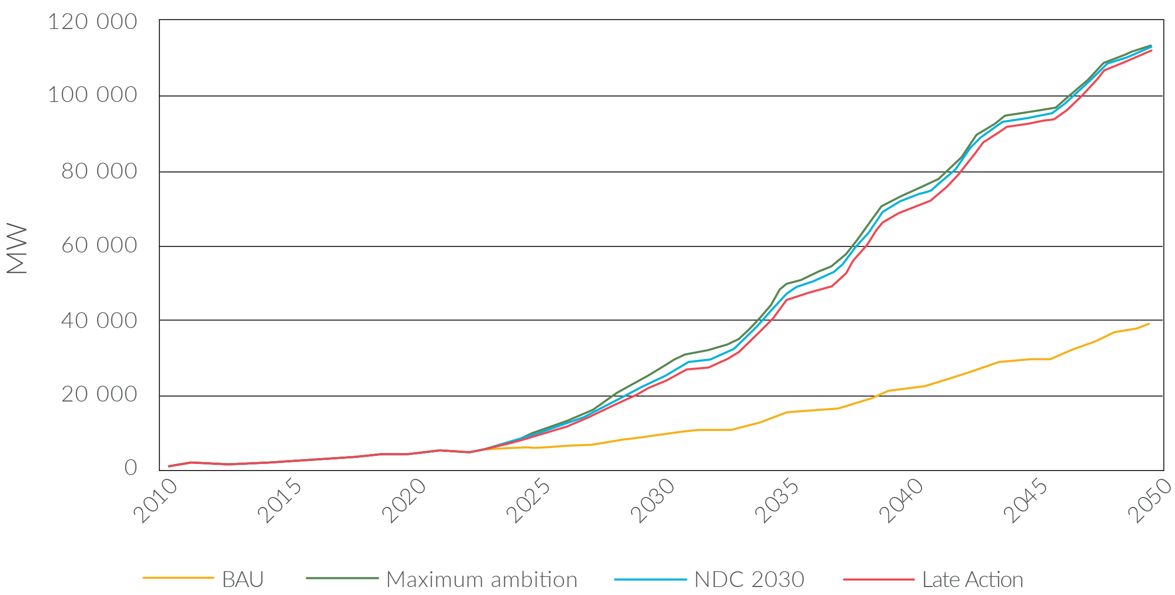
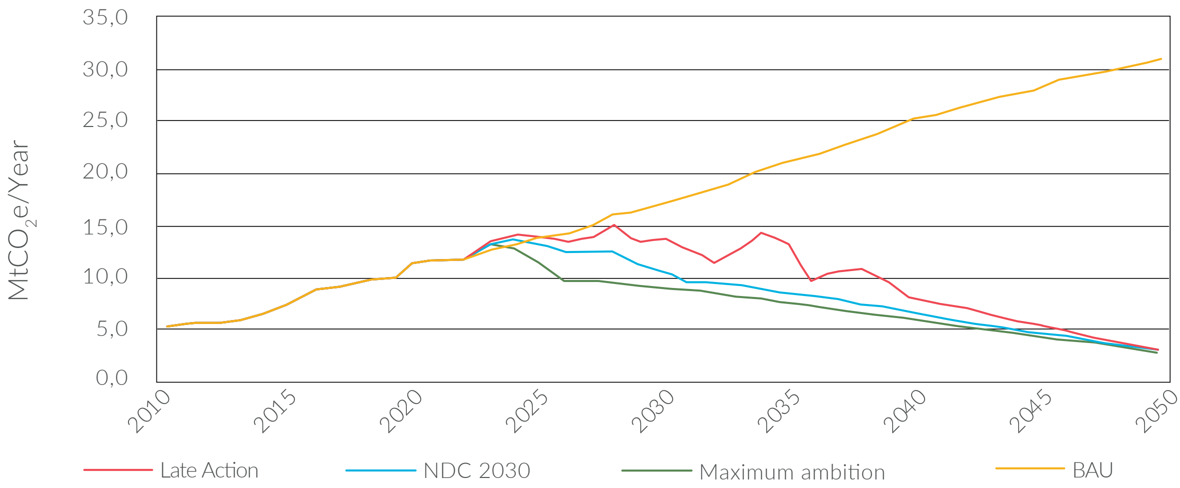


FIGURE 4.9

Total CO_2e emissions under the BAU and the low-emission development scenarios in the energy and transport sector

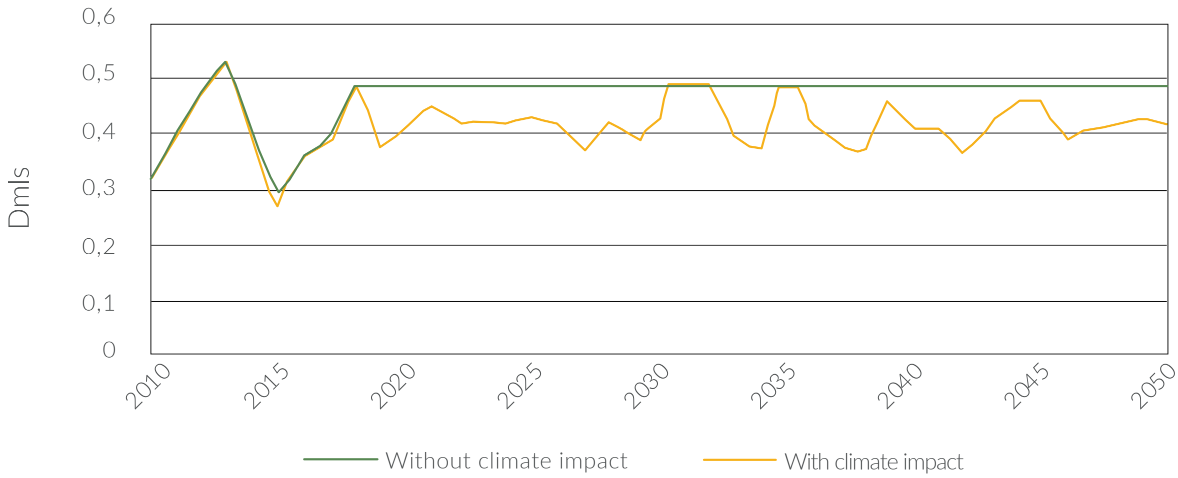


Climate resilience of the energy sector

The impacts of climate change in Ethiopia's energy sector considers a) the impact of water scarcity in reservoirs as a result of rainfall variability and b) the impact of increasing temperatures on the efficiency of thermal power plants and power distribution systems. Currently, in Ethiopia, missing generation capacity from hydropower plants during droughts or reduced rainfall seasons is offset by electricity from diesel generators, which increases the overall emissions of the energy sector during these periods. Figure 4.10 depicts the missing generation capacity as the difference in the load factor of the hydropower plants when rainfall variability due to climate change in the RCP4.5 scenario is considered, as opposed to a scenario without climate consideration (i.e., BAU scenario).

FIGURE 4.10

Load factor of hydropower plants in scenarios with and without climate impacts



Regarding the reduction in efficiency of thermal power plants, historical data indicates an average annual reduction of 4% in generation in past periods for fossil fuel-powered plants. Simulation results from GEM show that the annual reduction in generation of fossil fuel-powered plants and hydropower plants varies around 4–12% annually until 2050.

The long-term strategy of a climate-resilient energy sector in Ethiopia has been previously discussed and defined in Ethiopia's *Climate-Resilient Green Economy: Water and Energy*. As a long-term strategy for LT-LEDS, the following priorities are identified, which align with the actions defined in the CRGE strategy:

- **Diversify the energy mix** to reduce the dependency of hydropower plants on rainfall variability.
- **Improve energy efficiency** to reduce overall demand for electricity.
- **Improve efficiency of biomass use** to reduce the overall demand for biomass.
- **Accelerate non-grid energy access** to improve electrification of rural areas.

Based on a discussion with the power sector working group, two key climate adaptation measures for the power sector, as listed in Table 4.3, are identified and modeled in GEM to assess their contribution in reducing the adverse impacts of climate change in the energy sector. The modeling of these measures represents the potential benefits of diversifying the energy mix and improving energy efficiency in the power system.

TABLE 4.3

Adaptation interventions and their respective targets in the energy sector that are modeled in GEM

Adaptation intervention	Indicator	Baseline indicator 2018	2030 Target	2050 Target
Increasing the share of PV, wind, and biogas to replace the share of fossil fuels in electricity generation	% of renewable electricity generation, excluding hydropower plants	9%	80%	100%
Reduction of transmission losses in the electricity distribution system	% of transmission losses	19.6%	12.5%	10.0%

The modeling results show that increasing the share of non-hydro renewables to cover the shortfall in generation reduces total emissions by an average of 16.1% for 2020–2050, which would otherwise be emitted by diesel generators. The differences in the share of non-hydro renewables in the BAU (without adaptation measures) and LT-LEDS (with adaptation measures) scenarios are shown in Figure 4.11. Regarding reducing transmission losses in the electricity distribution system, on average, 7.5% less electricity is generated annually during 2020–2050. This is a significant reduction in total primary energy, resulting in lower costs and increased resilience of the power system.

In the energy sector, in addition to the quantitative adaptation benefits of adaptation actions that were modeled, there are important adaptation co-benefits of the mitigation actions. The following table illustrates the analysis results, identifying the most important adaptation synergies and trade-offs of the energy mitigation actions.

FIGURE 4.11

Share of non-hydro renewables in electricity generation with and without adaptation interventions

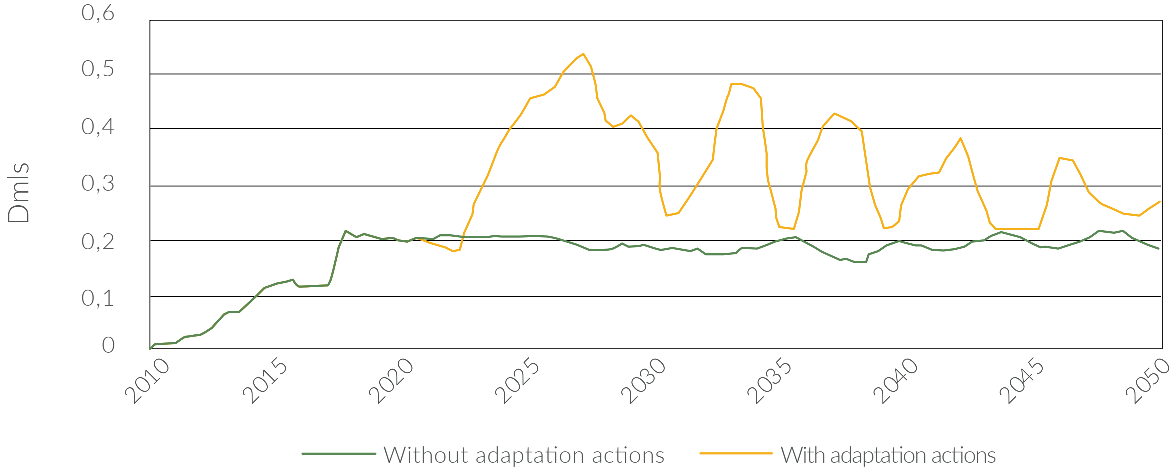


TABLE 4.4

Adaptation co-benefits and trade-offs of mitigation actions in the energy sector

Mitigation action	Adaptation co-benefits	Adaptation trade-offs
Electrification of households (petroleum demand reduction) Electrification of industries (petroleum demand reduction) Electrification of transport (petroleum demand reduction)	> Resilience can be increased due to the connection to distributed grids, given that energy security standards will be in place. > Reduction of exposure to fluctuating fossil fuel costs and escalating carbon costs for vulnerable populations disproportionately impacted by climate change. > Increased energy security and less reliance on primary energy imports (e.g., fuels, coal)	Renewable energy infrastructure that does not follow security standards can increase vulnerability
Energy efficiency improvements	Reduction of energy consumption and improvement of grid reliability	
Increased share of renewable energy in total capacity	More resilient energy system toward extreme events	
Transmission losses	Reduction of primary energy demand and increased resilience of the power system	

4.3 TRANSPORT SECTOR DECARBONIZATION PATHWAYS

Sectoral background

Transport policy frameworks

To achieve decarbonization, the transport sector requires the adoption of clean, secure, and connected mobility, including a shift to electric mass transportation and an increase in the use of clean fuels. To this end, the most important policy documents are the **Climate Resilience Transport Sector Strategy** document, the **National Transport Policy**, and the **National Non-Motorised Transport Strategy** as well as the 2nd National Communication of the Government of Ethiopia, the Global Fuel Economy Initiative Study in Ethiopia, the Transport Sector Annual Statistics Bulletin, and the Intergovernmental Panel on Climate Change (IPCC, 2006) guideline. These policies envisage the expansion of the required infrastructure to enable the structural transformation of the transport system. This involves the construction of additional railway kilometers and bus rapid transit lanes as well as bicycle and pedestrian lanes in urban areas. Moreover, car-free zones shall be promoted and road parking replaced by underground parking. The number of both public and private electric vehicles is aimed to be increased while, at the same time, promoting the expansion of charging stations. Regulations are becoming stricter by limiting and then banning the import of used vehicles to increase vehicle efficiency. This outcome shall be supported by granting tax reductions to low-emission vehicles and incentivizing more efficient fuels.

The transport sector in Ethiopia primarily comprises of road, rail, water, and air-based modes of transport. The GoE (FDRE, 2018) reveals that among the different modes, land-based transport contributes the largest share of transport emissions. Furthermore, road transport accounts for over 90% of the total transport sector emissions, excluding public transport, freight transport, and nonmotorized transport. Within the road transport sector, freight vehicles account for over 50% of road transport emissions while public transport vehicles with more than 12 seats account for over 20% of emissions. Regionally, Addis Ababa accounts for 63% of the total road emissions. The GoE, through the Ministry of Transport and Logistics, underpins the importance of transport for its citizens and seeks to employ best practices to support the sustainable implementation of policies. The National Transport Policy (FDRE, 2020) was developed to address the increasing infrastructure demand and the need for sustainable transportation in the country. The strategy, as depicted in the National Transport Policy, aims at using stakeholders both externally and internally to ensure a coordinated and sustainable development.

Business-as-usual scenario

The BAU scenario estimates the total emissions from the Ethiopian transport sector are 4.81 million tons of CO_2e in 2020 and are expected to increase to approximately 15.63 million tons of CO_2e by 2050, as shown in Figure 4.12,., left. Energy consumption in the transport sector is expected to increase from just over 66.08 PJ in 2020 to 214.63 PJ in 2050 (see Figure 4.12, right).

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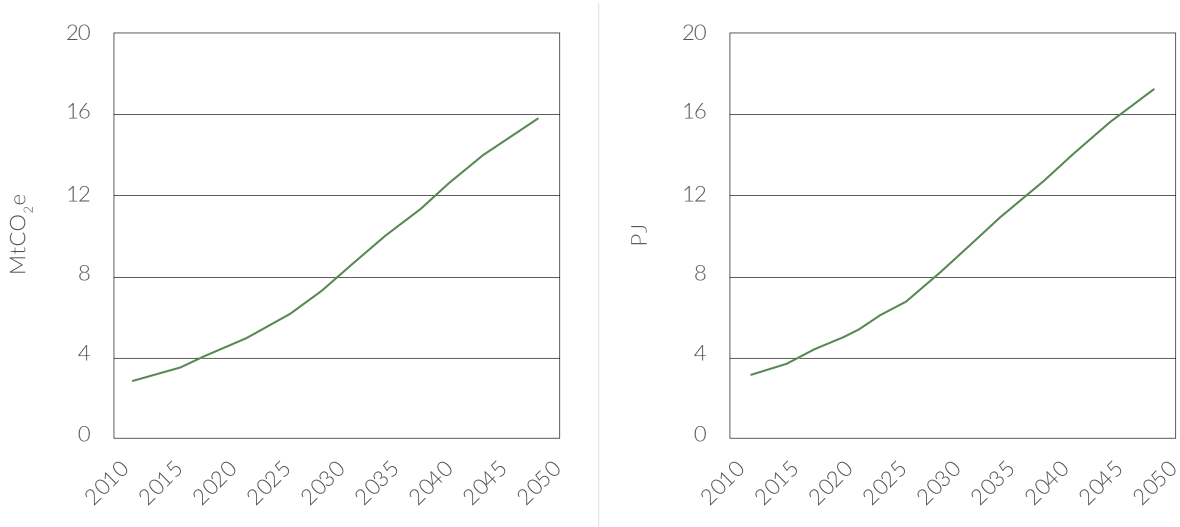
FIGURE 4.12

Total transport sector emissions (left) and energy consumption (right)



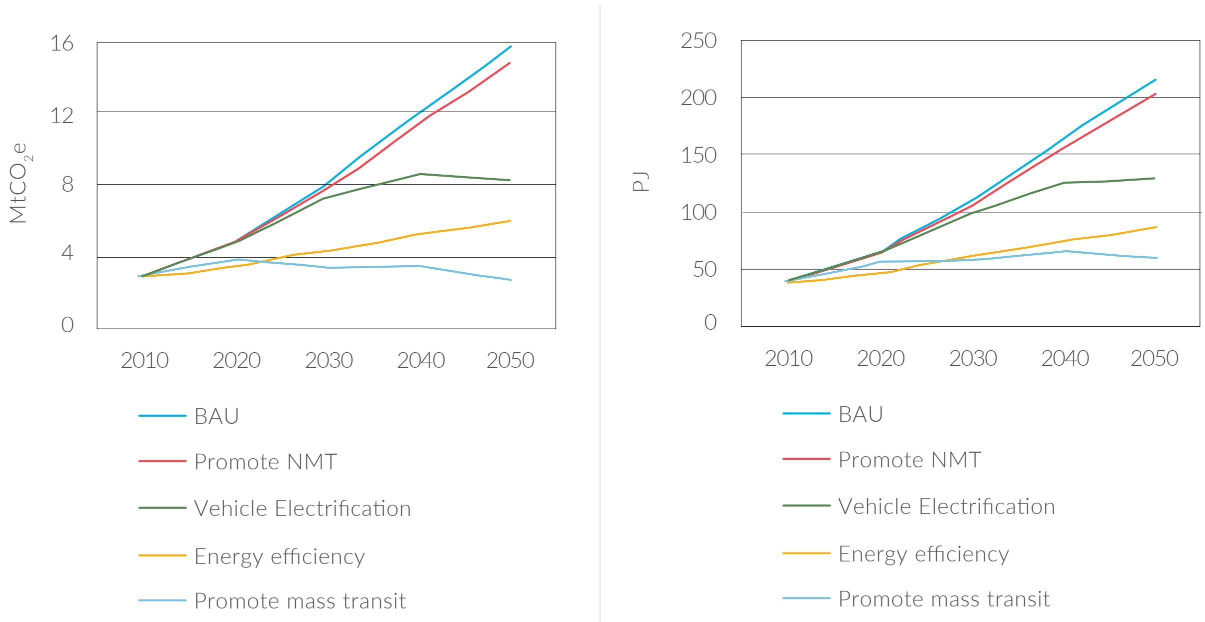
Low-emission scenario

Based on the targets defined in the existing transport policy reports in Ethiopia, the impact of the implementation of those targets on energy demand and carbon emissions can be estimated. The policy on nonmotorized transport (NMT) offers the least projected emissions reduction, whereas promoting mass transit—which comprises interventions dealing with an increase in passenger and rail freight transport—shows the highest projected emissions reduction in 2050.

Figure 4.13 on the left shows the result for carbon emission reductions in each policy combination relative to the BAU scenario, while Figure 4.13 on the right reveals how energy consumption responds to the same policies. These policy actions cannot simply be aggregated, as they would lead to negative emissions in the transport sector.

FIGURE 4.13

Low-carbon emission pathways (left) and energy consumption pathways (right) in the transport sector



Based on this information, the LT-LEDS targets in the transport sector are defined in a way that they can be modeled for the long-term scenario. Table 4.5 shows the intended interventions and developmental objectives of the GoE for the transport sector. The GoE is working to make the transport sector easily accessible, affordable, sustainable, and climate resilient. Currently, the government has set its 10-year targets with objectives of the FDRE (2020). The table shows specific transport-sector climate mitigation intervention policies and validated targeted levels of implementation by 2030, 2040, and 2050, as compared to 2020.

TABLE 4.5

Transport policy interventions and targets

Transport: high-level interventions	2020	2030	2040	2050	Source
Transport (shift from petroleum to hybrid and electric vehicles)					10YDP
Maximum ambition scenario	0%	15%	44.5%	75%	
NDC-aligned scenario	0%	10%	34.5%	75%	
Late action scenario	0%	7.5%	15%	75%	
Enhance NMT (bicycle, walking)	5%	60%		100%	NMT strategy and 10YDP
Improve mass transport (BRT, rail, trolley bus)	34%	70%		100%	10YDP
Fuel quality and efficienc	0%	16%		18%	Outside the purview of the transport ministry
Vehicle age limit	0%	100%			Excise Tax Proclamation No. 1186/2020 new proclamation on February 13, 2020. From 5% to 300% excise tax adding Draft vehicle age limit regulation
Improve transport mobility (reduce congestion, parking, pricing)	0%	50%			Expert judgement is used given the ongoing construction of parking facilities, BRT, and intelligent transport systems
Increase share of rail transport Freight Passenger	7% 2%	7% 10%	20%	50% 50%	10YDP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Based on these policy ambitions, the low-emission scenario presents itself as follows, in terms of energy demand and carbon emissions:

Shift from petroleum to hybrid and electricity. There is significant emission reduction potential in hybrid and electric vehicles. The latter has already been demonstrated in the electricity-powered Addis Ababa Light Rail Transit (AALRT) service. As electricity can be used for all transport types, the GoE intends to extend this policy to other subsectors and modes of transport.

The GoE will support this intervention by focusing on increasing the generation of electricity from local clean sources, like hydro and wind (currently main sources of generation), to support the expansion of the rail network and services. Meeting the demand for additional electricity in the transport sector by 2030, as captured in the NDC scenario, would require an additional 300 GWh yearly, which corresponds to 2% of the current annual consumption of electricity. Therefore, this extra demand can be accommodated in the current power generation plans.

The recent implementation of different tax exemption levels for the importation and local manufacturing of all electric vehicles is expected to boost the growth of the electric vehicle sector, thereby reducing the reliance on imported petroleum products to power the transport sector.

