GHG Emission Reduction Impact Assessment of CRGE Policies and Actions within the Energy Sector in Ethiopia

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Initiative for Climate Action Transparency

Initiative for Climate Action Transparency - ICAT

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PREPARED UNDER

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Acronyms and Abbreviations

AfDB	African Development Bank
BAU	Business As Usual
CDM	Clean Development Mechanism
CFL	Compact Fluorescent lamp
CRGE	Climate Resilient Green Economy Strategy
DSM	Demand Side Management
EAREP	Electricity Access Rural Expansion Project
EEA	Ethiopian Energy Authority
EEP	Ethiopian Electric Power
EEU	Ethiopian Electric Utility
EFCC	Environment, Forest and Climate Change
ENREP	Electricity Network Reinforcement and Expansion Project
ER	Emission Reduction
EREDPC	Ethiopian Rural Energy Development and Promotion Centre
ERG	Ethio Resource Group
ES	Ethiopian Standard
ESA	Ethiopian Standards Agency
GEM	Green Economic Modelling
GHG	Greenhouse Gas
GIZ	German Agency for International Cooperation
GMSP	Grid Management Support Program
GOE	Government of Ethiopia
GTP	Growth and Transformation Plan
GWP	Global Warming Potential
ICAT	The Initiative for Climate Action Transparency
ICS	Improved Cookstove
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
kg	kilogram
kVA	kilo Volt Ampere
kW	kilo Watt
LED	Light Emitting Diode
LUCF	Land Use Change and Forestry
M tCO2	Million ton Carbon dioxide
MEPS	Minimum Energy Performance Standard
MFI	Micro Finance Institution
MOA	Ministry of Agriculture
MOE	Ministry of Education
MOH	Ministry of Health
MOWE	Ministry of Water and Energy
MRV	Measurement, Reporting and Verification
MSW	Municipal Solid Waste
MTF	Multi-Tier Framework

MW	Mega Watt
MWh	Mega Watt Hour
NDC	Nationally Determined Contributions
NEP	National Electrification Plan
NGO	Non-Governmental Organization
NICS	National Improved Cookstoves (a national program)
O&M	Operation and Maintenance
PF	Power Factor
PFC	Power Factor Correction
PV	Photovoltaic
SHS	Solar Home Systems
SL	Solar Lanterns
SNV	Dutch Development Organization
SWDS	Solid Waste Disposal Site
tCO2	Ton Carbon dioxide
T&D	Transmission and Distribution
UDP	UNEP-DTU Partnership
UN	United Nations
UNEP-DTU	United Nations Environment Program-Danish Technical University
USD	United States Dollar
W	Watt
WRI	World Resources Institute

Executive summary

This study was initiated by the UNEP-DTU Partnership (UDP) and, as part of the Initiative for Climate Action Transparency (ICAT) it is designed to provide information and develop GHG mitigation assessment and reporting capacity of the environment and climate change unit at the Ministry of Water and Energy (MOWE). The overall objectives of the study are to: i) Provide the government of Ethiopia information on the mitigation effects of selected mitigation policies and actions in the country's energy sector until 2030, which will be an important basis for future mitigation policy making, target setting, and action planning; and ii) Improve the country's capacity to comply with the international rules on climate action transparency through targeted training for the country's inventory preparation and MRV team for the energy sector.

The main focus of the study is assessing Greenhouse Gas (GHG) emission reduction impact of energy sector policies and actions that were prioritized and recommended for implementation in the Climate Resilient Green Economy Strategy (CRGE) document and other sectoral initiatives.

The energy sector policy and actions assessed are shown below and include actions aimed at improvement of energy end-use efficiency, substitution of non-renewable biomass and liquid fossil fuels with renewable biofuels, supply side improvement of electricity on the national power grid, and supply of renewable electricity to off-grid area.

Policy or action	*Sector targeted*
Demand side energy efficiency measures	
Improved (fuelwood) cookstoves(ICS)	Residential, small-scale commercial
Standard and Labelling for electric Injera mitad	Residential, small-scale commercial
Introduction and large-scale use of efficient electric lamps	Residential, small businesses
Fuel switching – renewable fuels	
Ethanol – cooking	Residential
Ethanol – gasoline blend for vehicles	Transport
Gird electricity	
Upgrading of transmission and distributions lines	Electric powered generation
Power factor correction	Industry, large-scale
Power generation from MSW	Electric powered generation
Off-grid renewable electricity supply	
Mini-grids in rural areas for non-electrified communities	Residential, business, community services
Standalone PV systems	Residential, business, community services

The GHG emission reduction assessment was conducted following the *GHG Protocol, Policy and Action Standard* developed by the World Resources Institute (WRI).[1] For quantifying GHG emissions reduction resulting from implementation of the various GHG mitigation policy or actions indicated above relative the business as usual (BAU) practices. Where appropriate CDM GHG emissions calculation methods and tools were also used. The main findings from the assessment are discussed below.