Enhance NMT (bicycle, walking). Nonmotorized transport modes play a fundamental and unique role in the efficiency of transport systems, providing a low-carbon travel option. The main implementation activities of the GoE that will enhance the adoption of NMT include the following:

- Design and implement high-quality walking and cycling facilities in secondary cities and towns
- Update national street design standards
- Prevent encroachments on NMT facilities
- Conduct audits and surveys to monitor progress on implementation of the strategy
- Develop safe pedestrian access in school zones
- Repair faulty streetlights and expand street lighting into new streets
- Develop dedicated cycle tracks along major streets

Improve mass transport (BRT, rail, trolley bus). Efficient public transport greatly mitigates GHG emissions and reduces energy use. With this policy, the GoE recognizes the crucial role of mass transport in the aim to achieve low-carbon economic development in Ethiopia. The main actions of the GoE that will encourage the implementation of the mass transit improvement policy include the following:

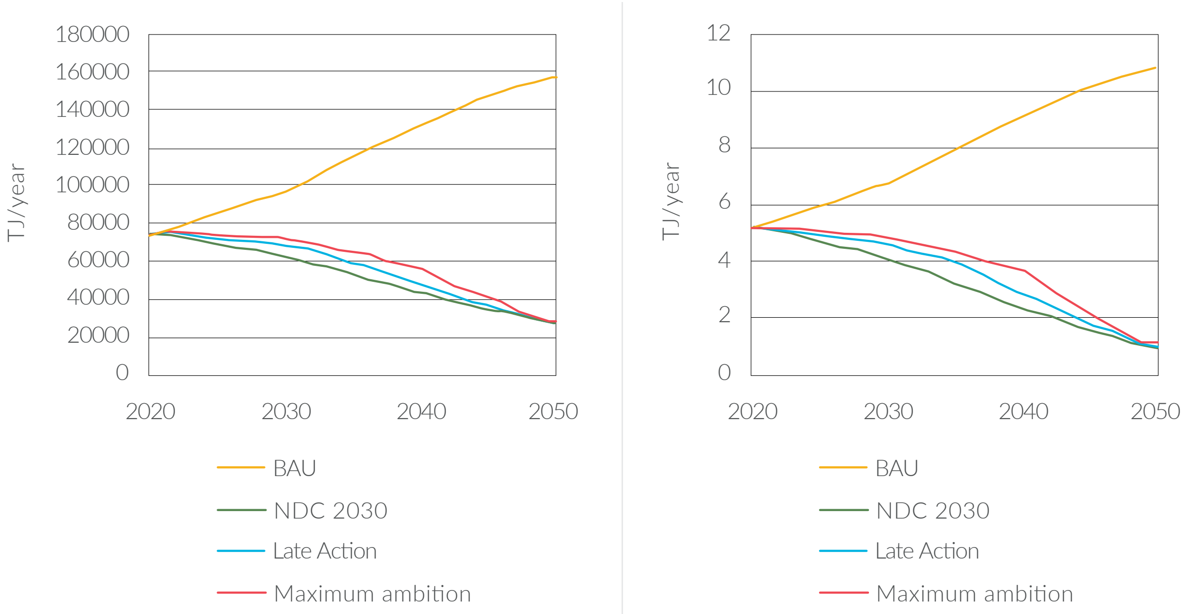
- Expand the infrastructure coverage of bus rapid transit (BRT) and light rail transit (LRT) networks
- Improve the frequency of services
- Improve the safety and comfort of public transport terminals and services to further attract commuters
- Introduce policies like prioritizing public transit vehicles at signalized intersections
- Increase both fleet size of road-based services and the rolling stock of the LRT

Fuel quality and efficiency. Since the transport sector in Ethiopia is highly dependent on fossil fuel imports, the government is developing an initiative to reduce the carbon content of fuel by improving fuel quality and efficiency. This policy intervention will be achieved through sustained development of biofuels, such as ethanol-blended gasoline and biodiesel. Ethanol fuel, when blended with gasoline, is an attractive alternative to fossil fuels, not only because of environmental and health benefits but also because it is competitive in terms of cost. A key strategy proposed in this document focuses on developing micro-distilleries that could produce 1,000 to 5,000 liters per day and would be designed to fit farm-scale operations and exploit niche feedstock. The National Biofuels Policy plan promotes ethanol both for stoves and for blending with gasoline as a transport fuel.

Increase the share of rail transport. The GoE intends to grow the rail sector because of the potential of rail transport to support the increased movement of people and goods, thus expanding the economy. From a low-carbon emission perspective, the rail sector does not contribute to emissions in the transport sector since it is powered by low-carbon electricity. Therefore, the policy intervention's focus on the upgrade expansion and maintenance of passenger and rail freight sectors will significantly contribute toward achieving the NDC 2030 low-emission scenario in line with the GoE's drive for low-carbon development, particularly when the electricity mix is based primarily on renewable energy sources.

FIGURE 4.14

Low-emission scenarios for transport energy demand (left) and transport emissions (right)



Climate resilience of the transport sector

Climate change is expected to significantly impacts various phases of the transportation sector—including planning, design, construction, and operations—with the greatest impacts on the design of new roads primarily affecting slopes, with an expected increase in localized damage. The main triggers will be increases in the intensity of short, extreme rainfall events and more severe flash flooding, which could affect the stability of slopes due to surface runoff and increased erosion. Other affected road infrastructure assets or components include pavement, road geometry, vegetation, bridges and protective structures, signage, and barriers.

In addition to road transport, impacts are also expected on rail and air transport, with the latter experiencing the strongest impacts from severe weather events, which will have a profound effect on the operational aspects of aviation, overall air traffic, and airspace management. In addition, the increasing frequency of very hot days will mean that asphalt pavements (although some pavement materials cope better with temperature extremes than others) and buildings and structures will require more maintenance due to deterioration of materials. For rail transport, temperature increases can raise the danger of rail buckling, and it is highly exposed to surface runoff and potential landslides.

To address the climate impacts in the transport sector, the GoE sees multiple opportunities to decrease emissions and jump-start the development of sustainable transport. The climate-resilient transport sector strategy also envisages the contributions of the transport sector to the resilient development pathway through the transport long-term strategies of building sustainable transport systems for resilience through enhanced access to mobility and increasing climate-resilient designs and safety standards for transport systems.

Favorably, there are many synergies between the mitigation and adaptation actions that have been defined for implementation in the country, as Table 4.6 exhibits. In fact, most of the actions defined in *Ethiopia's Climate Resilient Transport Sector Strategy* have high mitigation potential and have also been selected as mitigation actions in the LT-LEDS.

TABLE 4.6

Adaptation co-benefits and trade-offs of mitigation actions in the transport sector

Mitigation action	Adaptation co-benefits	Adaptation trade-offs
Transport (shift from petroleum to hybrid and electric vehicles)	Resilience can be increased due to the connection to distributed grids, given that energy security standards will be in place	
Enhance NMT (bicycle, walking)		> Users/pedestrians are vulnerable to climate conditions, such as heavy rainfall or heat waves, which might have health impacts > To improve this, more climate-proofing investments in the urban sector are required.
Improve mass transport (BRT, rail, trolley bus)	> Greater use of public transport enables more mass exit strategies from disasters > Cities can re-urbanize in ways that promote transport sector adaptation and mitigation	Highly ICT-dependent public transport may not be resilient during disasters, but this can be managed via local shared mobility systems related to local social capital
Improve transport mobility (reduce congestion, parking, pricing)		Relieve pressure from the transport sector and reduce its vulnerability
Increase share of rail transport	Greater use of public transport enables more mass exit strategies from disasters	Vulnerable to certain climate impacts (rising temperatures and extended heatwave periods can increase rail buckling), which can be managed through proper adaptation actions

In the transport sector, apart from the synergies between mitigation and adaptation, there are also great synergies between other sectors, especially the forestry sector. Increased reforestation and reduced deforestation will ultimately increase water retention and reduce surface runoff. Implementing these measures near transportation-related infrastructure will thus reduce the likelihood of landslides and soil erosion and significantly contribute to improving the resilience of the transport sector.

4.4 MODERNIZING THE AGRICULTURE SECTOR THROUGH CLIMATE-RESILIENT AND LOW-CARBON PRACTICES

Sectoral background

Agriculture Policy Frameworks

Considering its significant contribution to the country's economic development, the GoE has focused on the agricultural sector over the past three decades. In collaboration with its development partners, it has been striving to transform the agriculture sector by designing and implementing successive policies, strategies, and programs. Since the beginning of this century, the **Sustainable Development and Poverty Reduction Program (SDPRP, 2003–2005)**, the **Plan for Accelerated and Sustained Development to End Poverty (PASDEP, 2006–2010)**, and the **Agricultural Sector Policy and Investment Framework (2010–2020)** have been implemented successively, focusing on capacity development of smallholder farmers, enhanced food security, crop diversification promotion, improvement of the livelihoods of pastoral communities and their resilience, and poverty reduction by improving rural-urban linkages, developing rural nonfarm enterprises, and prioritizing agricultural investment. In line with these programs, the **Agricultural Growth Programs (AGP I and II, 2011–2020)** aimed at increasing agricultural productivity and market access for key crop and livestock products. AGP I was implemented in selected woredas across Amhara, Oromia, SNNP, and Tigray regional states. AGP II focused on enhancing agricultural research for appropriate technology generation, smallholder irrigation development, agricultural marketing, and value chain development.

Meanwhile the **Gender Equality Strategy for Ethiopia's Agriculture Sector** was developed in 2017 to accelerate development of the sector through added focus on women's empowerment in the sector.

Agriculture is the backbone of Ethiopia's economy, accounting for more than 80% of exports and employing about 70% of the workforce. Due to its diverse agro-ecological zones, several crop types grow on about 13 million hectares, including cereals, pulses, oilseeds, roots and tuber, fruits, and vegetables. Ethiopia has the largest livestock population in Africa, and millions of farmers and pastoralists depend on livestock for their livelihoods. However, agriculture in Ethiopia is a subsistence-oriented farming system, and more than 95% of crops are produced by smallholder farmers.

According to the Agricultural Development Led Industrialization strategy, agriculture is a driver of national economic growth and has enabled the country to achieve rapid growth in agricultural production and improve the livelihoods of rural households. The current 10YDP indicates continued government support of the agricultural sector, with objectives including creating sufficient job opportunities in rural areas, improving the supply of raw materials for agro-industries, and ensuring food and nutrition security by transforming agri-food systems in the country. Consequently, agriculture is projected to grow at an annual average rate of about 6% over the next ten years.

Despite appreciable achievements in increasing agricultural productivity, several challenges hamper efforts toward transforming the country's agriculture sector. Food production has not kept pace with the country's population growth rate. Some of the systemic constraints in Ethiopian agriculture include a shortage of improved seed, dependency on rainfall, limited mechanization, agricultural land degradation, shortage of livestock feed, poor soil fertility, and prevalence of pests and diseases.

Business-as-usual scenario

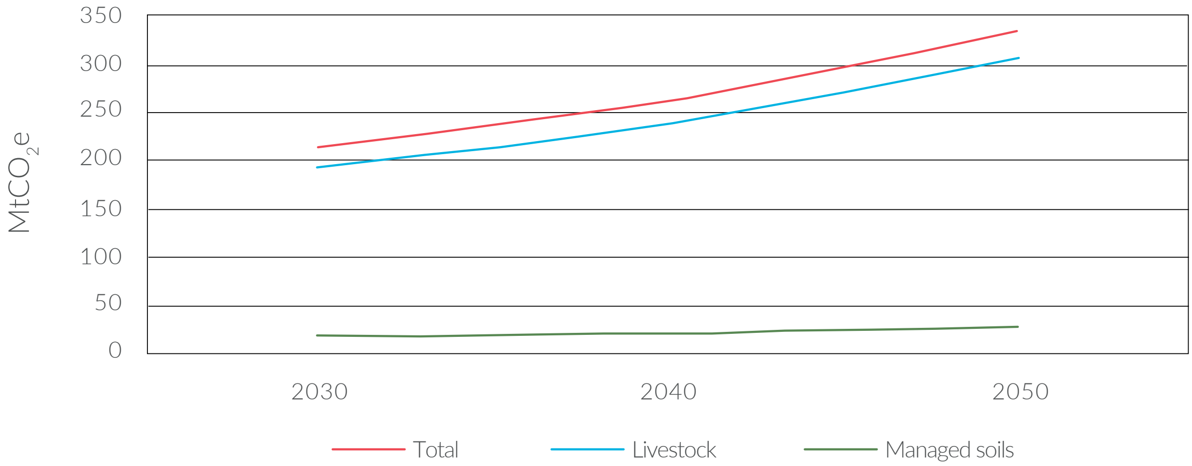
Based on past trends in Climate Smart Agriculture (CSA) data, the BAU scenario considers an increasing trend of areas of land under annual crops, perennial crops, and rice production. Likewise, the projected livestock generally shows an increasing trend for all livestock species. The main driver of this trend will be population growth, which triggers agricultural land expansion to ensure food and nutrition security. In sum, the major factors that increase GHG emissions from the Ethiopian agriculture sector over the next 30 years include the following:

- An increase in the livestock population (cattle, sheep, goats, mules, donkeys, horses, camels, and poultry).
- An increase in the area of land under annual crop cultivation (e.g., cereals, root crops, pulses, and rice), mainly in lowlands.
- An increase in the quantity of synthetic fertilizers used for crop production.
- An increase in the quantity of pesticides used for crop production (herbicides, insecticides, fungicides).
- An increase in the quantity of lime application to treat agricultural land affected by soil acidification.

On the other hand, there will be an increase in the area of land under perennial crops cultivation, such as coffee, tea, enset, and several types of fruit orchards (e.g., mango, avocado, orange, banana, papaya), which will mitigate GHG emissions. It is estimated that national GHG emissions from the agriculture sector will be 333 MT CO_2e/year by 2050. Specifically, emissions from the livestock subsector will be the largest (304 MT CO_2e/year), as indicated in Figure 4.15.

FIGURE 4.15

Estimated annual GHG emissions for the agriculture sector, without considering perennial crops.

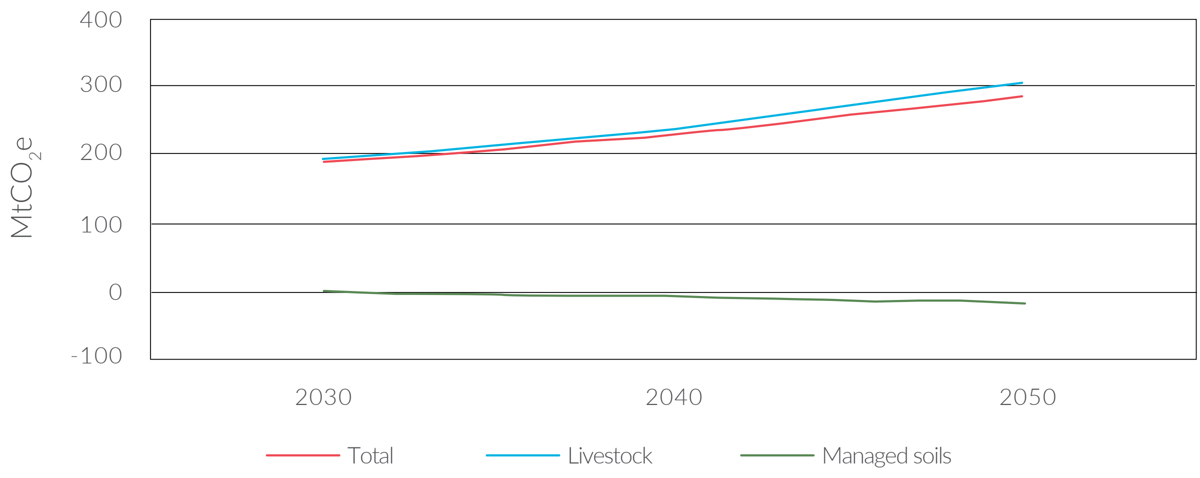


The estimation of GHG emissions from managed soils shows carbon sequestration, even under the BAU scenario, when perennial crops (e.g., coffee, fruits, chat, and tea plantation) are considered (Figure 4.16). Emissions from managed soils refers to emissions from annual crop production, fertilizer use, lime application for the amelioration of acid soils, and pesticides to control weeds, insects, and bacterial and fungal diseases. Therefore, emissions from managed soils consist of CH_4 and N_2O gases from annual crops production, CO_2 from limestone application, and N_2O from nitrogen fertilizers.

When perennial crops such as fruits and coffee are considered, there is accumulated carbon sequestration of -18 MT CO_2e/year by 2050. As part of the Green Legacy Initiative, which has demonstrated Ethiopia's bold leadership in climate action, planting fruits and coffee has been given appreciable attention. This initiative is expected to continue for the next decades.

FIGURE 4.16

Estimated annual GHG emissions for the agriculture sector, considering perennial crops (BAU scenario)



Low-emission scenario

To develop the low-emission pathway for the country's agriculture sector, promising and high-level mitigation interventions are proposed, as depicted in Table 4.7 below.

TABLE 4.7

High-level mitigation measures for low-emission pathways for Ethiopia's agriculture sector

Agriculture: high-level Interventions	2020	2030	2050
Manure management	0%	20%	40%
Feed management (oil seed feeding)	0%	10%	25%
Improved livestock productivity	0%	14%	40%
Substitution of poultry for cattle	0%	10%	20%
Agricultural mechanization	0%	10%	25%
Production of fruits and other perennial crops (ha of land)		1.5 million ha	3.5 million ha
Integrated soil fertility management	0%	15%	25%
Improved rangeland management	0%	20%	40%

Manure management: methane emissions from livestock production will be significantly reduced through proper management of manure, including aeration of manure stockpiles and using manure to prepare compost together with other materials. Given the large livestock population in the country, effective management of manure is needed to reduce methane and enhance crop productivity by leveraging organic fertilizers, such as farmyard manure and compost. Furthermore, biogas generation will be promoted to reduce GHG emissions under dairy farms in urban and pre-urban areas.

Feed management: considering the local farming conditions, the adoption of appropriate feeding strategies (e.g., corn or legume feeds) that reduce GHG emissions will be fostered among livestock keepers, mainly in intensive and mixed crop-livestock farming systems. Promotion of feasible cattle feed additives will also be made to reduce methane production based on research recommendations.

Improved livestock productivity: through improved animal nutrition and breeding programs, the country's livestock productivity will be enhanced to eventually reduce GHG emissions. To this end, agricultural extension and advisory systems will be strengthened, improved livestock feeding systems will be widely promoted, and breeding programs will be designed and implemented, tapping into the opportunities that innovations in science and technology offer.

Substitution of poultry for cattle: the country has great potential to gain environmental and economic benefits from poultry production by reducing its dependency on cattle production. Expansion of poultry production will be prioritized, particularly by small and medium enterprises. The supply of improved poultry breeds will also be enhanced to be adopted by smallholder farmers, coupled with good management practices. Furthermore, an enabling environment will be created for the private sector to actively engage in a large-scale poultry production.

Agricultural mechanization: currently, agricultural mechanization development is at an infant stage in the country. Smallholder farmers largely depend on animals to carry out agricultural activities, such as land cultivation, crop threshing, and transportation. Expansion of agricultural mechanization technologies that fit smallholder farmers' context will be prioritized to reduce the reliance on animal traction, which contributes to the reduction of GHG emissions from the livestock sector.

Production of fruits and other perennial crops: the country has tremendous potential to produce a vast array of fruits (e.g., mango, avocado, and citrus) and other perennial crops (e.g., coffee). These crops have considerable potential to reduce GHG emissions by enhancing soil carbon sequestration. Furthermore, the expansion of perennial crops will foster efforts toward improving food and nutrition security by reducing climate change risks. The government will continue to strongly support the production of fruits and other perennial crops through initiatives such as Green Legacy.

Integrated soil fertility management: this involves the combined application of organic fertilizers (e.g., compost and farmyard manure) and chemical fertilizers. On top of mitigating GHGs by increasing nitrogen use efficiency, this approach is more economical than the sole application of chemical fertilizers in maintaining sustainable crop productivity. Thus, an integrated soil fertility management approach will be promoted to be widely adopted by millions of smallholder farmers in the country.

Improved rangeland management: Ethiopian rangelands support several million households and a significant proportion of the country's livestock population. However, rangelands are highly degraded, primarily due to unsustainable grazing management, fire, and land conversion, leading to increased GHG emissions. The livelihoods of agro-pastoralists and pastoralists that live in the degraded rangelands are also threatened. To restore the degraded rangelands, improved grazing management approaches will be promoted to enhance quality forage production and increase perennial species through appropriate technical and social innovations. Restoration of the degraded rangelands will also increase aboveground and belowground soil carbon stocks.

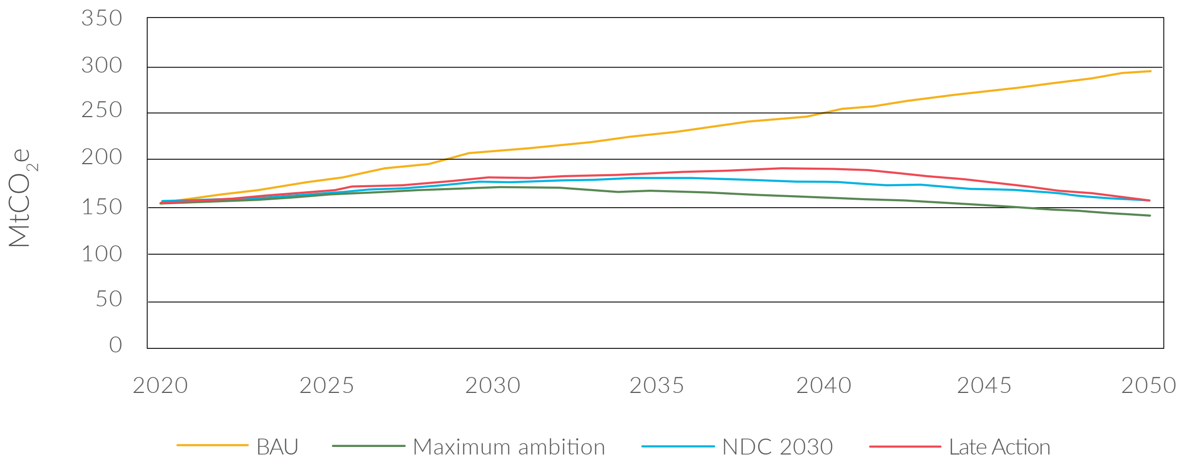
The following interventions will be implemented to realize the agriculture sector low-emission pathway:

- Expanding agricultural financial services
- Developing sustainable land-use and spatial planning
- Strengthening public-private partnerships
- Promoting market-oriented agricultural production
- Strengthening research and extension systems to foster the adoption of mitigation measures among farmers
- Developing institutional and technical capacities needed to switch to low-emission pathways
- Transitioning from diesel-based irrigation to solar-powered irrigation systems
- Expanding agroforestry practices and restoration of degraded agricultural land
- Promoting regenerative agriculture to enhance soil carbon sequestration
- Promoting green energy innovations along agricultural value chains

In connection with the expansion of solar-powered irrigation, appropriate technologies will be adopted to enhance water use efficiency. Furthermore, integrated watershed management will be implemented to increase groundwater recharging, reduce siltation in dams and reservoirs, and enhance soil and water conservation, which will contribute to achieving SDG 6.4.1 and ensure sustainable water management. Under the low-emission pathway, GHG emissions will be significantly reduced from Ethiopia's agriculture sector, as indicated in Figure 4.17. Compared to the BAU scenario, emissions in 2050 will be 163 Mt CO_2e lower in the low-emission scenario.

FIGURE 4.17

Projected GHG emissions from Ethiopia's agriculture sector (under low-emission pathways).

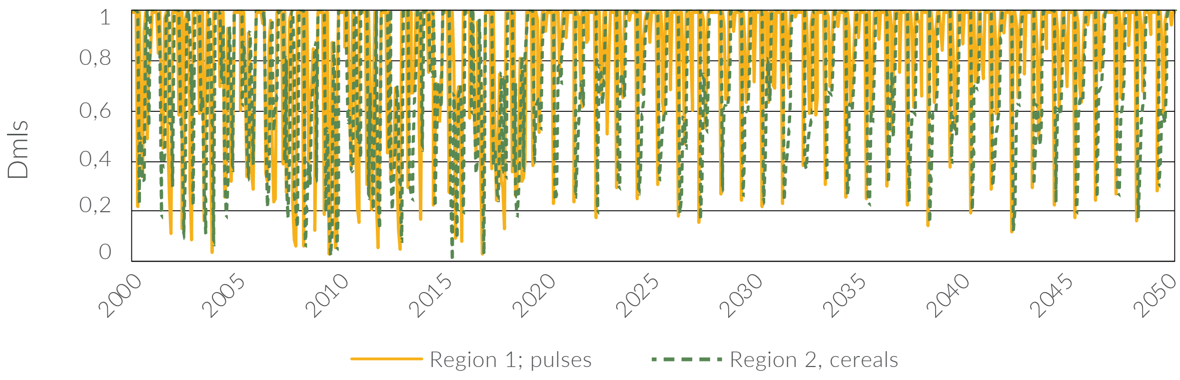


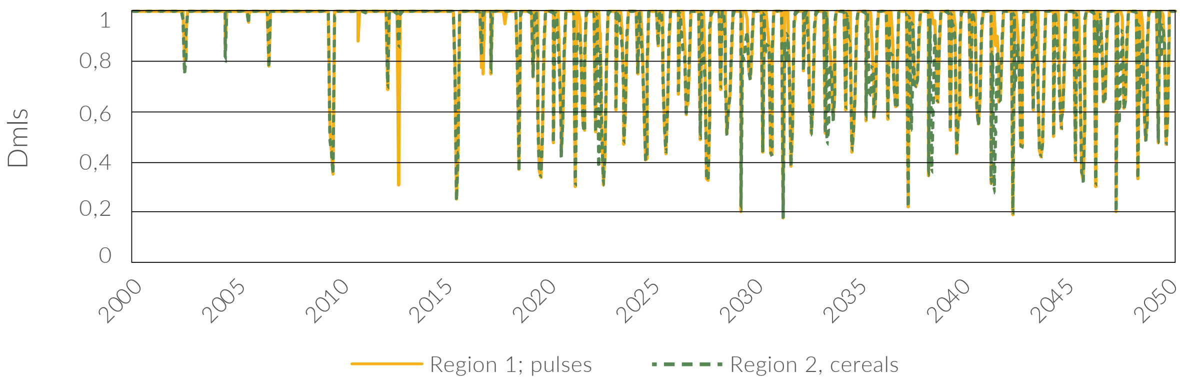
Climate resilience of the agriculture sector

The agriculture sector in Ethiopia is highly vulnerable to the impacts of climate change, with droughts becoming more frequent and severe. Ethiopia has a high dependence on rain-fed agriculture and relatively low adaptive capacity to deal with climate impacts. The analysis of the climate change impact on agriculture in the LT-LEDS considers the consequences of water scarcity due to precipitation variability in crop yields. Lost value in agriculture is calculated by multiplying the lost crop production by the average profitability per crop. Water scarcity impacts are assessed by comparing net crop water demand by crop type and month-to-month rainfall. A water scarcity impact threshold is applied, calibrated based on information from the historical data on average temperature and precipitation as provided by the National Meteorology Agency of Ethiopia. The impacts of water scarcity in cereals and pulses for two selected regions are shown in Figure 4.18 based on the modeling results. The downward spikes show that the impacts of water scarcity occur only in certain months. The figure also shows two important observations: water scarcity impacts different crops differently, and the impacts are not uniform across the country, instead varying by region.