[1]GHG Protocol Policy and Action Standard: An accounting and reporting standard or estimating the greenhouse gas effects of policies and actions.WRI, July 2014.

Demand side energy efficiency measures

Improved cookstoves (ICS)

The ex-post GHG emissions are computed based on ICS production and dissemination data provided by MOWE. Estimated ex-post GHG emission reduction achieved relative to the baseline case shows that by 2020 this action had reduced 18.5MtCO2e. The GHG emission reduction for the period 2021-2030 was also estimated and by 2030 the mitigation impact will be reduction of 62.2MtCO2e.

Standard and Labelling for electric injera mitad

Standards for electric injera mitad were approved in June 2020, and to date only a total of 453 labelled electric Injera mitads have been sold. Over 85% of these mitads were label 3 and label 4 with thermal efficiencies ranging between 68% and 78%.Considering that the Ethiopian Standard Authority will make the electric injera mitads MEPS mandatory in five years, and that the proportion of electric injera mitads that meet MEPS would by 2030 reach 100%, the expected GHG emission reduction in 2030 would be about 0.15MtCO2e.

Introduction and large-scale use of efficient electric lamps

The first large scale introduction and dissemination of improved lighting was initiated in 2009 and by the end of 2012 over 9.6 million CFLs were imported and initially freely distributed and later sold at subsidized prices mainly to households in Addis Ababa. Comparison with use of the incandescent lamps shows that in 2020 the GHG emission reduction was 0.027MtCO2e. Further reduction of GHG emission reduction on the grid is also assessed assuming the introduction of LED lamps in the period from 2021 to 2030.

Fuel switching

Ethanol for cooking

Ethanol for cooking (displacing kerosene and biomass fuels) was introduced in 2012 and continued to be supplied to users until 2018. In this period, monthly ethanol consumption had steadily increased from 45 thousand litres in 2012 to 104 thousand litre in 2018. Within this period the action had contributed to cumulative GHG emission reduction of 0.041Mt CO2.

Ethanol–gasoline blend (vehicles)

Between 2010 and 2020, a total of 60.4 million litres of anhydrous ethanol was blended with gasoline at various proportions from 4.7% of gasoline consumed in Addis Ababa to as low as 0.5%, before the blending was totally stopped in 2018. Within this period, the GHG emission reduction due to ethanol blending was about 0.07MtCO2 or about 1.1% of the corresponding total GHG emission from use of gasoline for transport in Addis Ababa.

The ex-ante GHG emission reduction estimated based on subsequent increase in the volume of ethanol used for blending with projected gasoline demand between 2021 and 2030, shows that GHG emission reduction of1.75MtCO2e could be achieved by 2030.

Grid electricity

Upgrading of transmission and distributions lines

The baseline GHG emission is projected assuming the distribution loss will remain about 12.3%, while ex-ante projection uses percentage losses that will, by 2030, reduce loss to about 8%. Based on these assumptions the GHG emission reduction from reduction in distribution loss in 2030 will be about 0.075Mt CO2.

Power factor correction (PFC)

Assessing the impact of power factor correction at the national level requires data and information that currently could only be available at EEU and EEP, which is not publicly available. For this reason, estimation of GHG and other non-GHG impact of PFC was not possible. But an indication of what energy and emission reduction is achievable relative to business-as-usual practices is indicated for some factories for which PF correction is piloted.

Power generation from municipal solid waste (MSW)

The power plant at Reppi (a solid waste landfill site) has been operational for about 2 years. In this period the plant has incinerated about 594,000 tons of solid waste. The impact of incineration is estimated to reduce/avoid the emission of 57,000tCO2e (methane). If the operation continues to 2030 the GHG emission reduction will reach close to 0.048MtCO2e and the cumulative reduction to 0.326MtCO2e.

Off-grid renewable electricity supply

Mini-grids in rural areas for non-electrified communities

The National Electrification Plan (NEP) was first issued in 2017 and later updated in 2019. Implementation of the NEP started in 2018 but the first mini-grid pilot by the EEU became operational only in 2021. Ex-post GHG emission thus will need to be conducted in subsequent implementation years.