FIGURE 4.18

Impact of water scarcity on the yield of cereals and pulses in region 1 (top) and region 7 (bottom)





As shown in Table 4.8, several climate adaptation actions are defined and modeled in the NZE scenarios to empirically analyze their role in minimizing the losses and improving the resilience of the agriculture sector.

TABLE 4.8

Adaptation interventions and their respective targets in the agriculture sector that are modeled in GEM

Adaptation intervention	Indicator	Baseline indicator 2020	2030 Target	2050 Target
Reduce preharvest losses in crop production	% of losses in yield	25%	23%	10%
Increase climate-smart agriculture practices	Share of land that has CSA practices	0%	25%	80%
Increase irrigation schemes	Area under irrigation schemes	0.49 mil. ha	1.2 mil. ha	3.6 mil. ha

TABLE 4.8

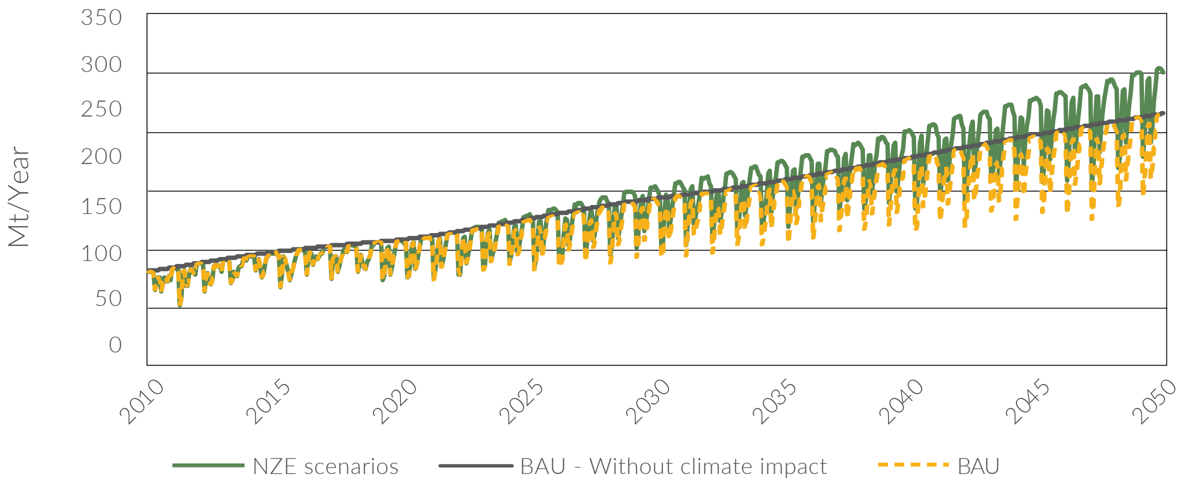
Adaptation interventions and their respective targets in the agriculture sector that are modeled in GEM (cont.)

Adaptation intervention	Indicator	Baseline indicator 2020	2030 Target	2050 Target
Diversify crops by using improved climate-resilient seeds	Share of land that uses improved seeds	Teff: 31,000 ha Barley: 70,000 ha Wheat: 413,000 ha Corn: 438,000 ha	Teff: 100,000 ha Barley: 193,000 ha Wheat: 673,000 ha Corn: 823,000 ha Sorghum: 360,000 Pulses: 85,000 Oilseeds: 50,000 Potato: 110,000	Teff: 250,000 ha Barley: 400,000 ha Wheat: 1,500,000 ha Corn: 1,800,000 ha Sorghum: 720,000 Pulses: 190,000 Oilseeds: 120,000 Potato: 260,000
Utilize climate-smart, technology-based mechanical agriculture	Annual increase in mechanization rate in crop production	NA	1%/a	1%/a
Diversify livestock using genetically improved breeds	% of improved dairy cattle	2.7%	17%	30%

Cumulatively, the forecasted crop production losses due to climate change in 2020–2050 total 202 million tons (10.5% of maximum potential yield) in the BAU scenario. In the NZE scenarios, total crop production in 2020–2050 is 3.5 million tons higher than in the BAU without climate impacts, implying that adaptation measures—in the form of sustainable practices and expanded irrigation—and their respective targets are capable of completely offsetting the negative impacts of climate change with respect to crop production in the agricultural sector. The results of the total crop production, along with the monthly variability, is shown in Figure 4.19 The results of all NZE scenarios are similar as the ambition levels for the adaptation actions were not varied across the scenarios.

FIGURE 4.19

Reduction in crop production in the NZE scenarios with and without climate impacts



Besides the adaptation actions that were modeled in GEM, several long-term adaptation strategies are defined in the LT-LEDS to enhance the resilience of Ethiopia's agriculture sector to the changing climate. These strategies were selected based on various discussions in the Agriculture Working Group and workshops and then validated in a larger group of national stakeholders through national consultation processes. The long-term climate adaptation measures for the agriculture sector are defined as follows:

- Expanding (solar) irrigation-based crop production
- Enhancing integrated crop disease and pest management
- Strengthening and expanding animal health services
- Promoting early maturing and drought-tolerant crop varieties
- Improving the water supply to livestock production
- Improving irrigation-based forage and fodder production
- Developing an insurance system for crops and livestock
- Strengthening seed systems
- Developing a sustainable marketing system for crops and livestock
- Strengthening climate information services for farmers
- Expanding soil and water conservation measures
- Enhancing conservation of agro-biodiversity
- Reducing post-harvest losses and food waste in the country's agri-food system
- Expanding agricultural extension services to smallholder farmers on climate-resilient agriculture
- Promoting conservation agriculture in appropriate agroecological zones
- Developing the capacity of agricultural cooperatives and strengthening agricultural marketing systems
- Expanding agro-processing

In addition to the quantitative adaptation benefits of adaptation actions in the energy sector, there are important adaptation co-benefits of the mitigation actions in the agriculture sector. Table 4.9 illustrates the most important synergies and trade-offs of the agriculture mitigation actions.

TABLE 4.9
Adaptation co-benefits and trade-offs of mitigation actions in the agriculture sector

Mitigation action	Adaptation co-benefits	Adaptation trade-offs
Manure management	> Combined use of manure and mineral fertilizers leads to greater yield responses > The application of manure from livestock waste serves to improve soil fertility and soil organic matter	
Feed management (oil seed feeding)	> Improved animal performance	> Some secondary compounds can inhibit optimal performance, such as high fat content that can lead to milk fat depression > Proper processing and management of feed can mitigate these anti-nutritive components
Improved livestock productivity	> Improved resilience > Reduced feed requirement during drought	> Increased productivity of livestock systems generally increases overall food production and absolute GHG emissions, albeit at lower emissions per unit of food
Substitution of poultry for cattle	> Improved resilience; reduced feed requirement during drought	
Agricultural mechanization	> Improved resilience	> Not applicable in the context of scattered and fragmented landholdings, undulating and steep slopes, or terraced and nonuniform shape of crop fields > Agricultural intensification that improves crop productivity can increase incomes but undermine local livelihoods and well-being
Production of fruits and other perennial crops	> Improved resilience	
Integrated soil fertility management	> Improved resilience > Improved soil moisture > Flood risk protection > Improved soil fertility > Reduced soil erosion > Enhanced soil carbon storage	> It increases the incidence of pests and diseases and soil waterlogging > Minimum/zero tillage could also lead to lower yields, especially if solely adopted
Improved grassland/ rangeland management	> Improved resilience > Improved soil moisture > Flood risk protection > Improved soil fertility > Reduced soil erosion > Enhance soil carbon storage	> Shifting to rangeland for feed can strongly increase tropical deforestation

Although the adaptation co-benefits of the mitigation actions are many, several barriers prevent these synergies from being fully achieved. For example, increasing the share of perennial crops production, which contributes to additional carbon sequestration and improved resilience, faces resistance as the focus in Ethiopia remains on annual major food crops (e.g., wheat, maize, and teff) due to food insecurity. One plausible way of addressing this would be to widely promote production of perennial crops, like fruits, by developing robust strategies and a reliable market system for smallholder farmers.

At a much smaller sectoral level, limitations preventing these synergies from being fully utilized include limited farmers' skills in operating mechanized equipment; limited access to irrigation water in dry areas; and limited technical skills of agricultural extension workers in diversified crop production, disease management, and post-harvest handling. These can be addressed by enhancing the supply of seedlings, fostering adoption of improved crop varieties among farmers, and improving farmers' and extension workers' skills by providing customized capacity building and raising awareness.

4.5 CLIMATE ACTIONS IN FORESTRY AND OTHER LAND USE FOR ENHANCING CARBON SINKS

Sectoral background

Forestry policy frameworks

As part of the CRGE framework, Ethiopia developed its **National REDD+ Strategy** to improve management of forests and agricultural areas. The implementation of REDD+ programs contribute to significant emission reductions from land use, including forestry by reducing the rate of deforestation and forest degradation (MEFCC, 2018). The National REDD+ Strategy aims to implement the following actions (MEFCC, 2018): scaling up the areas under participatory forest management; enhancing appropriate afforestation; enhancing the timber supply to reduce pressure on nature forest; rehabilitation of degraded pastureland, farmland, and highlands to increase fertility and carbon sequestration; and encouraging communities to engage in sustainable wood biomass production for charcoal and firewood. With the aim to operationalize the CRGE and the REDD+ Strategy, the **National Forest Sector Development Program (NFSDP)** was initiated by Ethiopia's Ministry of Environment, Forest and Climate Change (MEFCC) as the main guiding document for coordinating strategic policy interventions and sector-wide investments for the coming ten-year period. The proposed actions with the most transformative potential include attracting private investment in commercial forestry and establishing industrial clusters for manufacturing timber and other industrial wood products for domestic consumption and export. This would help Ethiopia's transition to a green growth strategy that replaces energy-intensive construction materials, such as steel and concrete, with high-quality wood-based buildings and infrastructure. Further, the NFSDP aimed to establish payment for environmental services schemes to better valorize the forest's contribution to watershed management and carbon sequestration.

Forests regulate ecosystems, protect biodiversity, play an integral part in the carbon cycle, support livelihoods, and supply goods and services that can drive sustainable growth. Their role in climate change is twofold: deforestation and forest degradation are both a cause and an effect of the changing climate. Forests are also one of the most important solutions to addressing the effects of climate change.

With forestry in Ethiopia being primarily a rural activity, the sector has enormous potential to transform the rural economy. The sector also adds value through harboring biodiversity resources and other ecosystem services, such as climate regulation, fertile soil, water, and clean air. Ethiopia's diverse forest resources—including high forests, woodlands, and trees on farms—have among the highest biodiversity in the world and provide a wealth of goods and services to ensure a green economic growth pathway while maintaining rapid infrastructure development and urbanization.

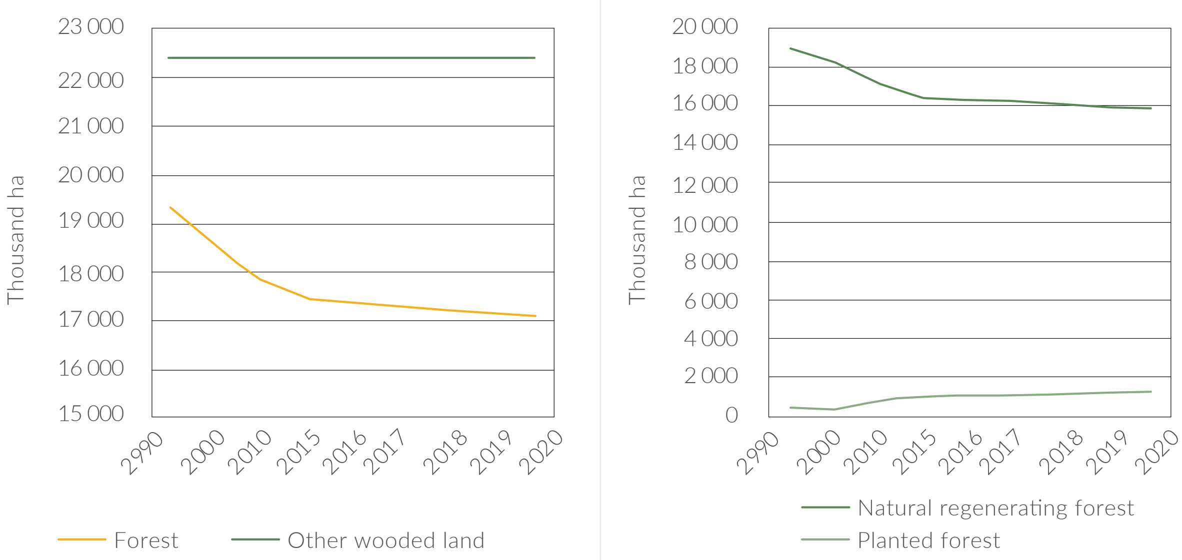
However, Ethiopia's forests face several challenges and threats: small- and large-scale agricultural land conversion, increased wood extraction for fuel and construction, pressure caused by increased livestock grazing and gaps in the application of forest policy and regulations; tenure/unclear forest user rights; lack of private investment in forestry development; population growth; and inadequate land use planning and participatory forest management (MEFCC, 2018). Consequently, the forestry sector is the second largest contributor of GHG emissions in the country after agriculture.

Historical land use change

Land use and land cover changes in Ethiopia are primarily influenced by increases in population and agricultural product demand, as well as low-efficiency combustion in rural households, which translate to deforestation and forest degradation. Deforestation correlates with the expansion of agricultural land needed for crop production, which is essential to ensure food security and poverty alleviation in the face of demographic pressure. Additionally, Ethiopia's rural energy needs are predominantly satisfied by biomass (>90%) (Federal Democratic Republic of Ethiopia, 2011). The development of fuelwood consumption is primarily influenced by population increase. Finally, authorized and unauthorized, logging is currently a relatively minor driver of deforestation and forest degradation. Since 1990, forest cover has progressively declined while other wooded land has remained the same, as seen in Figure 4.20. The main difference between forest and other wooded land is their tree density, with the former having an average of 124.7 trees per hectare and the latter only presenting 21.1 trees per hectare (MEFCC, 2018)

FIGURE 4.20

Forest and other wooded land (left) and natural and planted forest (right) (Source: FAO, 2020)



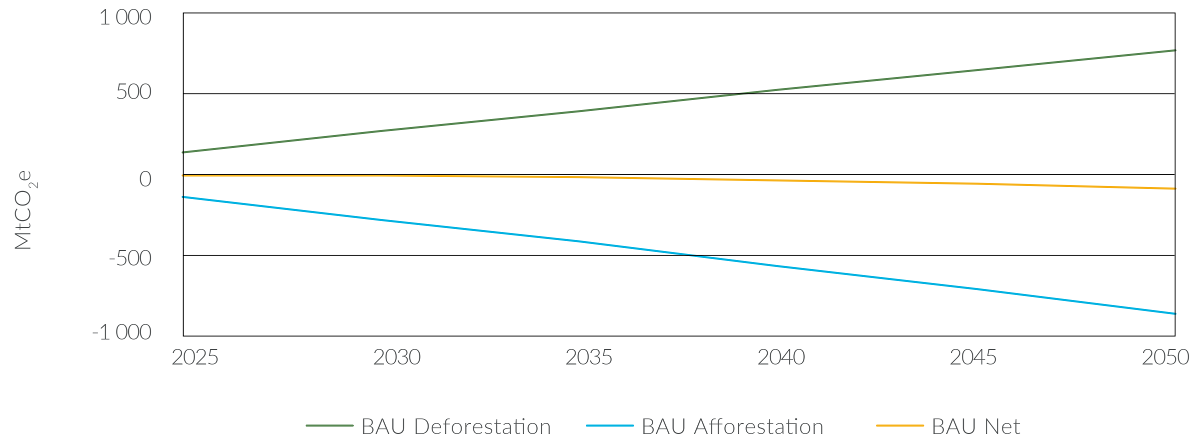
Not only is forest suffering degradation but natural forest is being lost (see Figure 4.21). From a GHG emissions perspective, this b ecomes even more important since a higher amount of carbon stocks are lost and the period to recover them is longer. The rate of deforestation for 2000–2013 and 2014–2020 was 91,735 ha/year and 38,194 ha/year, respectively. The rate of afforestation and reforestation for 2000–2013 and 2014–2020 was 18,928ha/year and 34,283 ha/year, respectively. A comparison of the panels in Figure 4.21 indicates a declining trend in deforestation and an increasing trend in afforestation and reforestation efforts (EFCCC, 2017, 2021). Although the forestry sector, along with the agricultural sector, is a main emitting sector, it has the potential to mitigate the totality of its emissions and contribute to Ethiopia's carbon neutrality goal while supporting sustainable economic development.

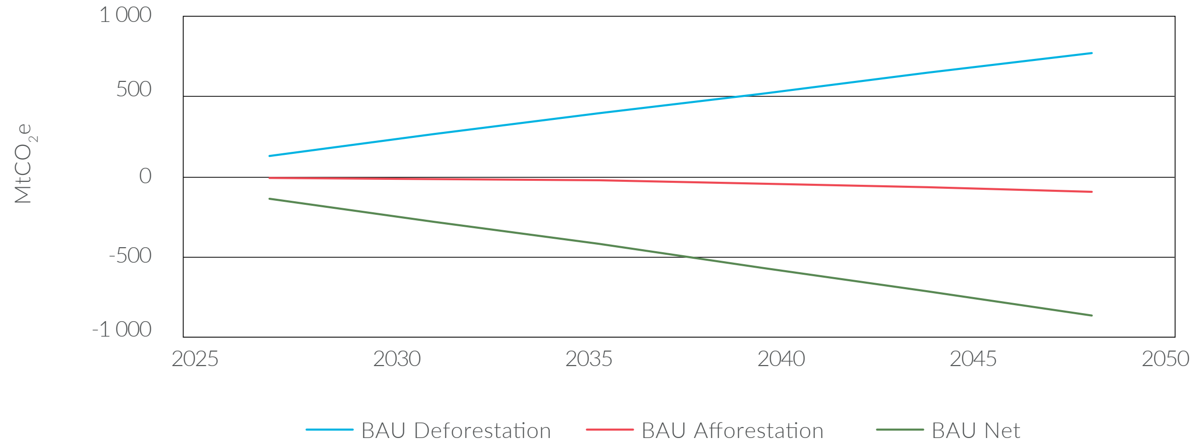
Business-as-usual results

The results from the aggregation of the five-year-long models indicate that emissions from the forestry sector will reach 771.04 million tons of CO_2e (Mt CO_2e) by 2050 while also capturing 859.99 Mt CO_2e by the same year. This would amount to net emissions (emissions minus carbon captures) of -88.95 Mt CO_2e in 2050 Figure 4.21.

FIGURE 4.21

National BAU GHG emissions for the forestry sector, 2020–2050 (cumulative)





The four biomes *Acacia-Commiphora*, *Combretum-Terminalia*, Dry Afromontane, and Moist Afromontane are net sources of emissions given their positive deforestation rates. Nevertheless, forest gains compensate these emissions. Additionally, average emissions per hectare and yearly average emissions have been estimated (Table 4.10). The GoE could use these indicators as a reference to set emission reduction goals of the different policies of interest. Additionally, when applied to the regional model, it would direct the focus toward efforts on those with higher emissions per hectare.

TABLE 4.10

National average emissions for 2020–2050 (tCO_2e/ha & tCO_2e/yr)

Region	Average annual emissions, tCO_2e/yr	Average annual reductions, tCO_2e/yr	Average annual net emissions, tCO_2e/yr	Total emissions, tCO_2e/ha
National	25,701,568	-28,666,535	-2,964,967	-1.3

Low-emission scenarios

Based on the review of existing policy documents and considering the opinion of the national experts of the established agriculture working group, three decarbonization interventions were selected to be modeled: reduction of the deforestation rate, afforestation and reforestation, and forest restoration.

These interventions were selected because they galvanized emission reduction and carbon sequestration activities currently being implemented and planned. These interventions were validated by an expanded group of experts (leaders and forestry program managers) invited by the Ethiopian members of the FWG during a workshop that also determined the ambition of each decarbonization priority.

TABLE 4.11

Quantitative targets of Ethiopia's forestry sector decarbonization and adaptation interventions

Forestry: high-level interventions	2020–2030	2030–2040	2040–2050	Total (2020–2050)
Reduced deforestation	**25% deforestation rate reduction** 2.5% annual reduction	**12.5% deforestation rate reduction** 1.25% annual reduction	**12.5% deforestation rate reduction** 1.25% annual reduction	**50% deforestation rate reduction**
Afforestation and reforestation				
Maximum ambition scenario	0.27 million ha/year	0.27 million ha/year	0.27 million ha/year	**8.2 million ha**
NDC-aligned scenario	0.27 million ha/year	0.18 million ha/year	0.33 million ha/year	**8.2 million ha**
Late action scenario	0.09 million ha/year	0.1 million ha/year	0.63 million ha/year	**8.2 million ha**
Forest restoration				
Maximum ambition scenario	1.1 million ha/year	0.45 million ha/year	0.45 million ha/year	**20 million ha**
NDC-aligned scenario	0.4 million ha/year	0.4 million ha/year	0.8 million ha/year	**16 million ha**
Late action scenario	0.15 million ha/year	0.15 million ha/year	1.3 million ha/year	**16 million ha**

As can be seen, the FWG and the expanded group of experts determined that the reduced deforestation and forest restoration decarbonization interventions would have a steadfast implementation rate during the first 10 years (2020–2030) and a less vigorous one the following 20 years (2030–2050).

Reduced deforestation target: deforestation is reduced at a faster rate until 2030 and continues being reduced afterward but at a slower pace. With the reduced deforestation target, Ethiopian forest would cumulatively emit 550.39 Mt CO_2e and would capture 859.99 $MtCO_2e$, with net emissions amounting to -309.61 Mt CO_2e during the 30-year analysis period. Compared to the BAU scenario, this decarbonization priority considerably reduces emissions. From 2020 to 2050, reduced deforestation would diminish GHG emissions by 220.66 Mt CO_2e, or 7.35 Mt CO_2e yearly.

Afforestation and reforestation target: Ethiopian forest would only cumulatively emit 225.1 Mt CO_2e and would capture 4,110.92 Mt CO_2e, with net emissions amounting to -3,885.52 Mt CO_2e for 2020–2050. The increase of forest cover would produce a significant amount of emission reductions when compared with the remaining emissions. These emissions are the result of the continuous deforestation suffered by other wooded land. Compared to the BAU scenario, this decarbonization priority considerably reduces emissions. From 2020 to 2050, afforestation and reforestation capture 3,796.87 Mt CO_2e, or 126.56 Mt CO_2e yearly. Since the late-action scenario first delays afforestation action, the ambition after 2040 must be correspondingly higher to still achieve the overall target.

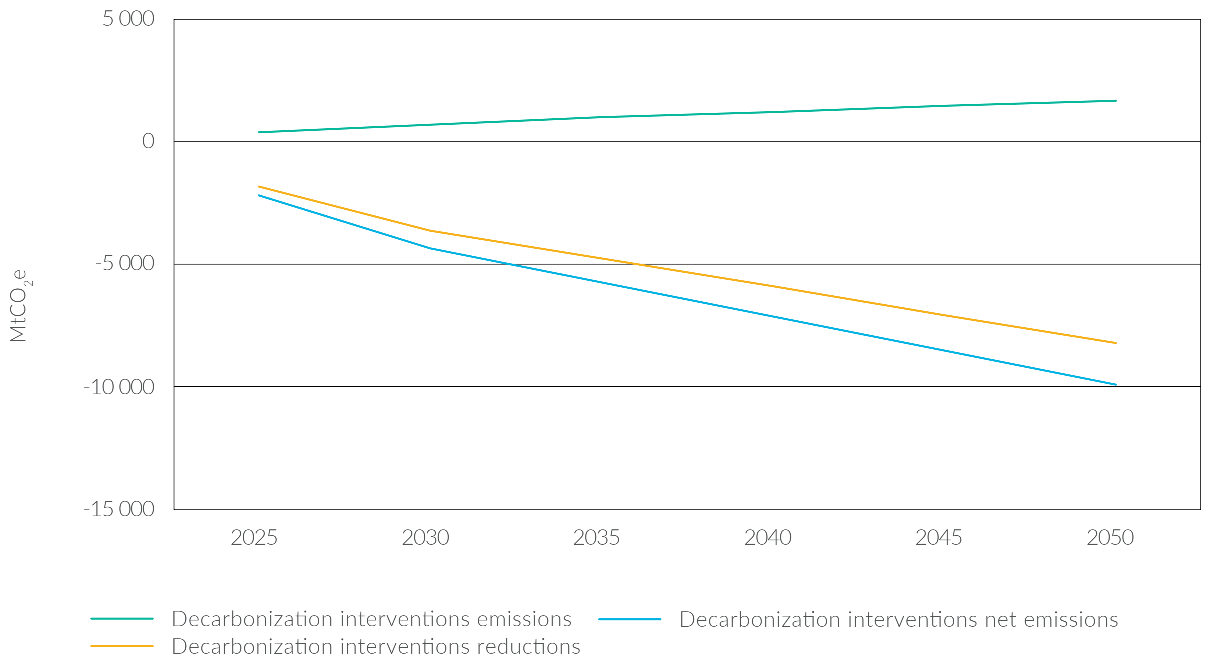
Forest restoration: the intervention of forest restoration causes emissions of 88.09Mt CO_2e—higher than the BAU scenario—but would capture 4,941.22 Mt CO_2e, with net emissions reaching -4,042.12 Mt CO_2e for 2020–2050. The higher level of emissions occurs because of the amount of degraded land in each biome and their different carbon content factors. Although considerable areas are restored, they are allocated in the ***Acacia–Commiphora*** biome, which has the lowest carbon content factors among Ethiopian ecosystems. Additionally, given that deforestation is kept as an underlying driver, the areas transferred from other wooded land to forest are not enough to counter its effect. When contrasted with the BAU scenario, this decarbonization priority produces the highest number of emission reductions. From 2020 to 2050, it captures 3,953.17 Mt CO_2e, or 131.72 Mt CO_2e annually.

Mitigation potential of the forestry sector

To estimate the potential of the implementation of the three decarbonization interventions, their emission reductions were summed and contrasted against the BAU scenario. The addition of the individual emissions of all decarbonization interventions amount to 1,674.58 Mt CO_2e, with their removals reaching 9,912.13 Mt CO_2e and net emissions reaching -8,237.55 Mt CO_2e along the 30-year period (Figure 4.22).

FIGURE 4.22

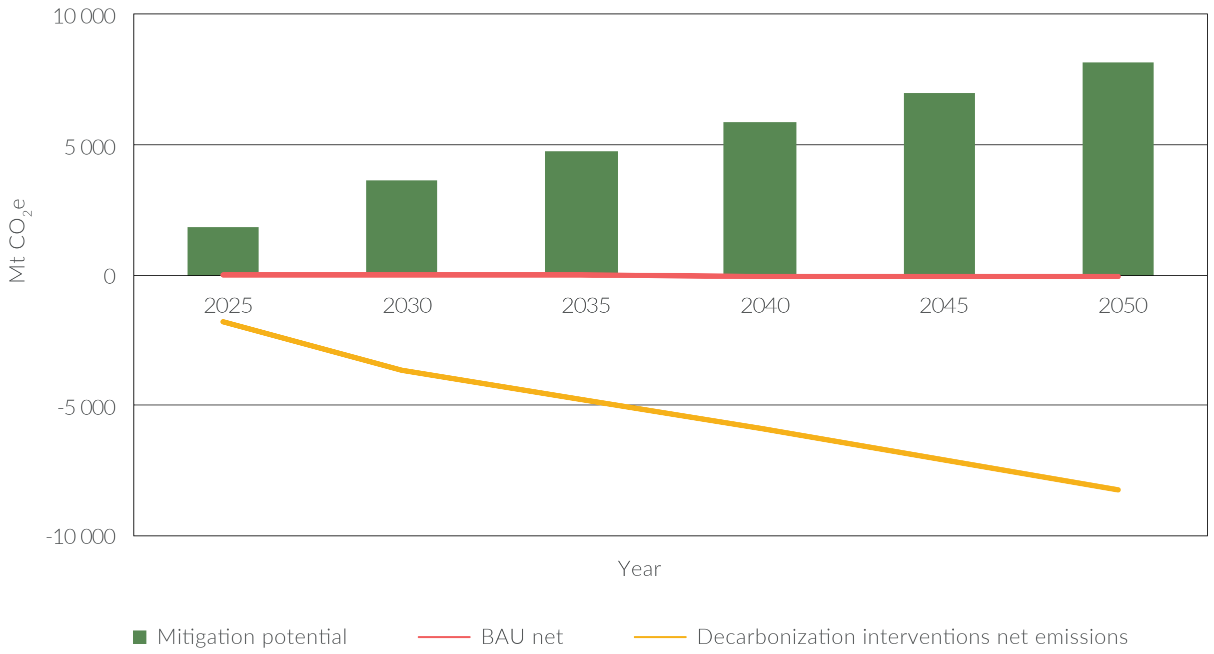
Emissions pathways for decarbonization forestry intervention actions, 2020–2050



When compared with the BAU scenario, all decarbonization interventions produce 14,466.93 Mt CO_2e of carbon removals, or 482.23 Mt CO_2e per year (Figure 4.23).

FIGURE 4.23

Emission pathways and mitigation potential for BAU and decarbonization intervention actions



Additional mitigation actions for increased ambition

Using forests to help mitigate climate change globally involves finding ways to increase their potential to be carbon sinks. Due to the complexity of some mitigation actions, a lack of data to model their emissions, or linkages with other emitting sectors, the LT-LEDS did not include the following actions, which should be considered for future climate efforts:

I. Reduction of fuelwood consumption through improved cooking and baking technologies

II. Shift from unsustainable biomass energy demand to electric stoves and renewable biofuels while establishing safeguards to avoid carbon leakage from a high-emitting energy matrix in the power generation sector

III. Improved forest management in commercial plantations to enhance their carbon capture potential

IV. Fostering the rehabilitation of degraded pastureland, farmland, and highlands, leading to enhanced soil fertility and thereby ensuring additional carbon sequestration

V. Implementing Payment for Environmental Services schemes to better valorize the forest's contribution to watershed management and carbon sequestration.

Climate resilience of the forestry sector

Increasing forest cover in the highlands of Ethiopia will dramatically improve their hydrological functions through infiltration and soil protection, thereby reducing floods while increasing availability of surface water and groundwater across the country. Water is a strategic resource for Ethiopia as it could be harnessed to generate hydropower sustainably, used for irrigation agriculture, and even exported to nearby dry land countries for generating hard currency. Forest development can also positively impact other sectors, such as tourism and wildlife development, besides its role in conservation of animal and plant diversity (MEFCC, 2018).

Investment in the forest sector is a strategic move to mitigate the impact of climate change and is a key component in Ethiopia's national growth and transformation plan (MEFCC, 2017). Ethiopia recognizes that its forests are ideally placed to produce multiple dividends in the fight against climate change. The Forestry Working Group has decided to adopt the same strategies from the Ethiopia's NDC update for the long-term climate resilient strategies of the forestry sector in the LT-LEDS.

TABLE 4.12
Mitigation and adaptation actions of the forestry sector according to the updated NDC

Mitigation actions	Adaptation actions
Forest restoration	Perform restoration and reforestation through tree planting
Afforestation and reforestation	Increase national forest coverage
	Implement forest protection and health enhancement measures in natural forest ecosystems
Reduce residential biomass use	Enhance sustainable forest management
	Improve sustainable utilization of forest

Mitigation and adaptation measures in the forestry sector likely have the greatest synergies among all sectors, which were also identified and assessed in detail by the Forestry Working Group. Table 4.13 illustrates the results of the assessment, showing the main adaptation synergies and trade-offs of the forestry mitigation measures.

TABLE 4.13
Adaptation co-benefits and trade-offs of mitigation actions in the forestry sector

Mitigation action	Adaptation co-benefits	Adaptation trade-offs
Reduced deforestation Afforestation/ reforestation Forest restoration	> Ecosystem services conservation > Improvement of water-related ecosystem services > Reduced impact of heat island effect in urban areas > Income diversification (nontimber forest products) > Creation of green jobs > Carbon offset funds provide opportunities for protection and restoration of native ecosystems, with corresponding gains for biodiversity and reductions in carbon > Reforestation connecting fragmented forests reduces exposure to forest edge disturbances > The use of fertilizer-fixing trees can improve soil fertility through nitrogen fixation by increasing the supply of nutrients for crop production	> Reduced food security > Potential land competition > Local benefits, especially for indigenous communities, will only be accrued if land tenure is respected and legally protected

Several climate adaptation actions are also identified for the forestry sector to increase its capacity to adapt to climate change and to ensure its future sustainability. These actions are listed in Table 4.14 and are assessed based on their potential synergy and trade-offs in terms of mitigating emissions.

TABLE 4.14

Mitigation co-benefits and trade-offs of adaptation actions in the forestry sector

Adaptation action	Mitigation co-benefits	Mitigation trade-offs
Perform restoration and reforestation through tree planting	> Avoided emissions > Carbon capture	Potential emissions leakage in the agriculture sector (use of fertilizers to increase crop productivity in lesser cropland)
Increase national forest coverage	Carbon capture	Potential emissions leakage in the agriculture sector (use of fertilizers to increase crop productivity in lesser cropland)
Enhance sustainable forest management	Increased carbon capture based on sustainable forestry practices	Emissions from logging equipment
Improve sustainable utilization of forest resources	Increased carbon capture based on sustainable forestry practices	Emissions from forest resources transport
Implement forest protection and health enhancement measures in natural forest ecosystems	Avoided emissions	-

The question arises why the synergies resulting from the implementation of these measures are not fully exploited in Ethiopia when there are clearly significant additional co-benefits. Better institutional arrangements, such as greater coordination between forestry and agriculture sector institutions, and efforts to promote a holistic and integrated approach to forestry projects are essential to maximize synergies. In terms of potential trade-offs, efforts such as reducing food waste, promoting the production of durable wood products, and promoting no-till systems and agroecological practices can reduce pressure on potential land competitors. In addition, the introduction of regulations to reduce the fuel consumption of timber harvesting machinery and equipment will help reduce potential additional emissions that could result from adaptation measures in the forest sector.

4.6 IMPROVING WASTE MANAGEMENT SYSTEMS

Sectoral background

Waste Policy Frameworks

Waste sector policies are generally based on several overarching policy documents, starting with national environmental and health policies. At a lower level, there are more specific strategies, such as the **Urban Development Policy**, which aim at ensuring environmental conservation and sanitation in cities to avoid overcrowding and pollution as the urban population grows. This includes collaboration between the public and private sectors in solid and liquid waste management. **Solid Waste Management Proclamation No. 513/2007** is mainly concerned with promoting community participation to prevent the adverse effects of solid wastes, while the **Solid Waste Management Strategy** emphasizes ways to reduce, reuse, and recycle waste; composting of organic solid waste; energy production from incineration; and waste disposal. Regarding practical implementation, the **Solid Waste Management Standard** defines the requirements in the waste management chain, ranging from institutional and financial aspects to issues of waste storage, waste collection systems, recycling, and recovery.

The main GHGs emitted from the waste sector in Ethiopia are methane, due to the anaerobic decomposition of organic matter within municipal solid waste (MSW) at disposal sites, and carbon dioxide resulting from incineration and open burning of waste. Domestic and industrial wastewater treatment and discharge also contribute to large methane and nitrogen oxide emissions. In the updated NDC (2021), it was estimated that the waste sector would contribute 3% of total BAU emissions in 2030.

The increasing urban population and changing consumption patterns in Ethiopia have resulted in a steady increase of MSW generated in the country. Several studies have been conducted on the quantity of MSW being generated in the country, with estimations varying widely from 0.31–0.46 kg/capita/day.[2,3] A recent government study of 55 towns in Ethiopia[4] indicated a per-capita solid waste generation rate of around 0.31 kg/day with an average density of 241.8 kg/m^3. The composition was estimated at 73% organic and 22% recyclable/reusable. The study also indicated that municipal solid waste collection and disposal coverage is estimated to be 40% nationwide.

Currently, limited segregation of waste occurs at the household level and most of the waste is sent to landfills, which are generally open dump sites. Apart from landfills, waste burning, and dumping are common, at least in smaller towns. Formal recycling is estimated to be as low as 2%. There is an ongoing open window composting project in six cities (Adama, Bahir Dar, Bishoftu, Dire Dawa, Hawassa, and Mekelle) that reached 29,000 tons in 2020. A thermal waste-to-energy facility was set up at the Koshi landfill with a capacity to treat 1,400 tons per day of MSW.

Wastewater is generated through both domestic and industrial activities in the country. Published studies[5] indicate that the quantity of wastewater generated in Ethiopia is about 4.2 m^3/capita/year (which is 11.5 l/capita/day). While this is low, it sits well with

2 Hirpe, L., and Yeom, C. "Municipal Solid Waste Management Policies, Practices, and Challenges in Ethiopia: A Systematic Review." Sustainability 13, (2021) 11241.

3 https://www.mdpi.com/2227-7080/9/3/48.

4 Government of Ethiopia. Solid Waste Generation, Composition, Collection in 55 cities, 2020.

5 https://essd.copernicus.org/preprints/essd-2020-156/essd-2020-156-manuscript-version2.pdf

6 https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/53371/IDL-53371.pdf, page 136

other longterm studies, which indicate[6] only about 25 l/capita/day is available for domestic use. Even when sewer systems are present, the large-scale treatment of wastewater is still limited. The UNICEF and WHO data warehouse on water and sanitation presents the following figures for sanitation services in the country in 2019:[7]

- Unimproved sanitation: 58.5%
- Open defecation: 25.7%
- Limited services: 6.1%
- Basic services: 2%

Business-as-usual scenario

The BAU scenario is centered around parameters including projected change in the volume of waste generated, the evolving composition of waste, and improved waste management practices. For the development of the BAU scenario, MSW is expected to increase from 0.45 kg/capita/day in 2020 to 0.65 kg/capita/day in 2050. Organic waste content is assumed to decrease from 65% in 2020 to 55% in 2050, with plastic increasing from 6% to 11% and paper increasing from 6% to 11%. Other components remain relatively stable.

For MSW landfill disposal, a value of 40% nationwide was used, with the following distribution. (1) unmanaged shallow: 10%, (2) unmanaged deep: 70%, and (3) uncategorized solid waste disposal sites (SWDS): 20%. Referring to the values for the methane conversion factor for SWDS given in the IPCC 2006 Guidelines, the calculated weighted methane conversion factor (MCF for the country was determined as 0.72. For the wastewater sector in the BAU scenario, emissions will continue to rise due to increased population growth but wil decrease in open defecation and enhanced treatment facilities releasing methane.

Low-emission scenario

Based on the existing policy documents and expert discussions with the relevant ministries involved, seven actions have been selected to decarbonize the waste sector. They are distinguished by solid waste management and wastewater management.

TABLE 4.15

Ambition levels for the low-emission interventions in the waste sector (for all scenarios)

Waste: high-level interventions	2030	2040	2050
Processing of organic municipal waste	20%	40%	50%
Landfill gas reduction	5%	20%	35%
4R measures: reduce, reuse, recycle, and recover energy of inorganic/dry waste	10%	20%	25%
Solid waste collection and management	80%	85%	90%
GHG emissions reduction from urban wastewater management	10%	40%	80%
GHG emissions reduction from rural and industrial wastewater management	10%	30%	70%
Fecal sludge treatment	4%	15%	30%

7 https://data.unicef.org/resources/resource-type/datasets/

Solid Waste disposal

Disposal sites are a significant source of GHG emissions in the waste sector due to the large organic fraction that decomposes under anaerobic conditions to emit landfill gas (LFG). LFG consists mostly of methane (50–60%) and carbon dioxide (40–50%). As waste collection rates increase over time, GHG emissions will increase if waste ends up in landfills that are not well managed. A landfill can emit GHG for many years (up to 30 years), even after closure. To minimize such emissions, two main actions are proposed: divert organic waste from landfill for subsequent reuse and manage LFG emissions.

Accumulation of waste in landfills that are not well managed also increases the risk of fire, which releases carbon dioxide, fine particles, and toxic materials. In addition, the lack of established waste minimization strategies and collection systems in some cities and in most rural areas can lead to the burning of waste as the main disposal option. Improvement actions include waste collection services and source separation of recyclables, improved management of landfills, and implementation of the 4R measures: reduce, reuse, recycle, and recover energy of inorganic/dry waste. Actions are detailed as follows:

1. Organic waste processing: to achieve this target, multiple aerobic and anaerobic interventions are available. The resulting compost can be used as soil amender on agricultural land, returning valuable nutrients and carbon to land while decreasing reliance on synthetic fertilizers. This intervention is well aligned with existing government policies. Commercial centralized facilities will capture the bulk of the organic waste in urban areas, about 100–200 tons per day. Composting will be completed by other types of smaller-scale aerobic processing, such as vermiculture and black soldier flies, which also generate proteins for animal feed. In rural areas, actions will focus on promoting smaller-scale household- or community-level processing, such as pit or pile composting. Developing markets and community acceptance for compost will be a critical component of this intervention.

The other main technology is anaerobic digestion (AD). AD is a bio-chemical treatment process involving microbial anaerobic digestion of pretreated and homogenized organic materials to produce biogas that contains 50–60% combustible methane. The biogas is then converted to electricity using gas engines to produce about 30–35% of energy from the biogas generated. Additionally, 35–40% of energy can be recovered as heat to be utilized for maintaining the digestor temperature as well as the pretreatment of feedstocks. The resulting digestate can be further treated and used as fertilizer, enhancing agricultural soil productivity and reducing the need for synthetic fertilizers. The aim will be to set up medium-sized (1–3 MW) biodigesters in urban areas and industrial parks, close to the waste generation source. In the longer term, the biogas can be converted to other valuable materials, such as bio-compressed natural gas-which can be more easily transported-bio-methanol, or biohydrogen.

2. Landfill gas (LFG) management: LFG can be extracted using a series of wells and pipes to direct the collected gas to a central point where it can be flared or beneficially reused (similarly to biogas in action 1). Because retrofitting is more expensive, installation should be considered a priority for new landfills, in line with the government plan to construct up to 200 sanitary landfills. Active gas management systems (flaring or recovering) rely on expensive technology and should be considered mainly for the larger landfill sites such as Koshi.

Other lower-cost actions will also be prioritized, such as improved operation and maintenance (O&M), including proper compaction, cover of waste, and the use of biofilters to reduce LFG emissions. Together with the development and implementation of O&M procedures, these actions will also decrease the risk of fires with associated emissions.

3. Reduce, reuse, recycle, and recover energy of inorganic/dry waste: avoiding the waste in the first place is the best way to minimize emissions. Efforts will be targeted at reducing the consumption of single-use items (e.g., plastic bags and containers) through policy, regulations, and awareness-raising interventions. For waste already generated, the next best option is reusing and recycling. Feasibility studies will be conducted and partnerships with the private sector will be explored to establish processing facilities for wastes, such as plastic, paper, batteries, and e-waste.

Finally, residual waste that cannot be recycled can be targeted for energy recovery. There is one existing thermal waste-to-energy (W2E) facility in Addis Ababa. The country is learning about these expensive and complex technologies and hopes that in the medium term (around 2040), more W2E plants can be built for the larger cities. In addition, refuse-derived fuel (RDF) will be considered as another W2E option, with the waste replacing coal in cement factories. This is a more affordable option than purpose-built thermal facilities. RDF is produced from the mechanical processing of MSW to recover recyclable materials, remove contaminants (glass, stones, etc.), remove moisture, and increase the calorific value.

4. Improved waste collection services and source separation of recyclables: solid waste collection will be increased throughout the country by improving infrastructure, equipment (e.g., bins and trucks), and logistics; strengthening waste collection contracts with the private sector; improving fee collection and subnational institutional arrangements; and raising awareness and developing/implementing regulations. Value chains of recyclable materials at the household and commercial levels (source separation, storage, collection, and transport) will be strengthened to ensure the materials arrive at the recycling centers with minimal cross-contamination. The 90% target includes collection and source separation of waste for organic processing (actions 1 and 3), with the residual waste going to well-managed landfills, where LFG emissions and open burning are minimized (action 2).

Wastewater treatment and discharge

In urban areas, it is expected that household connections to sewerage systems will increase, together with downstream treatment at wastewater treatment plants (WWTP). Operating WWTPs can increase emissions, especially if O&M is deficient, thus interventions largely focus on the smooth operation of these systems. In rural areas, septic tanks and pit latrines are large contributors of methane, and interventions focus on improved decentralized sanitation.

5. Improved urban domestic wastewater management: as per government policy, sewerage and WWTP infrastructure will be developed throughout the country. Already, Addis Ababa manages 34% of its wastewater, with some other towns also having access to small WWTPs. A poorly maintained and operated WWTP can generate significant emissions due to wastewater stagnation and lack of aeration, which can result in anaerobic conditions. It is important that once the infrastructure is built, necessary institutional and financial arrangements are made—such as proper training of staff, regular desludging, and regular maintenance—ensuring water discharge standards are met.

6. Improved rural and industrial wastewater management: an open-defecation-free (ODF) Ethiopia, including through public and community toilets, should be a key target but may result in increased emissions if not managed properly. The standard of household septic tanks and latrines will be improved. Desludging at regular intervals will be required to reduce methane gas emissions, including the strengthening of desludging service provisions. In denser rural and peri-urban areas, community-level sanitation systems will be established, such as anaerobic baffled reactors and nature-based systems (e.g., constructed wetlands), with appropriate O&M. Household biodigesters connected to toilets will be promoted as an efficient way to reduce methane emissions while producing gas for energy supply.

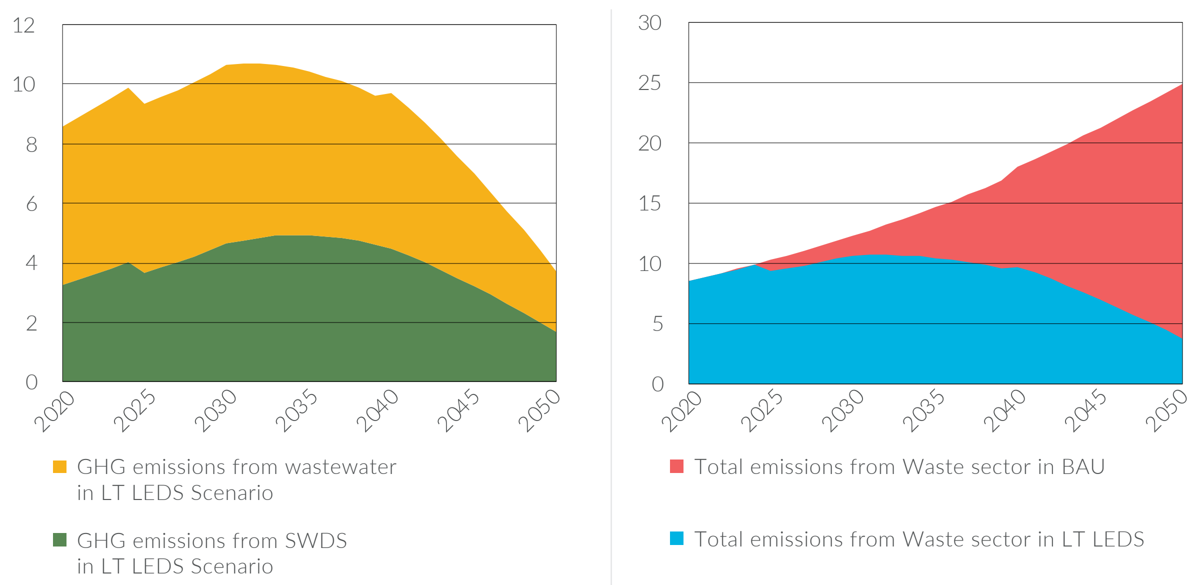
Industrial wastewater emissions are potentially important sources of methane emissions and pollution, especially from the food and beverage and agro-processing sectors. These also have high potential for value-added opportunities, such as methane capture and nutrient recovery. Efficient decentralized industrial wastewater treatment units will be installed, appropriately monitored by the government.