The ex-ante estimate shows that the national mini grid development program is expected to reduce GHG emission by 5.9 MtCO2e over the 2021-2030 period. Nearly all the emission reduction (97%) will be from substitution of diesel use by three-phase customers (those that were using diesel engines for grain mills and diesel generators). Because the mini grids are powered by PV-diesel hybrid systems there will still be some GHG emission.

Standalone PV systems

This set of policies contains actions based on standalone solar systems including Solar Home Systems (SHS and solar lanterns), solar water pumping systems, and solar systems for schools and health centres. SHS and standalone solar systems for schools and health centres are part of the ADELE program (SHS under component 3 and solar for schools and health centres and Component 4). Solar water pumping is not included under the ADELE project.

The standalone solar programs are estimated to result in GHG emission reduction of 2.2 MtCO2e during 2021-2030. SHS and solar potable water pumps account for 77% and 19% of this total. Solar irrigation pumps, solar systems in schools, and solar systems for health centres contribute just 3% of the total emission reduction.

Monitoring Reporting and Verification (MRV)

There is generally lack of sufficient data and information on implementation progress, outputs and outcomes, for most of the policy and actions assessed, and this appears to be more so for the on-going policy and actions that are financed (or were planned to be) with local sources (GOE, regional Governments) or expected to be financed by grant and/or loan from external sources.

Data and information needed, and actions recommended for establishing a well-functioning MRV processes for each of the policy and actions assessed is highlighted under the MRV section of this report. The key issues related to the lack of well-established MRV (or more generally ME) system and the necessary MRV capacity building needs are further elaborated and, recommended actions for improving the MOWE energy sector MRV are provided in a separate document.

1. Introduction and background

1.1 Major policies and actions in the energy sector

The Climate Resilient Green Economy strategy (CRGE) which was prepared in 2011 (FDRE, 2011) has identified several policy measures and actions that would help the country to become a mid-income climate resilient green economy with zero net carbon growth by 2025. The first Nationally Determined Contributions (NDC) of Ethiopia's was released in 2015 and this was later updated in 2021. As part of the design of the CRGE strategy sector Ministries and Institutions have prepared sectoral GHG mitigation strategies, and later resilience strategies (Water and Energy in 2015 and Agriculture and forestry in 2015).

Ethiopia has implemented mitigation and resilience activities in all sectors with varying scope and scale of investment – some sectors such as agriculture and forestry have received a large number of projects while the transport and energy sectors have received the highest level of investment from a limited number of projects. According to Climate Action Tracker Ethiopia is making progress reducing emissions significantly. However, the current projection is that emissions in 2030 will be between 155 and 219 MtCO2e with an expected mean around 185MtCO2e. In these sectors many of the resilience and adaptation actions are similar to on-going risk reduction, poverty reduction and conservation measures.

The updated Ethiopia's Nationally Determined Contribution (NDC) provides the major sectors, and corresponding sectoral mitigation and adaptation measures designed considering present national circumstances and future development plans, as well as the key expectations and requirements as set out in the Paris Agreement (NDC, July 2021). The Updated NDC builds on the Climate Resilient Green Economy Strategy of Ethiopia (CRGE, 2011), the various sectoral resilient strategies including the climate resilient strategy for Energy and Water, Agriculture and Forestry produced in 2015) which complement the CRGE strategy, as well as the Intended NDC that was produced and submitted to UNFCCC in 2015.

The updated NDC is produced employing economy-wide analysis and comprehensive stakeholder engagement to identify and prioritize mitigation and adaptation measures, define progress indicators, recognizes the need for strengthening Measuring, Reporting and Verification (MRV) capacity of the country (NDC, 2021). The updated NDC has also revised the previous baseline figures and projections, and produced projections of emission reductions for 2025, an intermediate year, and for 2030. In this projection two financing scenarios are considered: "unconditional scenario" where the interventions are to be fully financed by the GOE, and the "conditional scenario" which is based on consideration of international financial and technical support. The projections for the unconditional and the total (unconditional + conditional) emission reduction scenarios are presented in Table 1.1.

The total estimated emissions reduction potential in 2030 is 277.7 Mt CO2e or a 68.8% reduction of the business as usual (BAU) emission of 403.5 Mt CO2eq. For the unconditional scenario, the corresponding reduction will be about 56 Mt CO2eq, or 14% of the BAU emission level.