7. Improved fecal sludge management (rural and urban): both actions 6 and 7 will lead to the production of large volumes of fecal sludge at different stages of stabilization. Sending this sludge to landfills or letting it build up leads to the release of methane. Depending on the contamination profile, opportunities for reuse as soil amender will be investigated. Centralized treatment facilities will be built, either anaerobic digesters (the sludge can be combined with animal manure in rural areas or organic waste in urban areas—see action 1) or aerobic options (drying beds, planted beds, etc.), to generate soil amender.

Figure 4.24 shows how the policy actions for solid waste management and wastewater treatment contribute to the decarbonization of the waste sector. Whereas the actions initially manage to slow the increase in emissions, the pattern still shows upward trends due to the growth of population and the economy. However, in the 2030s, the actions also manage to overcome those tendencies and strongly reduce emissions. Even with ambitious actions, full decarbonization is not achieved in the waste sector, meaning that negative emissions in other sectors are required to achieve economy-wide NZE. But as Figure 4.24 reveals, emissions in 2050 are just a fraction of what they would be in the BAU scenario.

FIGURE 4.24

GHG emissions from waste sector (left) and maximum ambition emissions from waste sector (right)



Climate resilience of the waste sector

There are various climate impacts that could threaten the waste sector in Ethiopia, including increased rates of waste decomposition, deterioration, and impacts of odor and dust in settlements. The increasing likelihood of flooding also has major implications for the waste sector, as infrastructure, facilities, and suppliers may be disrupted or low-lying, flood-prone areas may be inundated. Equally critical is the waste sector's dependence on the transportation sector, as any disruption to road infrastructure affects the ability to transport waste and creates bottlenecks in limited storage capacity at many sites.

The NAP-ETH combines long-term strategies for the waste sector with the strategies for the urban or industrial systems. Closely based on this, two long-term strategies have been identified in the LT-LEDS as the long-term climate change adaptation strategies to underscore Ethiopia's commitment to a climate-resilient and low-carbon development of the waste sector. These adaptation strategies are:

> Building a climate-resilient urban infrastructure with a sustainable solid and liquid waste management system

> Engaging urban administration and management programs in promoting an efficient urban waste management system

An analysis of adaptation co-benefits examined the waste sector and related mitigation actions in the LT-LEDS, with the results reported in Table 4.16.

TABLE 4.16

Adaptation co-benefits and trade-offs of mitigation actions in the waste sector

Mitigation action	Adaptation synergies	Adaptation trade-offs
Improved solid waste collection and disposal	> Prevented surface water and groundwater contamination from toxic waste components that are higher in periods of intensive rain > Reduced risk of flooding due to uncollected solid waste blocking drainage systems, especially during extreme weather events. These floodwaters can also carry pathogens	> Possible decreased job opportunities in the informal waste collection sector (including waste pickers at the landfills)
Biological treatment of solid waste	> Improved crop yields through using compost > Improved moisture retention of soil (resulting in lower irrigation requirements) > Increased soil fertility and replenished organic matter and nutrients > Reduced soil erosion, which is higher during periods of intense rain and will become more common due to climate change > Biogas can increase energy security and reduce reliance on energy imports. It can also provide a valuable energy source in remote areas	
Wastewater treatment and discharge	> Reduced exposure to pathogens, including by overflowing treatment plants and drains during extreme weather events > Adaptive water management in wastewater treatments can help regulate uncertain hydrological changes due to climate change and their impacts > Wastewater that is properly treated can be used for irrigation purposes, reducing reliance on fresh water	> Increased energy requirements for an urban, centralized wastewater treatment system due to pumping and aeration

4.7 MODERNIZING IPPU THROUGH DECARBONIZATION INTERVENTIONS

Sectoral background

IPPU Policy Frameworks

The Ministry of Industry has developed its official Industrial Policy, which is now under revision. The draft policy document focuses on environmental and social inclusion and sustainable industrialization, in which environmentally friendly production processes that secure social health and comply with national and international environmental standards play a great role in sectoral growth. In addition, a circular economy and cleaner production are also considered, with incentivization mechanisms being prepared for their effective implementation. Related to this, **Proclamation No. 1263/2021** and the **Ethiopian Cement Industry Development Strategy** define environmental regulations in the industrial sector to confront increasing emissions due to the sector's expected growth in the coming decades.

While the industrial processes and product use (IPPU) sector's current contribution to Ethiopia's GHG emissions is low, it is expected to increase over the coming decades due to the growing population and the continued focus on industrialization through several industrial development strategies.

The 10YDP portrayed the share of the manufacturing sector as reaching a maximum of 17.2% of GDP by 2030, which in turn would increase GHG emissions from the sector in the coming years, thus different interventions have been proposed to reduce GHG emissions from the sector. The industry mitigation scope corresponds to the 2006 IPCC Guidelines in 1A2f on fuel combustion from non-metallic minerals and the IPPU subcategory 2A1 on cement production. The modeling analysis in the LT-LEDS focuses on the most important emission categories in the IPPU sector: those related to cement, lime, and steel.

Cement production: cement production is a major contributor of GHG emissions from IPPU in Ethiopia. The number of companies has been growing rapidly in recent years, resulting in a corresponding steady rise in GHGs from cement production. Close to 100% of clinker is produced locally. In 2018, the cement industry began mitigating CO_2 emissions from the industry by decreasing the amount of clinker in Portland pozzolana cement, from 78% to 70%, which resulted in a GHG emissions decrease for 2018–2019.

The construction of new mega-projects—such as the Grand Ethiopian Renaissance Dam, several industrial parks, sugar factories, highway and railway roads, and private sector projects—caused an increase in cement demand. The Ministry of Industry's Ethiopian Cement Industry Development Strategy cites accelerated industrialization and increased access to infrastructure through improving the capacity of the construction sector as major drivers of growth in the country.

Lime production: the two types of lime produced in Ethiopia are high calcium and dolomitic lime. Lime is used in the country mostly in construction, water and sewerage treatment, chemical industries, sugar industries, and agriculture and metallurgical industries. The current projections are based on historical lime sector data, and statistical methods were used for the 2050 projections. Existing data within the country linking economic activities to lime production and availability are limited, thus historical data was considered and trends were identified.

Iron and steel: as the IPCC 2006 Guidelines summarize, the production of iron and steel is associated with carbon dioxide, methane, and nitrous oxide emissions. For the current LT-LEDS, only CO_2 emissions were considered, since the GHG inventory is restricted to this GHG. These emissions occur in several types of industrial units: primary facilities that produce both iron and steel, secondary steelmaking facilities, exclusive iron production facilities, and off-site production units of metallurgical coke.

The iron and steel industry is an essential industry for achieving the development aims of Ethiopia. The country continues to be an importer of iron and steel (Getnet, 2018). The Ministry of Trade and

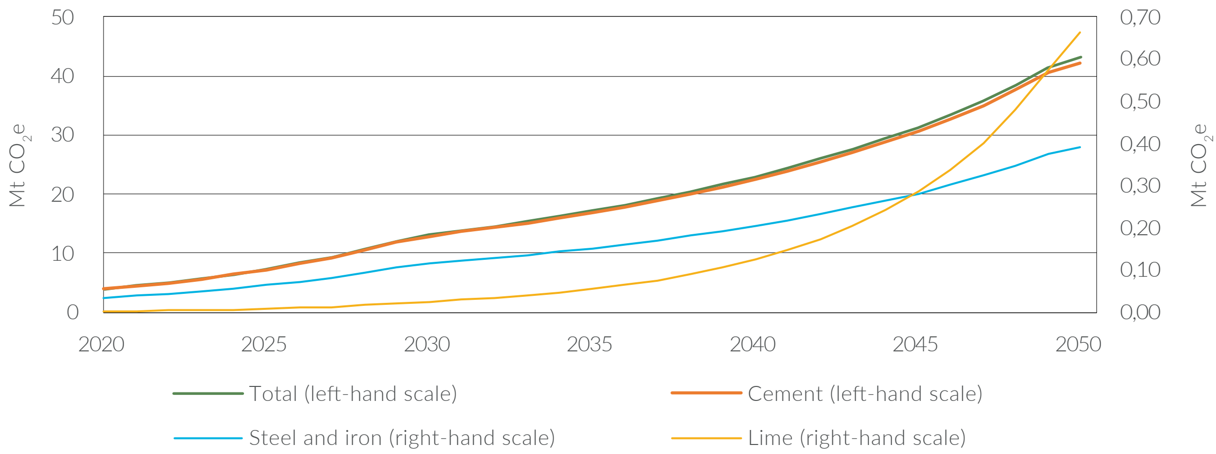
Industry (MOTI) decadal plan indicates that the country has an iron storage capacity of over 300 million tons, a production license for 72.5 million tons, and another 42,027 million tons under development. The plan also indicates the development of a special corridor for the industry, a focus on growing coal-fired steel industries, and enrichment of the steel and metal industries.

Business-as-usual scenario

The 2050 projections for this sector are dominated by the cement sector. The expanded sectors contribute to raising the numbers, but only marginally, compared to the cement sector. The projections are linked to the population and GDP values of the country and their respective projections. As Figure 4.25 shows, emissions in the IPPU sector are expected to grow more than eightfold until 2050.

FIGURE 4.25

GHG emission projections from the IPPU sector (Mt CO_2e)



Low-emission scenario

The following three policies are proposed under the IPPU to help reduce the country's emissions.

TABLE 4.17

Ambition levels for the low-emission interventions in the IPPU sector (for all scenarios)

IPPU: high-level interventions	2020	2030	2045	2050
Reduction of the share of clinker in cement	70%	70%		50%
Incorporation of recycled high-quality scrap in iron and steel production	0%	0%		10%
Long-term goal for CCS	0 Gg of CO_2e	0 Gg of CO_2e	100 Gg of CO_2e	500 Gg of CO_2e

Increasing the additive content in the cement sector: any measures that reduce emissions from burning fossil fuels to generate the required heat in cement manufacturing need to be accounted for under the energy sector as per the IPCC 2006 Guidelines, rather than under the IPPU sector. For example, in 2017, the World Bank and Korea Green Growth Trust Fund[8] explored the opportunities, challenges, and solutions to using alternative fuels in the cement sector in Ethiopia, which can largely reduce the emissions from the industry. Similarly, there are several opportunities to improve the thermal and energy efficiency of cement manufacturing.[9]

This section covers emission reduction opportunities in the process steps of cement manufacturing and measures that can contribute to reducing these process emissions. Ethiopia has moved toward reducing the clinker percentage to 70% in the cement manufactured, meaning the remaining 30% is additives. Research suggesting that additives up to 50% can be added has been long explored in the scientific community.[10] Limestone calcined clay cement,[11] which allows for up to a 50% combination of calcined clay with limestone, results in similar mechanical properties and improvement in some aspects of durability.

Recycling high-quality steel: the International Energy Agency (IEA) estimates that the short-term impacts of energy efficiency measures and the mid- to long-term impacts of scrap-based electric arc furnace and CCS measures can help the sector contribute to the 2°C target. Like the cement sector, the iron and steel industry also benefits from reducing its thermal and electrical energy consumption and replacing its energy sources with less carbonintensive fuels such as biomass. However, these are accounted for under the energy sector as per the IPCC 2006 Guidelines.

In 2012, the US Environmental Protection Agency[12] listed several energy efficiency opportunities in the iron and steel industry to help reduce GHG emissions from the sector:

> Sintering at integrated iron and steel plants

> Cokemaking

> Blast furnace at integrated iron and steel plants

> Basic oxygen furnace at integrated iron and steel plants

> Casting

> Hot and cold rolling mills

> Energy efficiency options for electric arc furnace steelmaking

While Ethiopia currently lacks the raw data to evaluate the applicability and impacts of these measures, high-quality steel scrap recycling has been proven to reduce the industry's GHG emissions. The IEA[13] identifies increased scrap collection to enable more scrap-based production as a short-term opportunity.

Forming a carbon capture and storage unit: while CCS is still not economically feasible in developing countries, it continues to be prominently featured in all existing approaches to achieving NZE. The expectation is that the technology will mature in the coming decades and be economically feasible for global implementation. Uncertainty remains regarding permanence of the technology, its scale of implementation, and the necessary public support. If these and other necessary conditions are met, the technology can contribute to a large-scale reduction in GHG emissions. The IEA analysis also covers future CCS as a key contributor in the iron and steel industry. The low-emission scenario defines itself as a deviation from the BAU scenario due to the policy interventions:

8 Use of Alternative Fuels in the Cement Sector in Ethiopia: Opportunities, Challenges and Solutions.

9 International Finance Corporation. 2017. Improving Thermal and Electric Energy Efficiency at Cement Plants: International Best Practice. Washington, D.C.

10 Langan, B. W., Joshi, R. C., and Ward, M. A. "Strength and durability of concretes containing 50% Portland cement replacement by fly ash and other materials." Canadian Journal of Civil Engineering 17, no. 1 (1990): 19–27, doi:10.1139/l90-004.

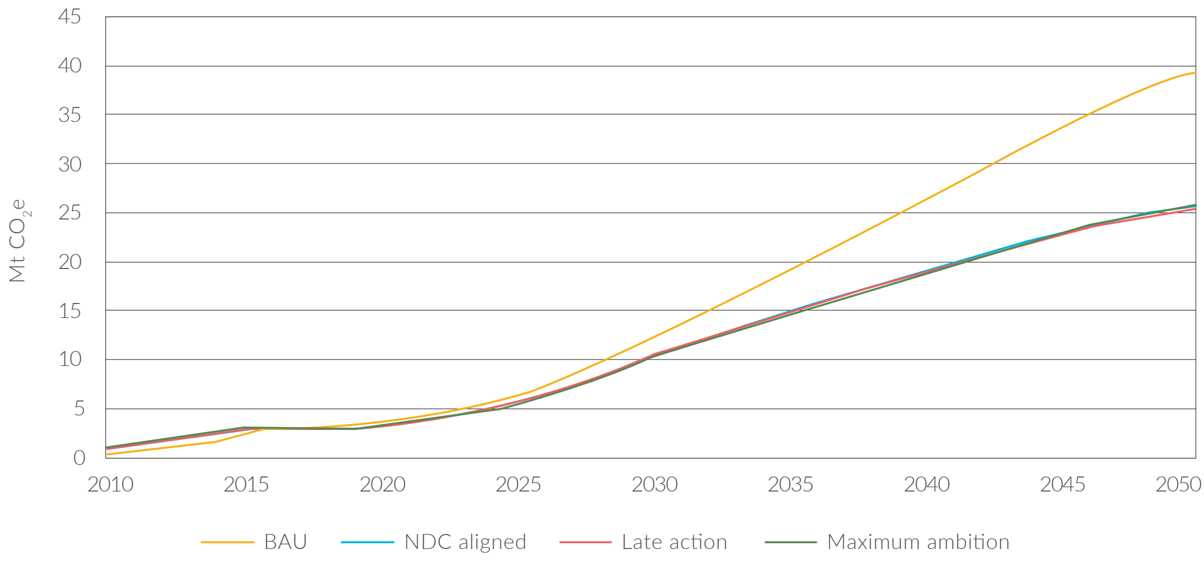
11 https://www.sciencedirect.com/science/article/abs/pii/S0008884617302454

12 https://www.epa.gov/sites/default/files/2015-12/documents/ironsteel.pdf

13 https://www.iea.org/reports/iron-and-steel

FIGURE 4.26

BAU and NZE scenarios for GHG emissions from the IPPU sector (mt CO_2e)



Climate resilience of the IPPU sector

The industrial sector in Ethiopia faces the risk of increases in temperature and rainfall variability. A main challenge is that natural resource degradation can lead to resource scarcity, affecting industrial developments. At the same time, increasing the frequency and intensity of climate impacts can lead to infrastructural damage, increasing the frequency of fire incidence, declining productivity, and increasing production costs in the industry sector. An analysis of adaptation co-benefits examined the IPPU sector and related mitigation actions in the LT-LEDS, with the results, as discussed with the IPPU working group, reported in Table 4.18.

TABLE 4.18

Adaptation co-benefits and trade-offs of mitigation actions in the IPPU sector

Mitigation action	Adaptation synergies	Adaptation trade-offs
Increasing the additive content in the cement sector	Replacing clinker with industrial waste or by-products, such as coal ash powder, reduces waste and land needed for disposal and landfills	
Recycling high-quality steel	Reduced energy demand compared to the production	
Forming a CCS unit		Additional energy demand due to cooling requirements and additional water demand

5. Macroeconomic and Cost and Benefit Implications of the Net-Zero and Climate-Resilient Pathways

5.1 IMPLICATIONS FOR ECONOMIC GROWTH AND EMPLOYMENT

The transition toward a decarbonized economy contributes to socioeconomic development in various ways. The energy sector transition leads to lower emissions and air pollution while creating additional jobs in power generation and in the supply chain surrounding electric vehicles. Key productivity gains are achieved from the implementation of energy efficiency measures, which reduce total energy consumption and related costs, making the economy more competitive. This process is supported by maintaining a high share of renewable power generation while, at the same time, phasing out diesel generators, which keeps electricity costs reliably low and creates synergies with the sectoral electrification ambitions.

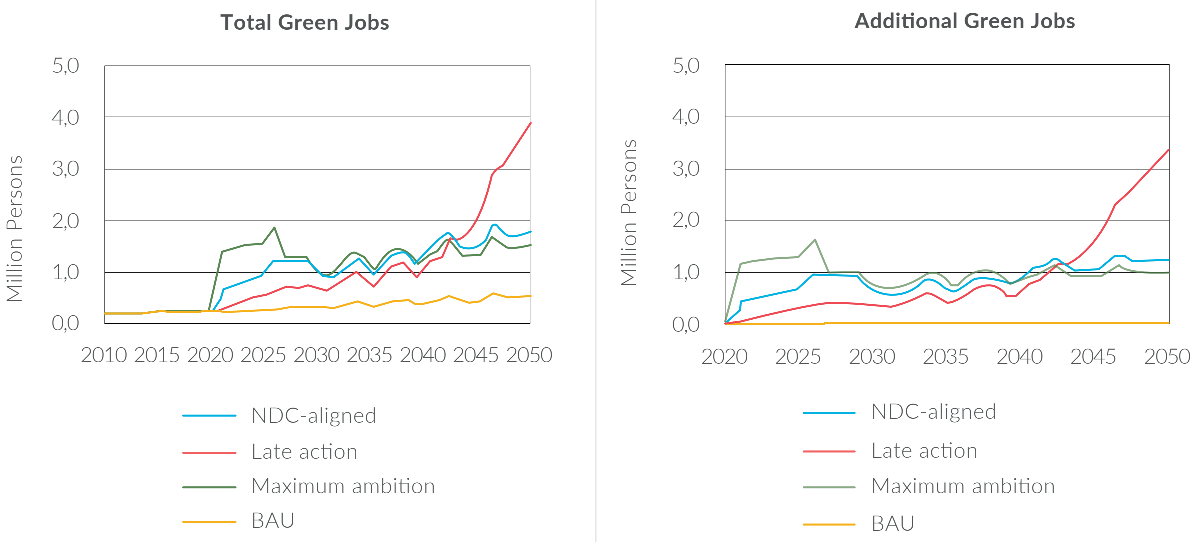
The changes in productivity induced by lower energy costs and reduced energy emissions lead to higher growth rates (see section 4.1), which in turn cause higher government revenues and public and private investment. For instance, while total government revenues in the BAU scenario are projected to increase, the higher growth exhibited in the NDC-aligned scenario causes government revenues to increase by 66.1% compared to the BAU in 2050, which amounts to an increase of USD 69.5 billion. In addition to the jobs generated from additional capital accumulation, the LT-LEDS ambitions are projected to create jobs in green sectors (e.g., renewable power generation, sustainable agriculture, or forestry), which addresses the need for job and income generation.

The decarbonization ambitions are projected to increase the total number of green jobs in the Ethiopian economy and create additional green jobs relative to the BAU scenario. The number of green jobs and the number of additional green jobs are presented in Figure 5.1. In the BAU scenario, the number of green jobs increases from around 240,200 jobs in 2020 to 540,000 jobs in 2050. The number of green jobs in the BAU scenario averages 387,100 per year between 2020 and 2050.

In the net-zero scenarios, the number of green jobs varies according to the timing at which ambitions are implemented. In the late action scenario, the number of jobs increases slowly between 2020 and 2040, after which it increases above the results obtained from the other net-zero scenarios. On average, for 2020–2050, the number of green jobs in the late action scenario is 1.32 million per year, which is 936,000 jobs more (on average) compared to the BAU scenario. The

NDC-aligned scenario falls between the late action and maximum ambition scenarios, regarding the number of green jobs in 2050, but provides a slightly lower number of green jobs on average for 2020–2050 compared with the two alternative scenarios. The annual number of green jobs in the NDC-aligned scenario averages 1.25 million per year for 2020–2050, which is 865,400 jobs more compared to the BAU scenario. Finally, in the maximum ambition scenario, the annual number of green jobs for 2020–2050 averages 1.35 million, which is 966,700 additional jobs per year compared to the BAU (on average) and the highest number of green jobs of the three net-zero scenarios simulated.

FIGURE 5.1
Total green jobs and additional green jobs



The share of green jobs in total employment for the selected periods is summarized in Table 5.1. On average, the share of green jobs in total employment for 2020-2050 is 0.56% in the BAU scenario, 1.76% in the late action scenario, 1.78% in the NDC-aligned scenario, and 1.99% in the maximum ambition scenario. This highlights that the earlier ambitions are implemented, the higher the average share of green jobs in total employment.

TABLE 5.1
Share of green jobs in total employment

Share of green jobs in total employment	2020–2030	2030–2040	2040–2050	2020–2050
Late action	0.94%	1.31%	2.93%	1.76%
NDC aligned	1.63%	1.66%	2.02%	1.78%
Maximum ambition	2.34%	1.76%	1.80%	1.99%
BAU	0.49%	0.56%	0.62%	0.56%

Table 5.2 depicts the total number of green jobs by scenario and the number of green jobs by category for selected years. The results show that the highest number of additional green jobs is created by land-based interventions (restoration and reforestation), followed by renewable energy and waste management. This highlights the job creation potential of generating the net carbon sink required to reach net-zero ambitions as well as the role that electrification and renewable energy play in creating a fair transition. Additionally, the number of jobs generated from waste management is also important, highlighting the benefits of additional recycling and of reducing the amount of waste landfilled, not only for emissions but also for employment generation.

TABLE 5.2
Total number of green jobs and green jobs by category

Total number of green jobs	Unit	2020	2030	2040	2050
Late action	Jobs	259,592	659,248	1,149,797	3,900,835
NDC aligned	Jobs	363,222	932,560	1,422,595	1,774,906
Maximum ambition	Jobs	707,976	1,000,668	1,317,742	1,518,207
BAU	Jobs	240,165	311,524	431,970	539,988
Green jobs by category					
Vehicle electrification					
Late action	Jobs	1,494	7,348	18,814	37,922
NDC aligned	Jobs	1,989	9,303	30,315	26,279
Maximum ambition	Jobs	2,972	16,736	24,662	20,284
BAU	Jobs	0	0	0	0
Energy efficiency					
Late action	Jobs	-27	1,297	2,244	3,053
NDC aligned	Jobs	-23	1,062	2,480	3,102
Maximum ambition	Jobs	-14	1,307	2,458	3,150
BAU	Jobs	0	0	0	0
Land-based interventions					
Late action	Jobs	14,438	180,727	394,867	3,037,500
NDC aligned	Jobs	117,563	435,818	664,282	926,447
Maximum ambition	Jobs	461,313	497,529	567,895	675,750
BAU	Jobs	0	0	0	0
Waste management					
Late action	Jobs	214,302	325,178	385,833	435,039
NDC aligned	Jobs	214,302	325,205	385,857	435,073
Maximum ambition	Jobs	214,302	325,221	385,873	435,098
BAU	Jobs	211,725	267,875	322,852	375,520
Renewable energy					
Late action	Jobs	29,386	144,699	348,039	387,321
NDC aligned	Jobs	29,392	161,171	339,661	384,004
Maximum ambition	Jobs	29,404	159,875	336,855	383,925
BAU	Jobs	28,440	43,649	109,118	164,468

5.2 COSTS AND BENEFITS OF THE DECARBONIZATION OF ETHIOPIA'S ECONOMY

The implementation of the LT-LEDS gives way to many costs and benefits that should be considered in exploring the appropriate pathways toward decarbonizing Ethiopia's economy. As Table 5.3 shows, benefits significantly exceed the costs in all scenarios, whereas an overall judgment sees advantages in favor of the NDC-aligned scenario. Future costs and benefits are discounted by a rate of 7.5% to account for the higher importance of current over future values. The main cost components are energy- and agriculture-related investments. Power generation and the electrification of the vehicle fleet and public transport together account for more than 50% of total investments required, while agriculture contributes around 25–30% in the NDC-aligned and late action scenarios. The maximum ambition scenario involves significantly higher investment in agriculture, mainly driven by costs incurred for reductions in the livestock sector. Other costs accounted for in this assessment are the costs of reforestation and forest rehabilitation, waste management, and industrial CCS.