Under the BAU, land use change and forestry (LUCF) will be the second most important driver of emissions (after livestock), however, since the improvement in land use and increasing forest coverage and forest management is one of the priority areas off the GOE, the LUCF sector will have the largest mitigation impact - achieving a reduction of the emission level in this sector

-99.9 Mt CO2e, and turning the LUCF a net sink by increase forest cover to 30% of the national territory by 2030. The LUCF sector interventions include large scale dissemination of improved fuelwood cook stoves which will significantly contribute to reduction of fuelwood demand.

Table 1.1 GHG Emission projections in BAU, Unconditional and Combined Pathways (Mt CO2eq)

	BAU			Unconditional		Total	
	2020	2025	2030	2025	2030	2025	2030
Industry	5.9	12.7	26.1	12.9	27.3	10.2	22.6
Energy	10.7	14.4	20	12.7	14.9	10.4	9.5
LUCF	125	133.8	140.2	112.6	91.8	21.4	-99.9
Livestock	146.4	169.5	194.8	168.7	192.9	162.8	180
Managed Soils	5.8	8.1	11	8	10.9	8	10.6
Waste	9.1	10.3	11.5	9.4	9.5	6	2.9
TOTAL	302.9	348.8	403.5	324.3	347.3	218.8	126

The column “Total” includes the impact of both unconditional and conditional pathways.
Source: Ethiopia’s Updated NDC, 2021, p. 10

The Energy sector contribution to the national GHG emissions is about 4 to 5% in the BAU, and will reach 8% of the total in 2030. The main interventions planned are:

- Economy-wide improvements of energy efficiency of appliances, machinery and their capital assets.
- Increasing number of households using renewable off-grid energy sources for lighting.
- Number of unstable and unreliable diesel-based standalone generator systems 36 systems in 2020 to zero in 2030.
- Percentage of reduced total electricity waste in transmission and distribution systems from the current (2020) level, 19.60% to 12.5% in 2030.
- Percentage of households using renewable off-grid energy sources for lighting (i.e. those not served by the grid) from the current 39.91% to 100% by 2030.
- Percentage of population with stable access to electricity from alternative off-grid renewable energy (RE) technologies from 11% to 35%.

NDC program budget and technical support: The total budget needed for implementing the mitigation and adaptation plans of the updated NDC – between 2020 and 2030 – is estimated at USD 316 billion (USD 275.5 billion and for mitigation interventions, and USD 40.5 billion form adaptation). And of the total budget the GOE intended to cover 20%, and the remaining 80% is expected to come as financial support from international sources. The updated NDC also outlines the need for building institutional capacity and transfer of technology. It underlines that the updated NDC is ambitious and requires a considerable amount of inputs for enhancing current institutional capacities, as well as, for instituting MRV systems capable of addressing reporting requirements as set in the Paris Agreement.

1.2 Objectives and outputs of policies and actions assessed

The overall objectives of the assignment are to: i) provide the government information on the **mitigation** effects of selected mitigation policies and actions in the country's energy sector till 2020 and 2030, which will be an important basis for future mitigation policy making, target setting, and action planning; and ii) improve the country's capacity in complying with the international rules on climate action transparency through targeted training for the country's inventory preparation and MRV team for the energy sector. The specific objectives are to:

- Map the implementation status of the selected policies and actions from CRGE 2011 to date and the data availability in terms of the baseline and implementation details, including their direct and indirect energy saving and GHG emission reduction effects.
- To determine the temporal and spatial boundary and select the appropriate methodology for each policy/action's mitigation impact assessment.
- Make a quantitative assessment of the GHG emission reduction effects of the mitigation policies and actions in the energy sector, including the duration and annual and accumulated volume of their direct mitigation effects.
- Determine outside influencing factors on the policies and actions assessed including synergies and contradictions with other policies, making it challenging to attribute mitigation effects.