Avoided costs and added benefits are the main drivers of the net benefits derived from the implementation of low-emission development. In terms of avoided costs, the energy bill is the main contributor. The main added benefits derived from the decarbonization of Ethiopia's economy are total real GDP and additional discretionary spending in the economy generated through job creation. The social cost of carbon (SCC) has not been included in the calculations. SCC reflects the average damage to people, infrastructure, and the economy in Ethiopia caused by climate change. Lower emissions thus mean lower costs. However, Ethiopia's LT-LEDS is one of the first to include climate change adaptation in its modeling analysis. Therefore, climate change impacts, such as on agricultural output and power generation, are already integrated in the macroeconomic figures, including GDP and employment. Adaptation modeling, to some degree, accounts for the costs of climate change and how these costs can be mitigated. Additionally, including SCC would create a risk of double counting.

While capital costs of investments mainly occur in the beginning of the 30-year period, particularly applying to the maximum ambition scenario, O&M costs are relevant throughout the lifetime of an investment. Overall, costs occur sooner, while the stream of benefits follows the investment, even going beyond 2050. In this regard, the total present value of benefits tends to be underestimated, as avoided costs and added benefits materializing during later years are heavily discounted. Furthermore, there are further qualitative benefits, such as positive health effects due to reduced air pollution and fewer accidents in the transport sector, improved environmental quality, and time savings due to higher energy efficiency (e.g. from efficient cooking stoves). Additionally, the LT-LEDS has important social effects including poverty reduction. The GEM estimates that households will enjoy an average nondiscounted increase in disposable income of between USD 2 and 3 billion per year.

TABLE 5.3
Discounted costs and benefits per scenario relative to the BAU scenario

	Unit	Late action	NDC aligned	Maximum ambition
Total cost of transport electrification	**USD bn**	**11.48**	**13.99**	**17.01**
Investment in chargers	USD bn	0.38	0.47	0.58
Investment in electric vehicles	USD bn	10.54	12.79	15.77
O&M cost of electric vehicles	USD bn	0.38	0.51	0.38
Investment in electric buses	USD bn	0.15	0.19	0.23
O&M cost of electric buses	USD bn	0.03	0.04	0.06
Total cost of power generation	**USD bn**	**67.32**	**70.14**	**72.55**
Investment in power generation	USD bn	55.23	57.39	59.24
O&M cost of power generation	USD bn	12.09	12.75	13.31
Investment in energy efficiency	**USD bn**	**1.36**	**1.33**	**1.31**
Total investment in agriculture	**USD bn**	**32.04**	**35.95**	**128.22**
Investment in sustainable agriculture	USD bn	1.01	1.01	1.56
O&M cost of sustainable agriculture	USD bn	6.56	6.56	19.55
Investment in crop diversification	USD bn	0.15	0.15	0.24
Investment in livestock interventions	USD bn	24.32	28.23	106.87
Total cost of land-based interventions	**USD bn**	**11.00**	**17.50**	**38.28**
Total cost of waste management	**USD bn**	**15.09**	**15.09**	**15.09**
Investment in waste management	USD bn	14.05	14.05	14.06
O&M cost of waste management	USD bn	1.03	1.03	1.03
Investment in industrial CCS	**USD bn**	**0.01**	**0.01**	**0.01**
(1) Total investment and costs	**USD bn**	**138.30**	**154.01**	**272.47**
Avoided costs				
Energy bill	USD bn	231.10	245.93	254.76
Investment in Internal Combustion Engine (ICE) vehicles	USD bn	0.33	11.78	14.25
O&M cost of ICE vehicles	USD bn	0.01	0.57	0.75
Investment in ICE buses	USD bn	0.00	0.15	0.19
O&M cost of ICE buses	USD bn	0.00	0.03	0.04
Inorganic fertilizer	USD bn	0.24	0.23	0.21
(2) Total avoided costs	**USD bn**	**231.45**	**258.47**	**269.98**

TABLE 5.3

Discounted costs and benefits per scenario relative to the BAU scenario (cont.)

	Unit	Late action	NDC aligned	Maximum ambition
Added benefits				
Additional real GDP	USD bn	841.15	838.21	838.65
Agriculture	USD bn	-12.98	-18.58	-24.25
Industry	USD bn	425.75	426.84	430.64
Services	USD bn	428.38	429.95	432.26
Discretionary spending	USD bn	18.37	18.39	23.66
(3) Total added benefits	**USD bn**	**841.15**	**838.21**	**838.65**
Net added benefits (2)+(3)-(1)	USD bn	934.31	942.67	836.16
Total benefits per USD invested	USD/USD inv	6.08	5.44	3.08
Net benefits per USD invested	USD/USD inv	6.76	6.12	3.07

Comparing the cost-benefit analysis of the three scenarios as compared to the BAU scenario, the differences are larger or smaller depending on the metric considered. The maximum ambition scenario yields the highest benefits but also the highest investment and costs. This can be explained by the expectation that technologies mature over time such that decarbonization actions become cheaper over time, thus making early action more expensive. In line with this, the late action scenario is the least cost scenario but also leads to fewer benefits.

The late action scenario has the highest efficiency in terms of both gross and net benefits (total benefits minus costs) per USD invested. Every USD invested in decarbonization and adaptation on average gives rise to benefits of USD 6–7. The values are similar for the NDC-aligned scenario with benefits of USD 5–6 per USD invested, but only at around USD 3 for the maximum ambition scenario. However, investment efficiency is not the only metric. Looking at the scenarios' effectiveness, the NDC-aligned scenario yields the highest absolute net benefits. This scenario matches effectiveness by optimizing costs and benefits while achieving this at a relatively high efficiency and also being ambitious regarding a carbon emissions reduction.

5.3 IMPACT ON THE BALANCE OF TRADE

Ethiopia strongly depends on the import of essential inputs for its economic growth to perform well. For most LDCs, limited access to foreign exchange and the burden of foreign debt is one of the most important development and growth constraints. This applies equally to Ethiopia, which has had a constantly negative balance of trade, as well as a deficit, in its overall current account during the past three decades. Domestic economic growth usually accompanies increasing imports since a certain share of household income is spent on imported goods from abroad. Moreover, the country depends on the import of capital goods to increase its national production capacity and productivity. But foreign exchange may be unavailable because lenders are unwilling to provide it or foreign debt servicing becomes uncontrollable as imports grow. To avoid a currency crisis, Ethiopia must manage its current account. This implies that the country's economic growth is constrained because fast growth intensifies the shortage of foreign exchange.

The GoE aims at both substituting domestic products for imports and strengthening export capacity (for instance, see 10YDP, section 4.2). The LT-LEDS is well-aligned with this endeavor to the extent that renewable energy and energy efficiency reduce the demand for fossil fuel imports and the balance of trade improves. As a second major component, higher agricultural efficiency and sustainable practices reduce reliance on synthetic fertilizer imports. The corresponding savings in foreign exchange can be used to import capital goods and allow for higher economic growth without running into a currency crisis.

Figure 5.2 depicts the expected savings in the imports of these two major components for each scenario relative to the BAU scenario, assuming a fossil fuel price of USD 70 per barrel. The more ambitious the scenario, the higher the savings. With up to USD 4 billion annually for 2041–2050 in the NDC-aligned scenario, fossil fuel savings compensate for the bulk of overall savings. Foreign exchange savings from reduced demand for mineral fertilizers are still considerable, with around USD 50 million annually in the same period. In a similar vein, Figure 5.3 reveals that the LT-LEDS allows for significant import savings as related to total imports, reaching its maximum of 4.1% for 2031-2040 for the NDC-aligned scenario. The growth potential arising from annual savings accumulates to a significant total growth effect until 2050. Therefore, due to the LT-LEDS, the Ethiopian economy can grow faster without deteriorating its external balance. Alternatively, instead of growing faster and increasing imports, the import savings provide the GoE with resources to service and reduce its foreign debt.

FIGURE 5.2

Average annual savings in imports of petroleum and inorganic fertilizer, in million USD

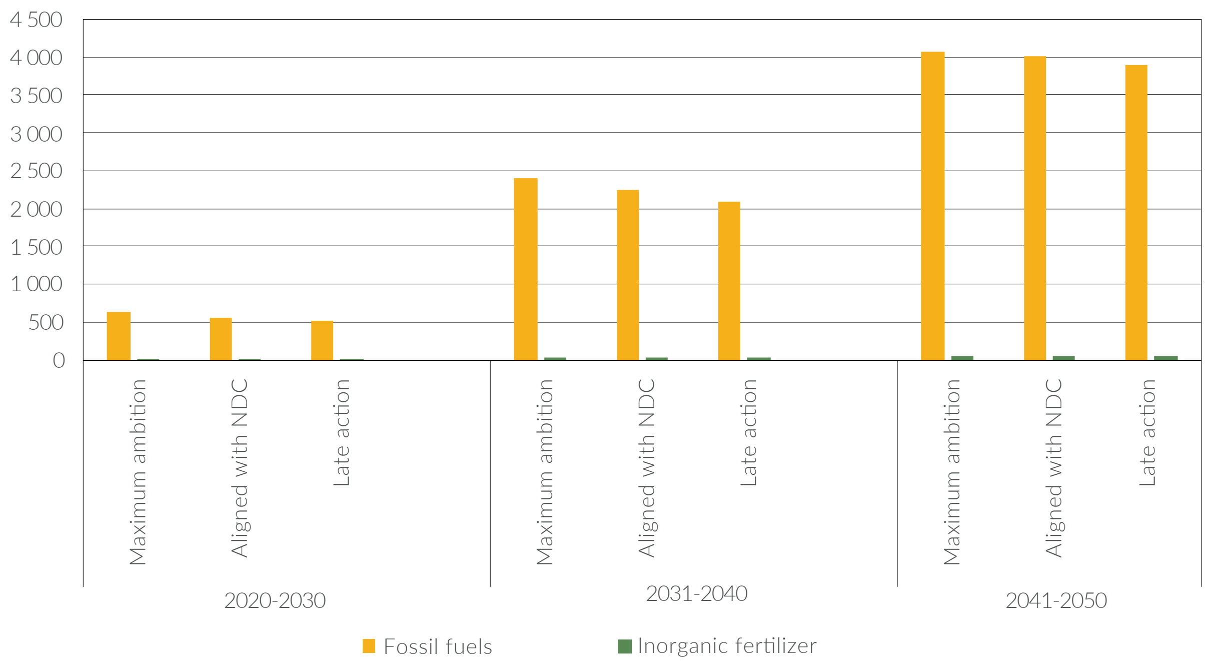
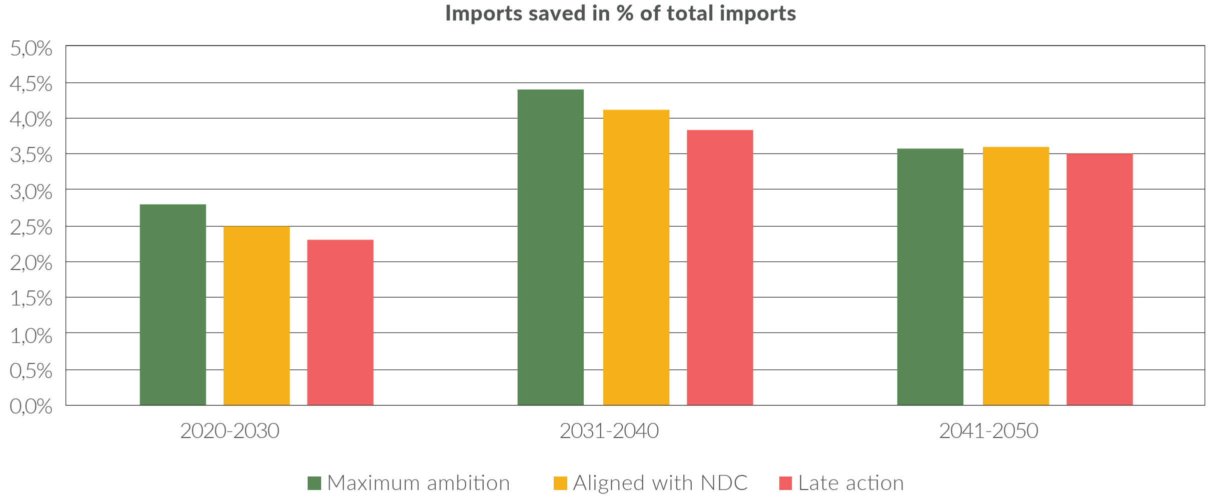


FIGURE 5.3

Average annual savings in imports of fossil fuels and inorganic fertilizer, combined in % of total imports



6. Assessing SDG Co-benefits of the Net-Zero Emission Pathways

Policy interventions to reduce GHG emissions will help achieve SDGs related to building resilient infrastructure (Goal 9, Target 9.4) and taking urgent action to combat climate change (Goal 13, Target 13.2). These interventions will help achieve not only the climate-related SDG but also other sustainability targets on efficient and sustainable resource use and natural capital protection. Linked to the Global Green Growth Index, GGGI's Green Growth Simulation Tool (GGSim) was applied to assess the progress on SDG indicators (section 6.2), which are included in the green growth framework.[14] The available data for the BAU and NZE scenarios, as discussed previously, allowed for the assessment of the SDG co-benefits listed in Table 6.1. Other assumptions about the scenarios required to apply the GGSim for these indicators are presented in the technical annex.

14 https://greengrowthindex.gggi.org/. The framework consists of four green growth dimensions: efficient and sustainable resource use, natural capital protection, green economic opportunities, and social inclusion. The SDG indicators in this framework were selected through collaborative and inclusive consultations with over a hundred of experts during the development of GGGI's Global Green Growth Index in 2019.

TABLE 6.1
Description of SDG indicators assessed

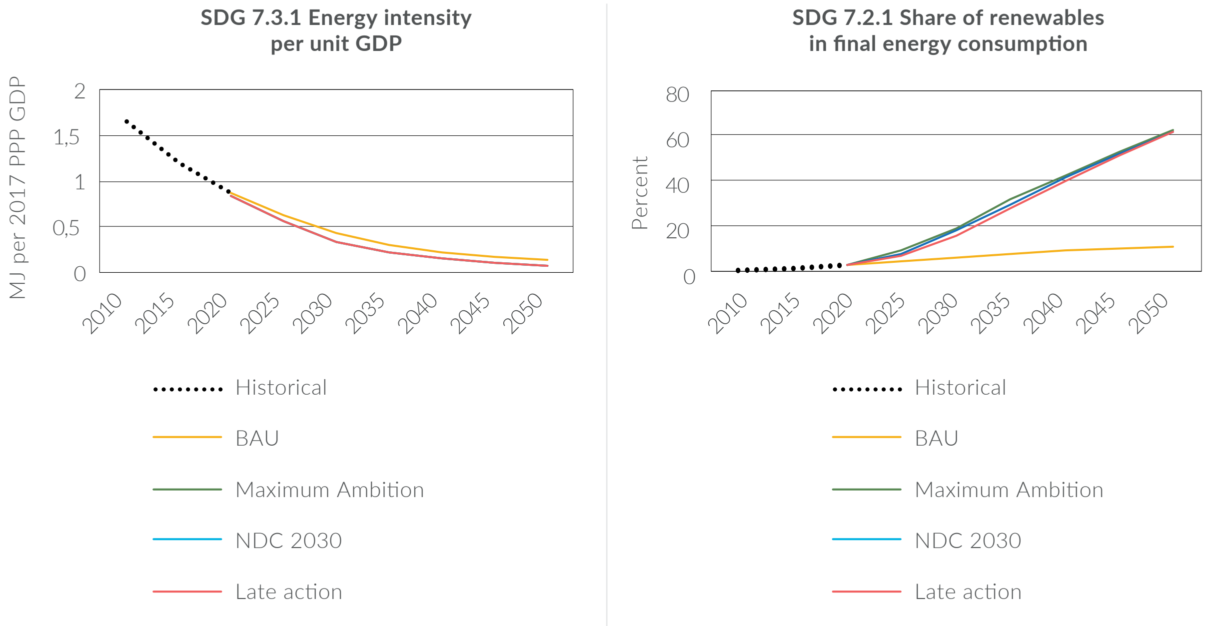
Sector	SDG number	Indicator name	Indicator unit	SDG goal
Energy	7.3.1	Energy intensity level of primary energy supply	MJ per 2017 PPP GDP	Ensure access to affordable, reliable, sustainable, and modern energy for all
	7.2.1	Renewable energy share in the total final energy consumption	Percent	
Water	6.4.1	Water use efficiency	USD per m^3	Ensure availability and sustainable management of water and sanitation for all
Agriculture	12.3.1. a and b	Food loss and food waste	Percent	Ensure sustainable consumption and production patterns
	15.3.1	Nutrient balance per unit area (directly linked to the proportion of land that is degraded)	Nitrogen kg per hectare	Protect, restore, and promote sustainable use of terrestrial ecosystems; sustainably manage forests; combat desertification; halt and reverse land degradation; and halt biodiversity loss
Forest	15.1.1	Forest area as percent of total land area	Percent	
	15.2.1	Aboveground biomass stock in forest	Tons per hectare	

6.1 CONTRIBUTION OF THE LT-LEDS INTERVENTIONS TOWARD SDG ACHIEVEMENT

Efficient and sustainable use of energy, as measured by energy intensity per GDP (SDG 7.3.1), has been consistently declining in Ethiopia from 2010 to 2020, with the BAU scenario showing continuation of this trend until 2050 (1, left). The trend indicates that less energy will be used to produce one unit of economic output, making use of energy more efficiently in the country in the next three decades, from 0.87 in 2020 to only 0.14 MJ per GDP in 2050. Policy interventions will contribute to additional progress in the decline of energy intensity for the three NZE scenarios, albeit only minimal. The relatively small progress in SDG 7.3.1 will be attributed to a less than 10% energy efficiency improvement in the NZE scenarios vis-à-vis the BAU scenario. But as Ethiopia's performance in this SDG indicator is already high, the limited policy intervention in energy efficiency appears to be justified. For the three NZE scenarios, the key focus of policy interventions will be on renewable energy expansion, particularly to support sustainable electrification, thus significant progress will be achieved in the share of renewable energy in the total final energy consumption (SDG 7.2.1). In 2050, the share of renewables will be 10% in the BAU scenario and will increase to about 62% in the NZE scenarios. In 2025, progress in SDG 7.2.1 will be higher for the maximum ambition scenario than in the other two NZE scenarios, but the gap will close in 2050 when all three scenarios achieve the goal of NZE.

FIGURE 6.1

Relevant SDG indicators for a transition to green growth in the energy sector

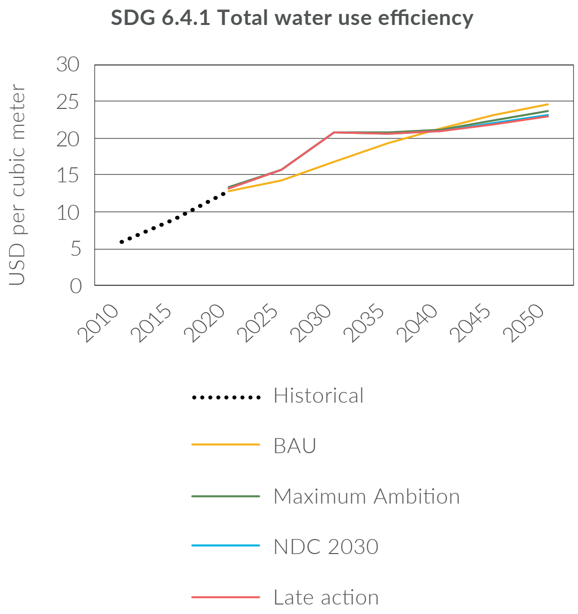


In the water sector, water use efficiency across all sectors (SDG 6.4.1) has shown an increasing trend for 2010-2020 (Figure 6.2). This progress is expected to continue in the BAU scenario until 2050 and in the NZE scenarios until 2030. All NZE scenarios will follow the same trend for 2020–2050 because of the same policy interventions being implemented. Slight divergence among them will be caused by differences in the GDP and population growth across the NZE scenarios. The progress in water use efficiency will be slightly higher in the NZE scenarios than in the BAU scenario for 2020-2030 due to improvements in irrigation technology, both decreasing surface irrigation and increasing drip/sprinkler irrigation by about 50%.

For 2030–2040, water use efficiency will stop rising for two reasons. First, the expansion of irrigated areas will cause an increase in water withdrawal in the agricultural sector, increasing the share of this sector to the total water withdrawal, relative to the municipal sector. But the municipal sector has a higher water use efficiency than the agriculture sector, so this shift will reduce the overall efficiency in the country. Second, the level of irrigation technology (i.e., 4% sprinkler, 46% drip) and traditional irrigation (50% surface) will not be sufficient to increase water use efficiency in the larger areas of irrigated land. While water use efficiency will again increase in the NZE scenarios due to a development priority shift from the primary industry (i.e., agriculture) to secondary and tertiary industries in 2040, the progress will not be sufficient to bring the level higher or even at par with the BAU scenario.

FIGURE 6.2

Relevant SDG indicators for a transition to green growth in the water sector

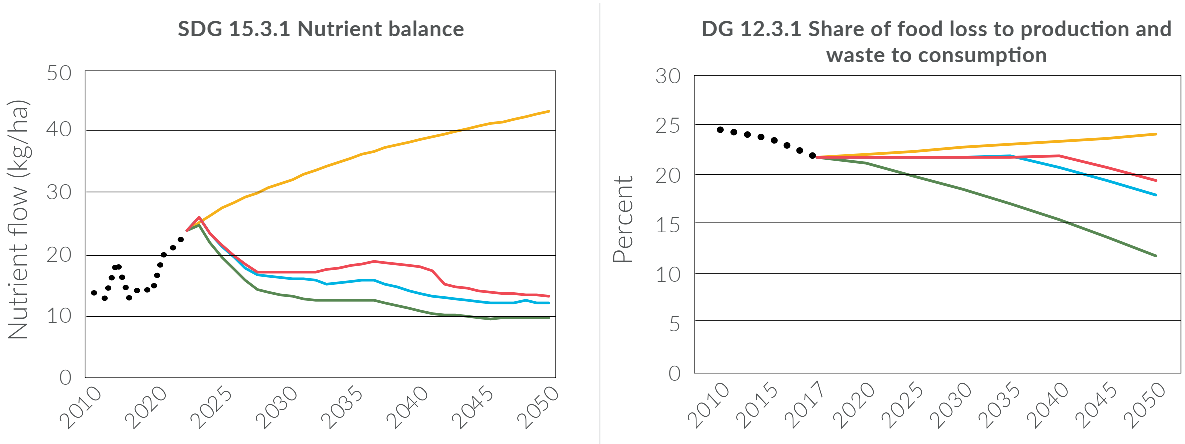


In contrast to the water sector, there will be overall progress in the performance of SDG indicators related to agriculture (Figure 6.3). Nutrient balance per hectare is directly linked to SDG 15.3.1 (proportion of land that is degraded). This indicator measures the total nitrogen left on cropland after crop removals and fertilizer applications, with atmospheric deposition assumed constant in the model. It also measures nutrient use efficiency of farm inputs, including synthetic fertilizers and livestock manure. While these inputs ensure productivity, in excess, they are harmful to the environment due to ammonia and GHG emissions.

In Ethiopia, nutrient balance recorded an increasing trend with some fluctuations in 2010–2020 and is expected to increase further, from 25 to almost 40 nitrogen kg per hectare, in 2050 under the BAU scenario. This negative trend will be reversed in the three NZE scenarios, where livestock (e.g., switch from cattle to poultry) and manure management will contribute to a decrease in the total manure availability and application rates. These policy interventions will be applied earlier in the maximum ambition scenario, causing the highest reduction in nutrient balance over time and achieving as low as 10 nitrogen kg per hectare in 2050. This scenario will also achieve the most progress in reducing food loss and waste (SDG 15.3.1), enabling the reduction trend during 2010–2017 to continue until 2050. In this scenario, policy interventions to reduce food loss and waste by 50% are introduced as early as 2020. In the absence of policy interventions and in the face of a growing population and food demand, food loss and waste will increase under the BAU scenario. This increase will be only partially addressed in the other NZE scenarios due to the delay in implementing the policy interventions in the NDC-aligned and late action scenarios in 2035 and 2040, respectively.

FIGURE 6.3

Relevant SDG indicators for a green growth transition in the agriculture sector

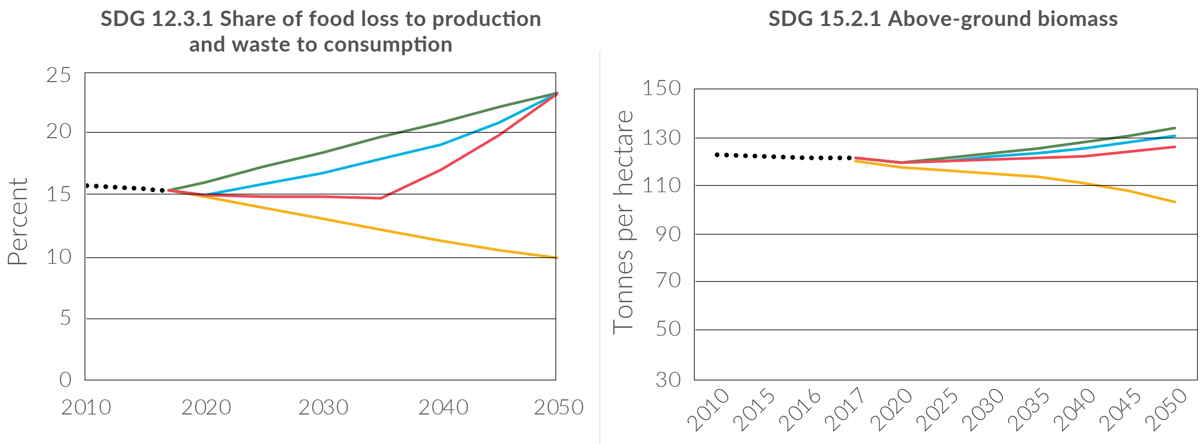


Finally, in the forestry sector, the historical decline in the share of forest land to total land area (SDG 15.1.1) and aboveground biomass (SDG 15.2.1) will continue in the BAU scenario in the absence of policy interventions to reduce deforestation and forest degradation (Figure 6.4). The mitigation actions to reduce deforestation and increase afforestation/reforestation, while also introducing forest restoration in the NZE scenarios will achieve significant progress in SDG 15.1.1. But progress will be less in the case of the NDC-aligned and late action scenarios due to the delay in policy interventions relative to the maximum ambition scenario. However, all NZE scenarios are expected to reach the same level of progress in this SDG indicator in 2050.

The increase in forest land directly impacts performance in aboveground biomass (SDG 15.2.1), which measures the gains in forest growth through biomass stock and reduction through wood removals, fire, wind, pests, diseases, and natural losses. Similar to the share of forest area to total land area, the maximum ambition scenario offers the best opportunity to achieve significant progress in improving aboveground biomass, which is a useful indicator of sustainable forest management and a measure of carbon pools. Higher levels of aboveground biomass per hectare will lead to higher amounts of CO_2 being captured by forests, enhancing the mitigation potential in the forest sector as described in the strategy's forestry section. The relatively lower aboveground biomass for the late action scenario is due to the implementation of reforestation only in 2035 (vis-à-vis 2030 in the case of the other NZE scenarios), thus allowing limited time to accumulate biomass until 2050.

FIGURE 6.4

Relevant SDG indicators for a transition to green growth in the forest sector



6.2 ACHIEVING SDG TARGETS THROUGH LT-LEDS INTERVENTIONS

The impacts of the climate policy interventions on Ethiopia's performance in achieving SDG targets in the NZE scenarios vis-à-vis historical and BAU scenarios are presented in Table 6.2. For SDG indicators without explicit targets in 2030 (i.e., SDG 7.3.1, SDG 15.2.1), the average values of the top five performing countries for the indicators were used as SDG targets.[15] Ethiopia's performance in SDG 7.3.1 on reducing energy intensity is on par with the highest performing countries, as it has already achieved the lowest average value, of 1.00 MJ/LCU, globally since 2020. Energy intensity will continue to fall, not only in the NZE scenarios but also in the BAU scenario, with values better than the SDG target. Achieving the target for SDG 7.2.1 (increasing the share of renewables) will only be possible with strong policy interventions to expand the renewable energy sector. While a target of 51.40% for SDG 7.2.1 will not be achieved in 2030, Ethiopia will significantly increase its share of renewables to about 19% in the maximum ambition scenario.

Performance in SDG 6.4.1 (increasing water use efficiency) will remain low across all scenarios but is expected to be higher considering an integrated watershed management intervention, including soil and water conservation measures for sustainable agricultural development. However, these measures were not included in the modeling exercise, thus their contribution to water use efficiency can be quantified. Modern irrigation methods will also be leveraged to increase water use efficiency in solar-powered irrigation systems.

15 This method is used in GGGI's Global Green Growth Index, SDSN's SDG Index, and OECD's Green Growth Indicators.

Current agricultural practices are expected to move the country away from achieving the targets for SDG 15.3.1 (maintaining nutrient balance) and SDG 12.3.1 (reducing food loss and waste) in the BAU scenario until 2030. Policy interventions in the agricultural sector will help to reverse this, allowing an increase in performance for these SDG indicators in the three NZE scenarios. Ethiopia will achieve the target for SDG 12.3.1, but the target for SDG 15.3.1 will require additional interventions to reach the same high level of performance. Performance in achieving the target for SDG 15.1.1 (increasing the share of forest) was high in 2010, with a value 15.77%. But the current rates of deforestation and forest degradation that continue in the BAU scenario will cause the country to move away from the SDG target of 17%. The policy interventions in the NZE scenarios will reverse this trend, with the target being reached in 2030 in the case of maximum ambition. Despite the significant policy interventions in the forest sector, the target for SDG 15.2.1 will not be achieved in the NZE scenarios as Ethiopia's level of aboveground biomass will remain low relative to the top five performing countries globally.

TABLE 6.2

Performance in achieving SDG targets in the BAU and low-emission scenarios

SDG number*	SDG target**	Units	Historical data	BAU scenario		Net-zero energy scenarios					
						Max ambition		NDC aligned		Late action	
			2010	2020	2030	2020	2030	2020	2030	2020	2030
7.3.1	1.00[a]	MJ/LCU	1.643	0.870	0.433	0.840	0.338	0.840	0.343	0.840	0.340
7.2.1	51.40[b]	Percent	0.83	2.63	6.45	2.64	19.32	2.64	17.92	2.64	15.82
6.4.1	265.76[c]	USD/m^3	5.84	12.75	16.87	13.32	20.81	13.13	20.75	13.13	20.83
15.3.1	0 & 5[d]	Kg/ha	13.69	25.34	33.93	24.81	12.45	26.07	15.90	26.07	17.13
12.3.1.	50[e]	Percent	24.43	21.93	22.62	21.02	18.44	21.72	21.72	21.72	21.72
15.1.1	17[c]	Percent	15.77	14.80	13.06	16.01	18.43	15.04	16.73	14.92	14.83
15.2.1	428.69[a]	Tons/ha	122.9	117.6	115.5	120.0	123.5	119.6	122.1	119.5	120.9

* SDG 7.3.1 Energy intensity level of primary energy supply (MJ per 2017 PPP GDP), SDG 7.2.1 Renewable energy share in the total final energy consumption (percent), SDG 6.4.1 Water use efficiency (USD per m^3), SDG 6.4.2 Freshwater withdrawal as a proportion of available freshwater resources (percent), SDG 15.3.1 (relevant) Nutrient balance per unit area (nitrogen kg per hectare), SDG 12.3.1.a/b Average of food loss and food waste index (percent), SDG 15.1.1 Forest area as percent of total land area (percent), and SDG 15.2. 1 Above-ground biomass stock in forest (tons per hectare).

**Sources of SDG targets: [a]Mean top five country performers, [b]Sachs et al. (2019), [c]OECD (2019), [d]FAO (2021), and [e]UNEP (2021)

7. Ensuring Gender and Social Inclusion in the Net-Zero Emission and Climate-Resilient Pathways

The LT-LEDS recognizes the critical role that women, youth, and vulnerable communities play in climate action, particularly in adaptation efforts linked to agriculture, food production, and natural resource management as well as mitigation activities (e.g., energy and waste management). Addressing gender and social inclusion considerations during the implementation of the measures envisaged under the LT-LEDS will be critical to maximize co-benefits of the strategy and ensure that the strategy contributes to the country's national and international commitments on gender equality, including the achievement of the SDGs (SDG 1 on poverty eradication and SDG 5 on gender equality) and the empowerment of youth and women.

The LT-LEDS proposes an economic transformation that will lead to the creation of economic opportunities and green jobs, through paid employment and entrepreneurship and in formal and informal sectors. Presented earlier, the NDC-aligned scenario, through additional capital accumulation and job creation in green sectors, will create around 0.932 and 1.77 million green jobs in 2030 and 2050, respectively. This forecasted increase in green jobs offers opportunities for an inclusive labor market in key sectors to drive growth in Ethiopia's economy.

The labor force participation of women in Ethiopia stands at 72%,[16] compared to 85%[17] for men. Most of the labor force is employed in the agriculture sector, at 60.3% and 76.5% for the female and male labor forces, respectively.[18] Women form 14%[19] of the workforce in transport, storage, and communication, which constitutes a small minority of the total female workforce. Fewer women than men work in renewable energy, and the gender gap is wider in leadership and STEM-related roles, though more women work in renewable energy compared with conventional energy sectors.[20] Other factors that impact

16 https://data.worldbank.org/indicator/SL.TLF.CACT.FE.ZS?locations=ET

17 https://data.worldbank.org/indicator/SL.TLF.CACT.MA.ZS?locations=ET

18 Central Statistical Agency & World Bank. "Ethiopia Rural Socio-economic Survey 2013" (survey report). Addis Ababa, 2014.

19 https://www.ilo.org/shinyapps/bulkexplorer52/?lang=en&segment=indicator&id=EMP_2EMP_SEX_ECO_NB_A

20 IRENA." Renewable Energy: A Gender Perspective," last modified 2019. https://www.irena.org/publications/2019/Jan/Renewable-Energy-A-Gender%20Perspective#:%7E:text=Renewable%20energy%20employs%20about%2032,lower%20than%20in%20administrative%20jobs.

women's positions in the labor markets include the pay differentials between men and women for similar jobs, which currently stands at 44%.[21] Women's financial access, key to economic activity, is lower than that of men. Furthermore, 29.08%[22] of Ethiopian women have ownership at a financial institution or mobile money service provider compared with 40.94%[23] of men.

Access to green jobs and sustainable livelihoods is key to the equal distribution of co-benefits from the LT-LEDS implementation. Central to the concept of "just transitions" is the preparation of the workforce for the demands of the future green labor market to ensure equal opportunities for women, men, youth, and workers currently engaged in informal and vulnerable jobs.

Identifying high potential sectors for women's empowerment—such as agriculture and food production, forestry, and certain areas of renewable energy where women are already well positioned—offer short-term wins toward 2030. The 2050 time horizon of the LT-LEDS lends itself to addressing deeper structural barriers that will bring women and youth into sectors, high-end jobs, and viable enterprises (e.g., through technical or leadership roles in wind and solar energy, transport, or construction). This will require deliberate strategic approaches to address the barriers women face when accessing jobs and economic opportunities, including the following:

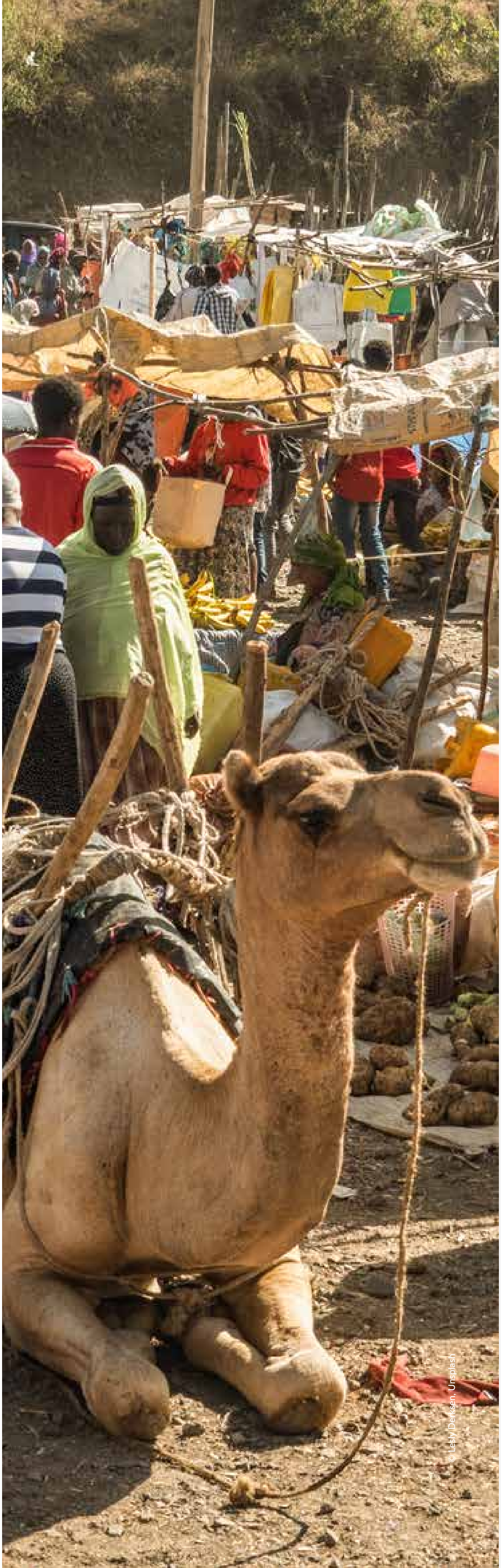
> **Skills mismatch.** Curriculum development for the reskilling and upskilling of women, girls, and youth in STEM at all levels of the education system—from primary to tertiary— and vocational education and trainings prepare the labor force for future green jobs. Ethiopian women and girls are currently less likely than male counterparts to enroll in education at all levels.[24] Women also face specific challenges linked to gender roles in participating in education and training opportunities, which will require focus and support to women's networks.

21 Ethiopia 10-Year Development Plan

22 https://data.worldbank.org/indicator/FX.OWN.TOTL.FE.ZS?locations=ET

23 https://data.worldbank.org/indicator/FX.OWN.TOTL.MA.ZS?locations=ET

24 World Bank. "The World Bank in Ethiopia," last modified 2018. https://www.worldbank. org/en/country/ethiopia/overview



- **Informality.** Women are more likely than men to engage in informal, home-based, and unpaid sectors of the economy. In agriculture, for example, women are more likely to be engaged in subsistence and minor crops, while men are more engaged in paid and commercial farming.[25] Indeed, an estimated 65% of women engaged in agriculture are unpaid subsistence farmers.[26] Targeted support to incentivize the formalization of women's economic activities through education and access to finance can help women leapfrog into higher-quality employment.

- **Unpaid care work.** Women spend more time performing unpaid care and domestic work than men do,[27] which inhibits women's roles in political and economic spheres and is caused by a lack of care services. Expansion of care solutions and investment in infrastructure in rural and urban areas can support women's access to opportunities created by the implementation of the LT-LEDS actions.

- **Social norms and gender stereotypes** dictate what are considered suitable jobs for men and women. In sectors where women are traditionally underrepresented (e.g., in energy and transport), a lack of role models can inhibit women's access to jobs as drivers, mechanics, engineers, and others in the green economy. Creating women's networks, such as the existing networks for women in renewable energy, are key to enhancing women's participation and retention and nurturing female role models.

- **Limited access to productive assets, finance, and markets** is a barrier to women, particularly in agriculture and forestry and in entrepreneurship overall. In line with the 10YDP, LT-LEDS implementation can work to eliminate pay differentials between men and women and enhance women's financial inclusion through the promotion of land and asset ownership. The development of financial products tailored to the needs of women and micro, small, and medium enterprises is instrumental both for women's empowerment and tackling key barriers to business start-ups and scale-ups. Finally, addressing issues of financial inclusion while also enhancing women's access to agricultural inputs, training, extension services, and information and smart-agriculture technologies are key measures to realize women's resilience and potential in climate action.

To maximize benefits associated with the LT-LEDS, the strategy recommends the development of a Women and Youth in Green Jobs Program, which will put forward strategic actions to overcome the barriers women and youth face to access green jobs while promoting the inclusive formalization of informal sectors. The program will emphasize skills development, job security, support to entrepreneurs and women-led businesses, and promotion of social norms to change women's participation in the green economy. Furthermore, the program can identify opportunities to leverage green economic policy instruments, such as through provisions for employment and investment criteria for more inclusive opportunities.

25 Environment, Forest and Climate Change Commission and the NAP Global Network. "Integrating gender considerations in Ethiopia's National Adaptation Plan (NAP) Process: Analysis and recommendations." 2018.

26 Central Statistical Agency. "Ethiopia 2013 Labour Force Survey." Addis Ababa. Last modified 2014. https://www.ilo.org/surveyLib/index.php/catalog/7142/download/43668

27 Environment, Forest and Climate Change Commission. 2018.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8.

Financing the Net-Zero Emission and Climate-Resilient transition

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This chapter provides a data-driven blueprint, aligned with and complementary to the existing national climate finance policies and strategies,[28] for financing the transition to a zero-emission and climate-resilient pathway by mid-century.

The objective of this chapter is threefold. First, it presents estimates of investments needed to achieve NZE by mid-century under the three selected scenarios. Second, it estimates the gap between the needed and available investments to meet the net-zero targets. Third, it reviews the strategy to close the financial gap by describing the financing options associated with costs estimates derived from the CBA. The technical annex shows the assumptions, modeling definitions, and interventions that guided the financing actions of the LT-LEDS.

28 The main policy documents considered for the financing strategy are Climate Resilient Green Economy (CRGE), Second Growth and Transformation Plan (GTP II) 2015-2020, Ten-Year National Development Plan (10YDP) (2021-2030), Ethiopia's Country Planning Framework for the GCF 2016-2020, Resource Mobilization Strategy for Ethiopia's National Adaptation Plan and its Implementation Plan, Financing Strategy for Updated Ethiopia's Nationally Determined Contribution and its Implementation Plan, and Financing the Child-Centered Sustainable Development Goals (SDGs) in Ethiopia.

8.1 INVESTMENT NEEDS FOR THE NDC-ALIGNED SCENARIO

Under the NDC-aligned scenario, the total investment requirement is estimated at USD 154 billion over a 30-year period (2020–2050).[29, 30] In net present value, the required investment equals approximately USD 5 billion per year. The achievement of the net-zero target requires, on average, the deployment of 33% of the total investment every 10 years until 2050.

The total investment includes capital investment of USD 133 billion and O&M costs of USD 21 billion. The power generation sector requires the highest capital investment, followed by the agriculture sector, land-based interventions, waste management, electrification of the transport sector, and CCS (see Table 8.1).

TABLE 8.1
Capital investments per sector and per technology (net present value)

Technologies	2020–2030		2031–2040		2041–2050		2020–2050	
	USD Billion							
Transport electrification	**$**	**5.33**	**$**	**4.76**	**$**	**3.35**	**$**	**13.44**
Electric vehicle chargers	$	0.21	$	0.15	$	0.11	$	0.47
Electric vehicles	$	5.05	$	4.54	$	3.19	$	12.78
Electric buses	$	0.07	$	0.07	$	0.05	$	0.19
Power generation	**$**	**24.25**	**$**	**24.84**	**$**	**8.30**	**$**	**57.39**
Biomass	$	1.17	$	1.10	$	0.37	$	2.64
Hydropower large scale	$	18.72	$	19.66	$	5.93	$	44.31
Solar large scale	$	0.18	$	0.16	$	0.07	$	0.41
Wind onshore	$	4.17	$	3.93	$	1.93	$	10.03
Geothermal	$	0.002	$	0.002	$	0.001	$	0.005
Energy efficiency	**$**	**0.43**	**$**	**0.53**	**$**	**0.36**	**$**	**1.33**
Agriculture	**$**	**7.08**	**$**	**10.55**	**$**	**11.77**	**$**	**29.40**
Sustainable agriculture	$	0.74	$	0.18	$	0.10	$	1.01
Crop diversification	$	0.11	$	0.03	$	0.01	$	0.15
Livestock interventions	$	6.23	$	10.34	$	11.66	$	28.23
Land-based interventions	**$**	**10.18**	**$**	**3.92**	**$**	**3.40**	**$**	**17.50**
Waste management	**$**	**3.23**	**$**	**5.88**	**$**	**4.95**	**$**	**14.05**
Waste management	$	1.60	$	2.78	$	2.34	$	6.72
Recycling	$	0.59	$	1.73	$	1.66	$	3.98
Composting	$	0.03	$	0.10	$	0.12	$	0.25
Landfilling	$	0.48	$	0.45	$	0.26	$	1.19
Waste collection	$	0.16	$	0.18	$	0.12	$	0.46
Waste energy recovery	$	0.35	$	0.31	$	0.18	$	0.84
Waste prevention	$	0.02	$	0.33	$	0.26	$	0.61
Industrial CCS	**$**	**0.0002**	**$**	**0.001**	**$**	**0.01**	**$**	**0.01**
Total capital investment	**$**	**50.50**	**$**	**50.49**	**$**	**32.14**	**$**	**133.12**

29 Expressed in the net present equivalent terms.

30 The total investment required expressed is an underestimation of the total investment required for a fully sustainable development transformation. This is because only the costs of the interventions that were modeled in the GEM are included, excluding important adaptation interventions and other soft interventions with costs that were not quantifiable.

Consistent with the CRGE strategy, Resource Mobilization Strategy for the NAP-ETH, and NDC Financing Strategy, the investment required will be financed from domestic public and private sources and from international funding sources. In line with the NDC Financing Strategy, it is assumed that the total investment constitutes 20% as unconditional (USD 31 billion), while 80% (USD 124 billion) will be conditional.

8.2 INVESTMENT REQUIREMENTS FOR MITIGATION INTERVENTIONS

The total investment required for mitigation interventions is about USD 86 billion. The largest share of the total mitigation investment will be required for the power generation sector (67% of the total estimated investment), followed by the waste management sector (16%), the electrification of the transport sector (16%), energy efficiency solutions (1%), and upgrading technology in the industrial sector and use of CCS technology (<1% of the total estimated investment).

Ethiopia will need to raise USD 17 billion to fund unconditional interventions (20% of the total investment), and the remaining mitigation interventions will require a further USD 69 billion to be secured from international sources and the private sector for 2020-2050. The country is facing a significant imbalance between financing mitigation and adaptation, in favor of adaptation.[31] Therefore, leveraging synergies with adaptation interventions under cross-cutting projects is crucial to the overall efficiency of the interventions.

Investment requirements for cross-cutting interventions

Ethiopia needs to mobilize USD 47 billion for cross-cutting interventions, supporting both mitigation and adaptation objectives simultaneously. The largest investment requirements will be for the livestock sector (60%), followed by land-based interventions (i.e., forestry, 37%), sustainable agriculture, livestock interventions, and crop diversification (3%). The considered cross-cutting interventions focus on the sectors that have been identified as most vulnerable and in need of adaptation based on the NDCs, namely agriculture, forestry, health, water, and urban development. The full list of cross-cutting-related interventions considered is shown in the technical annex.

The LT-LEDS assumes that at least USD 9 billion (20%) will be financed using domestic resources (unconditional), and international public and private sector sources will cover the remaining costs (conditional). This aligns with Ethiopia's NDC Financing Strategy, which states that domestic and international funding with no conditionality must be prioritized for adaptation (over mitigation) interventions to build the country's resilient and adaptative capacity to climate change, at least during the first 10-year period of the LT-LEDS implementation.

31 The estimated ratio of adaptation and mitigation finance received in Ethiopia during 2011–2017 was 62% to 38%, see in Care. 2020. Climate Finance Adaptation Study Report Ethiopia. https://careclimatechange.org/wp-content/uploads/2021/01/Ethiopia-Climate-Adaptation-Finance-Tracking.pdf

8.3 INVESTMENT REQUIREMENTS OF THE MAXIMUM AMBITION AND LATE ACTION SCENARIOS

The maximum ambition scenario substantially increases the initial investments of all interventions at an early stage to reach the net-zero target by 2035, while the late action scenario reduces the early ambition of some interventions, leading to a reduction of initial investments and O&M costs. For 2020–2050, the total investment difference is about 75% between the NDC-aligned and maximum ambition scenarios and about 10% between the NDC-aligned and late action scenarios (see Table 8.2).

TABLE 8.2

Investment needs estimates per LT-LEDS scenario (net present value)

Scenarios	2020–2030	2031–2040	2041–2050	2020–2050
	USD billion			
NDC aligned	$55	$59	$40	$154
Maximum ambition	$88	$78	$106	$272
Late action	$43	$51	$44	$138

Source: Total discounted investments and cost, Updated NDC Financing Strategy

The financing strategy of the LT-LEDS assumes similar conditional and unconditional targets as those of the updated NDC. For both cross-cutting and mitigation interventions, the target is to raise 20% of the required investment from the domestic sector (i.e., unconditional) and 80% of the required investment from the public and international funding sectors (see Table 8.3).

TABLE 8.3

Conditional and unconditional investments (net present value)

Scenarios	Maximum ambition	NDC-aligned	Late action
	USD billion, 2020–2050		
Conditional (80%)	$218	$123	$110
Unconditional (20%)	$54	$31	$28

The LT-LEDS modeling exercise suggests the allocation of public funds to specific interventions based on historical trends of financing sources utilized for each sector and considering the existing sectoral financial incentives. Based on historical data and assuming similar trends, public funds are allocated to interventions in urban development (e.g., waste management), public transport and power generation, and reforestation, while private funds are allocated to agriculture, private transport, and IPPU-related interventions. However, as a strategy for a green economy transformation and to enhance financial sustainability, private funds should be maximized for cross-cutting and adaptation-related interventions.

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TABLE 8.4
Suggested potential utilization of public vs. private funds (net present value)

Scenarios	Maximum ambition	NDC aligned	Late action
	Cumulative USD billion, 2020–2050		
Public funds	$144 (53%)	$117 (76%)	$105 (76%)
Private funds	$128 (47%)	$38 (24%)	$33 (24%)

8.4 FINANCE GAP

The finance gap is defined as the difference between the needed and available resources to implement the LT-LEDS goals. The values of the finance gap were estimated using historical public and international climate expenditure data. According to Ethiopia's 2020 submission to the Standing Committee on Finance of the UNFCCC, the GoE has mobilized over USD 22 billion during 2011–2019 (or USD 3.2 billion per year) for climate projects. The resources were used on mitigation and adaption projects and programs in the agriculture, energy, transport, industry, forest, urban development, and health sectors. Of this, USD 6.4 billion, 8.1 billion, and 7.6 billion were invested in climate change adaptation, mitigation, and cross-cutting activities, respectively.[32] Therefore, it is estimated that Ethiopia's average annual finance mobilization for mitigation and cross-sectoral interventions is approximately USD 1.96 billion.

Assuming the climate finance mobilized has an annual growth rate of 13% for 2020–2030 based on the 10YDP government expenditure assumptions for climate-related interventions, the cumulative funds available for LT-LEDS interventions for 2020–2030 is estimated at USD 48 billion. When the cumulative funds available are compared to the required total costs of USD 86 billion

32 Government of Ethiopia. "Submission to the Standing Committee on Finance calls for evidence for the 2020 Report on the needs of developing country Parties related to implementing the Convention and the Paris Agreement and the 2020 Biennial Assessment and Overview of Climate Finance Flows," last modified 2020. https://unfccc.int/sites/default/files/resource/CF%20Needs_Ethiopia_rev.pdf.

from the NDC-aligned scenario (undiscounted amount), an annual finance gap of USD 4 billion for 2020–2030 is estimated. The gap is likely to increase, particularly due to external shocks, such as the COVID-19 pandemic, which has diverted resources to large emergency relief programs.[33, 34] Moreover, the momentum was not fully used to make the government disbursement programs more conditional on environmental performance of the supported business activities.

In addition, recent geopolitical developments might further divert international financial resources away from implementation of the climate agenda.[35, 36, 37] Nevertheless, the rising and increasingly volatile prices of fossil fuels caused by various market frictions (e.g., military conflicts) might provide some stimulus toward renewable resources. Assuming a decrease in the government allocation for climate-related projects of 8%,[38] an annual finance gap equivalent to USD 9 billion or higher could be expected.

8.5 STRATEGY TO CLOSE THE FINANCING GAP

The challenge of financing the LT-LEDS interventions at the scale required is significant. Ethiopia's Resource Mobilization Strategy for the NAP-ETH, NDC Financing Strategy, and other national and regional financial assessments provide key recommendations to close Ethiopia's climate finance gap. The following strategy aligns with the recommendations provided by the climate finance reports in Ethiopia. The strategy follows three specific objectives, with each having at least one specific intervention.

Objective 1. *Increase mobilization of domestic—public and private—financial resources to finance climate projects with socioeconomic development co-benefits.*

I. **Achieve private funding leverage through blended finance.** Most of the climate finance in Ethiopia comes from public funds, followed by international aid, while private sector finance plays a limited role.[39] Under a constrained public budget and decreasing overseas development assistance, leveraging private resources is critical to closing the finance gap. Blended finance is particularly relevant to motivate private sector-led investments focused on mitigation and adaptation and can support projects to become financially viable at scale.

II. **Reinforce an enabling environment for climate finance.** The access and disbursement of public, international, and private finance in Ethiopia are influenced by the country's financial environment. Increasing transparency on climate change mitigation and adaptation spending, having a climate finance taxonomy, and establishing policy and regulatory frameworks that promote private sector investments linked to climate and socioeconomic development are actions that reinforce an enabling environment for climate finance in Ethiopia.

Objective 2. *Increase the mobilization of international funding (multilateral and bilateral and development) partners with a climate focus to close the existing financing gap.*

III. **Increase the capacity of the CRGE units and related ministries to a) develop or identify bankable project proposals that are attractive to international financiers and b) navigate and comply with the requirements of financial institutions.** Despite being a leader in climate change action in Africa, Ethiopia lacks comprehensive capacity development efforts for increasing access to climate finance from multilateral, bilateral, and

33 ADB. "Green Finance Strategies for Post-COVID-19 Economic Recovery in Southeast Asia," last modified 2020.

34 Convergence. "The State of Blended Finance 2021," last modified 2021

35 Bounds, A., and Fleming, S. "EU nations should tap recovery plan funds amid Ukraine crisis, says official." Financial Times, last modified 2022.

36 Beckmann, A., and Vykhor, B. "Assessing the environmental impacts of the war in Ukraine." WWF, last modified 2022.

37 Bhushan, C. "Russia-Ukraine conflict could derail the Climate Agenda." Heinrich Böll Stiftung, last modified 2022.

38 Assumption based on the Financing Strategy for Updated Ethiopia's Nationally Determined Contribution and its Implementation Plan and World Bank, "Draft Analysis – COVID-19: Potential Poverty and Social Impacts in Ethiopia and Policy Responses," last 2020.

39 UNDESA. "Ethiopia's Capacity Building on Climate Change Financing," last modified 2022. https://www.un.org/ldcportal/content/ethiopia-capacity-building-climate-change-financing.

private sector financing vehicles.[40] Ethiopia's CRGE Facility,[41] assessment report (2019), and NAP-ETH (2020) indicate capacity gaps in developing well-formulated projects; in implementing, tracking, and reporting climate response interventions; and in fulfilling various financial requirements. CRGE limitations and external circumstances hinder Ethiopia's access to international climate finance.

Objective 3. Implement innovative financing instruments and climate finance policies to raise revenues domestically that can support climate financing activities (e.g., carbon market instruments, thematic bonds, payments for ecosystem services, debt for nature swaps).

IV. **Implement carbon pricing policies.** Carbon pricing mechanisms can incentivize a fuel switch, increasing energy efficiency across all emitting sectors. They also improve the efficiency of the fiscal system, which decreases the opportunity costs of public funding channeled to carbon mitigation (and adaptation) activities in Ethiopia. To maximize the benefits, carbon pricing must be accompanied by various complementary policies.

V. **Mainstream the use of innovative financing mechanisms.** Innovative financing instruments—specifically green, social, and sustainable bonds, debt for nature/climate swaps, and payments for ecosystem services— could be explored and piloted with a view to scale financial resources from the international capital markets and manage debt. These innovative financing mechanisms would be appropriate to deliver funding for interventions that achieve both climate and development objectives.

VI. The technical annex for the financial section summarizes the potential use of each intervention, the current barriers to their maximization, and specific actions to be taken to overcome such barriers.

40 UNDESA. "Ethiopia's Capacity Building on Climate Change Financing," last modified 2022. https://www.un.org/ldcportal/content/ethiopia-capacity-building-climate-change-financing

41 A national financial mechanism that mobilizes and manages domestic and international climate finance to support the institutional capacity building and implementation of the country's climate change adaptation and mitigation projects.

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9. Ensuring Implementation of the LT-LEDS: Institutional Arrangements and Monitoring and Evaluation System

9.1 INSTITUTIONAL SETTING FOR IMPLEMENTATION OF THE LT-LEDS

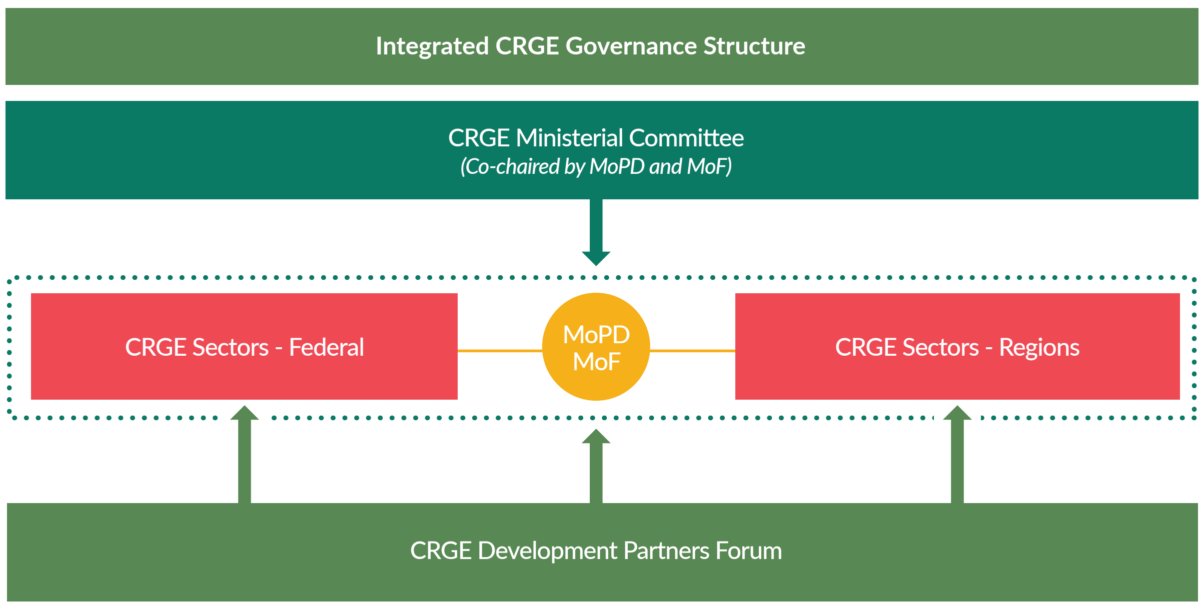
Towards the overarching objective of integrating climate into the national development planning framework, it is pertinent to design an institutional arrangement aligned with the primary mandates of government bodies for an effective and integrated governance approach to climate-resilient green growth and development. Based on lessons from the institutional setup in realization of the CRGE (GTP I and GTPII) and Ethiopia's NDC, an integrated CRGE governance structure will be utilized for the implementation of the LT-LEDS. The new integrated CRGE governance structure is based on the new definition of powers and duties of government bodies in proclamation 1263/2021. The MoPD is mandated to coordinate the sectoral government bodies to effectively implement and manage the low emission and climate resilient green development strategy within the national development planning framework. At the national level, integrating the governance of CRGE will re-strengthen a unified CRGE Ministerial Committee, chaired and co-chaired by the MoPD and the MoF respectively. The members of the CRGE governance include the public sector, which directly contributes to climate change at the federal and regional level and all development partners.

All the technical works specific to CRGE sectors will be integrated and conducted at each relevant government body and inter-ministerial management, which is a high-level decision-making body guiding the nationally integrated CRGE process. The CRGE technical capacities within each sector will be strengthened through the Sectoral Strategic Affairs Executive Office (department) aligned with the spirit of integrating sectoral level climate and development programs and plans through the establishment of the Sectoral CRGE Desk. Although it is important to integrate and conduct the CRGE activities at each relevant government organ, in the event of a requirement for collaborative technical special undertaking, ad hoc technical committees may be established as deemed necessary.

The CRGE Development Partners Forum is designed to strengthen the role and participation of the development partners in their climate actions and investments in Ethiopia. This platform will also help unlock and mobilize new sources of climate action support, finance, and technology to enhance Ethiopia's climate resilience including adaptation and mitigation.

The integrated CRGE governance provides a single engagement point where stakeholders can engage and make decisions about climate change issues, thus enhancing coordination, effectiveness and reducing fragmentation of programs and projects. Figure 9.1 below shows the integrated CRGE governance structure. The interaction of all actors and stakeholders will be flexible and will be managed through structured, regular meetings on cross-cutting matters, planning, monitoring and evaluations. As the national coordinator of the integrated CRGE, MoPD can adopt an action plan for the engagements and meetings with line ministries, regional governments, and development partners. Each sector, including the relevant regional bureaus, can also have a separate engagement with other stakeholders, including the development partners. For any regular correspondence, each CRGE line ministry can assign a state minister (based on work proximity to the CRGE matters). If regular correspondence is required, there can be (if appropriate) engagements and meetings with the represented State Ministers and Director Generals. The main role would only be to coordinate and steer routine cross-cutting matters in accordance with the CRGE Ministerial Committee guidance and decisions.

FIGURE 9.1
Ethiopia's integrated CRGE Governance structure



Based on the new CRGE Governance structure, the government stakeholders' or government bodies' roles and responsibilities are identified based on their primary mandates and expected institutional climate and development deliveries. In the past, roles and responsibilities were largely designated at technical and steering committee levels and institutional capacities and memories were not able to be strengthened.

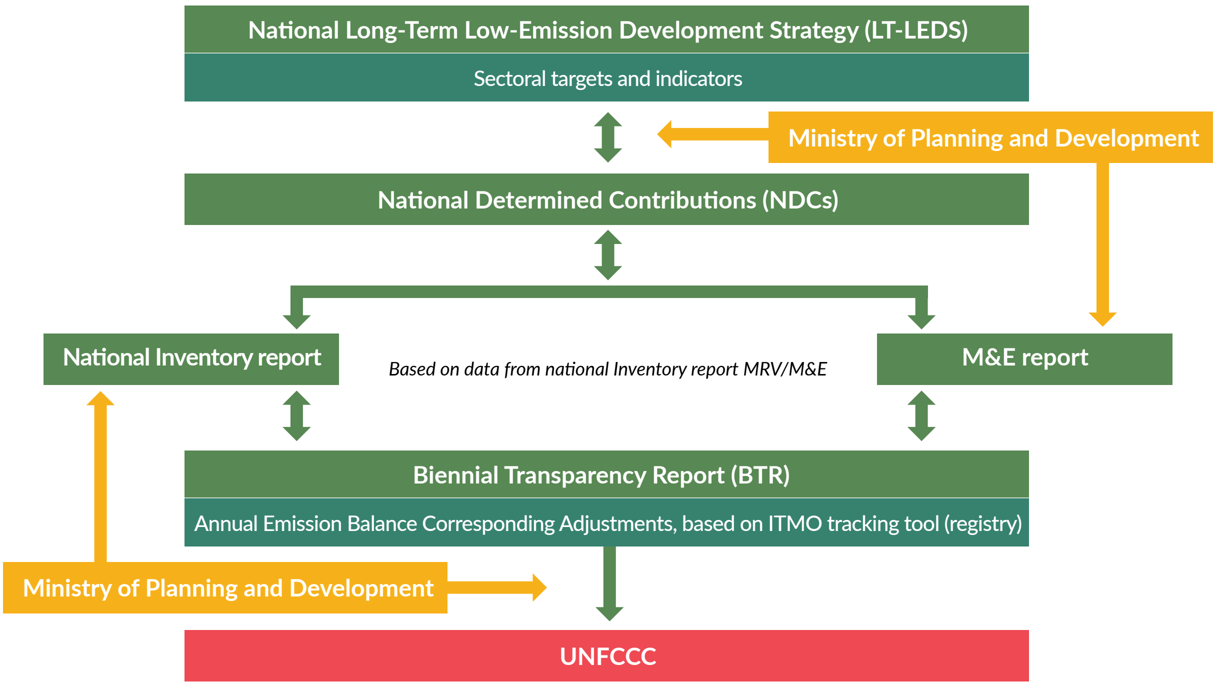
9.2 MONITORING AND EVALUATION SYSTEM OF THE LT-LEDS (INCLUDING MRV)

A measurement, reporting, and verification (MRV) system and an adaptation monitoring and evaluation (M&E) system should be developed in an integrated manner to support Ethiopia in evaluating progress toward implementing the actions and achieving the aims of the LT-LEDS. These aims and targets will steer the country in identifying opportunities for increasing the ambition in its next NDC revision. The adaptation M&E system will enable Ethiopia to better understand the resource needs and constraints of adapting to the impacts of climate change and how its stated adaptation targets in the LT-LEDS are achieved.

More specifically, an integrated climate change and development planning process and framework will also support the setting-up of an integrated and aggregated Monitoring, Reporting and Verification (MRV) and Monitoring and Evaluation (M&E) system for monitoring progress of climate action. The existing climate MRV and development M&E system would eventually be integrated into the new Climate and Development Reporting (CDR) System. The integrated and aggregated CDR process and system will be developed by the MoPD, EPA and relevant sectors and ministries. Both external and domestic financing of growth and development are expected to be subjected to integrated and aggregated CDR process and system which aims to aggregate the progression beyond previous efforts.

Furthermore, the MRV and M&E framework for Ethiopia's LT-LEDS, will be improved through successive NDC revision cycles, and will work toward full alignment with Article 4 (Mitigation), Article 6 (Cooperative Approaches), Article 7 (Adaptation) and Article 13 (Enhanced Transparency Framework) under the Paris Agreement. Article 13 specifies elements of reporting in the Biannual Transparency Report, with further flexibility for LDCs. While LDCs like Ethiopia can report "at their discretion," Ethiopia is working toward meeting international best practices to demonstrate a high degree of ambition and climate policy leadership. Therefore, Ethiopia will also comply with mandatory reporting and accounting for market mechanisms as well as provide information on sustainable development promotion, environmental integrity, and transparency.

FIGURE 9.2
Ethiopia LT- LEDS MRV and M&E framework



To this end, the MRV and M&E framework will eventually be fully mainstreamed in the 10YDP, and successive development plan targets and indicators will be provided for each sector (Figure 9.2). Therefore, international support is critical in building capacity for stakeholders who will undertake the tracking, collection, and reporting of data, as the integrated CDR through the MRV and M&E systems are a prerequisite for successful implementation of the LT-LEDS, including reporting to the global community (e.g., UNFCCC and other key processes).

In addition, the MoPD has established a modeling unit that could explore and adjust targets based on performance using the data generated from the MRV and M&E systems. The modeling unit could provide the necessary analytical capacity for the next NDC and LT-LEDS revision cycles.

9.3 MANAGING, MONITORING, AND EVALUATING INCLUSIVE OUTCOMES

Based on lessons from CRGE implementation and the NDC, LT-LEDS implementation will be governed by the Inter-Ministerial Steering Committee with responsibilities to set policy direction and guidance to enhance coherence and collaboration across the national program. This includes alignment with the overarching national priorities for gender, women's empowerment, and social inclusion. It is recommended that the Ministry of Women and Social Affairs become part of the Inter-Ministerial Steering Committee to support implementation, monitoring, and accountability for inclusive outcomes.

Expertise on gender and social inclusion can be secured through the technical committee, who is responsible for developing policy brief guidelines and tools for LT-LEDS implementation, which also guide relevant IEs and EEs. The Ministry of Finance's gender-responsive budgeting will support target setting and achievement of inclusive outcomes from the LT-LEDS implementation, including the proposed Women and Youth in Green Jobs Program to maximize gender and youth co-benefits by promoting access to green jobs. In line with the requirement for national plans to apply sex-disaggregated data and information in annual plans and reports, the LT-LEDS, in alignment with the NDC and NAP MRV and M&E frameworks, will be implemented with sex-disaggregated targets and indicators. Enhancement of the availability of sex-disaggregated data at the sector level will gradually enhance the MRV on inclusive outcomes.

Capacity building on MRV

In addition to climate finance, achieving NZE and sustainable and climate-resilient development will require an adequate level of capacity building. Ethiopia's LT-LEDS is sector-wide and has shown high ambition in both mitigation and adaptation. To integrate and fully implement the interventions proposed, Ethiopia seeks support on MRV and M&E capacity building in the following areas:

- Strengthen MRV systems and their institutional setup with adequate infrastructure and human resources, which requires staff with the required skills and knowledge and institutional capacity to enhance the coordination of entities monitoring NDC implementation and produce periodic reports horizontally across sectors and vertically at different administration levels
- Establish a green coding system in public financial management for proper tagging and tracking of climate finance
- Integrate MRV/M&E with a national statistical data management system
- Enhance accessibility and availability of data through state-of-the art technology
- Strengthen coordination among sectors and regional counterparts for better implementation, for M&E of the LT-LEDS through successive NDCs, and for rounds of LT-LEDS updates

Ethiopia's net-zero and climate resilient development strategy

Total GHG emission (Mt CO_2e): 272 Mt (2020) → 0 Mt (2050)

Energy

	2030	2040	2050
Share of renewables in electricity production	100%		
Annual energy efficiency improvement	8%/a		
Electrification of households (petroleum)	10%		75%
Electrification of households (biomass)	14.5%		60%
Electrification of industry (petroleum)	20%		50%
Electrification of transport	10%		75%
Shift from petroleum to hybrid and electric vehicles	10%	44.5%	75%

Agriculture, livestock and land-use

	2030	2040	2050
Improved manure management for livestock	20%		40%
Feed management (oil seed feeding)	10%		25%
Improved livestock produtivity	14%		40%
Substitution of cattle for poultry	10%		20%
Agricultural mechanization	10%		25%
Integrated soil fertility management	15%		25%
Improved rangeland management	20%		30%
Production of fruits and other parennial crops	1.5 million ha		3.5 million ha

Forestry

	2030	2040	2050
Reduced deforestation	25%	37.5%	50%
Afforestation / reforestation (ha of land)	1.8 million ha	4.5 million ha	8.2 million ha
Forest restoration (ha of land)	4 million ha	8 million ha	16 million ha

Waste

	2030	2040	2050
Processing organic municipal waste	20%	40%	50%
Landfill gas reduction	5%	20%	35%
Solid Waste collection and management	10%	20%	25%
4R measures	90%	85%	90%
GHG emission reduction from			
1. urban wastewater management	10%	40%	80%
2. rural/industrial wastewater management	10%	30%	70%
Fecal sludge treatment	4%	15%	30%

IPPU

	2030	2040	2050
Reduction of the share of clinker in cement	60%		50%
Long-term goal for CCS	100 Gg CO_2e		500 Gg
Incorporation of recycled high-quality scrap in iron and steel production			10%

2020 | 2030 | 2040 | 2050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