The assessment should include a quantitative estimation of both the emission reduction impacts and social-economic impacts of the selected policies and actions. The scope of work includes the assessment of the effects of the following policies and actions:

- The policy of distribution of improved cookstoves
- The policy of introduction of Incandescent lamps by CFL and LED lamps and banning of Incandescent lamps
- The policy of Promotion of Power Factor correctors, especially in large industries (high electricity consumers)
- The directives for labelling for Electric Injera mitad, cook stoves, and other appliances
- The policy of introduction of mini-grids in rural areas for non-electrified communities.
- The policy of upgrading of transmission and distributions for reduction of TD losses, and standard implementation
- The policy of grid-connected waste to energy in the Addis area and elsewhere
- The policy on bio-ethanol.
- Promotion of Off-grid renewable electricity supply[2]

The assessment will include the establishment of a baseline, the monitoring system, and throughout the consultancy, support will be provided to build capacity for emission assessment (ex-ante and ex-post) for the key experts in the line ministries, institutes, and agencies involved in MRV of energy in order to enable an emissions assessment by the institutions in the future. This will be done through at least one training session.

1.3 Approach and methodology

In estimating the GHG effects and co-befits of the policy and actions described above the study has largely adopted guidelines and procedures provided in the GHG Protocol: Policy and Action

[2] Including solar water pumping, solar home systems, solar lanterns, solar street lighting, solar refrigerators for health posts and clinics.

Standard[3], and as far as possible, has followed recommended specific GHG assessment steps. To provide better structured information on the different policy and actions, the policy and actions described above (Objectives and outputs) are categorized in to the following major categories:

a) Demand side energy efficiency measures: covering Improved (fuelwood) cookstoves (ICS), Introduction and large-scale use of efficient electric lamps, and Standard and Labelling for electric Injera mitad;

b) Fuel switching – renewable fuels: use of Ethanol for cooking, and use of Ethanol–gasoline blend for partial substitution of gasoline (in gasoline vehicles);

c) Supply and demand side improvement of Gird electricity: Upgrading of transmission and distributions lines; Power factor correction, Power generation from MSW;

d) Off-grid renewable electricity supply: mini-grids in rural areas for non-electrified communities, and **Standalone PV systems.**

Action Boundary

GHG and non-GHG effects: The assessment covers the three major GHG gases: CO2, CH4 and N2O. When computing the CO2 equivalent of CH4 and N2O emissions the 100-year GWP of CH4 and N2O (25 for CH4, and 298 for N2O) proposed in the IPCC Fourth Assessment Report recommended by the UNFCCC[4] is used. The significance of each GHG emissions from specific policy or action and only the most important and significant gas(es) are considered/estimated.

Physical boundary: The GHG emission and GHG emissions reduction of actions covered only those that occur within the geographic (jurisdiction) area, and not cover those that occur or are likely to occur upstream or downstream (the only exception is for fuel ethanol where GHG emission form production of ethanol from molasses is considered).

Temporal boundary: The GHG impact assessment covers two continuous but distinct planning and implementation periods - the first period covers 2011 to 2020, and the second period 2021 to 2030.

Ex-post and ex-ante GHG assessment

Ex-post GHG assessment (2011 – 2020): This is the first phase of the GHG mitigation (and adaptation) policy action implementation period and is completed. The GHG impact assessment therefore focuses on assessing the impact of energy sector policy and actions planned in the CRGE and first NDC documents. However, where appropriate and monitored performance data and information are available the ex-ante projections included in the CRGE/first NDC documents were adjusted, before the net GHG impact of policy and actions were estimated and reported. Where available monitored policy and actions implementation performance data for CRGE/first NDC, were collected from MOWE and EFCCC (and other relevant institutions) for the period covering (2011 to 2020).

The ex-post assessment (depending on data and information availability) recalculated the baseline emissions to better assess the impact of policy and action within the assessment

[3] The GHG Protocol Policy and Action Standard: An accounting and reporting standard for estimating the greenhouse gas effects of policies and actions.WRI, July 2014

[4]https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/frequently-asked-questions/global-warming-potentials-ipcc-fourth-assessment-report

period. The Consultants adapted and used existing GHG impact assessment models[5] and/or design simple and transparent calculation models (excel spread sheet models) that supplement the GHG protocol, consistent with CDM methodologies and tools. The Consultants also used the guidance in the protocol to assess the non–GHG impacts: environmental, social, and economic impacts of the energy policy and actions.

Ex-ante GHG assessment (2021 to 2030): In this period, the assessment focused on taking lessons learned from planning and implementation of policy and actions in the first phase of the country's GHG mitigation and adaptation plan and incorporated these lessons to provide better specific energy policy and actions for the current phase of GHG mitigation and adaptation period. Although the policy or action in the energy and other sectors included in the updated NDC are projected mainly using top down approach (economy-wide analysis using Green Economic Modelling, GEM), in conducting the ex-ante assessment for specific energy sector policy and actions included in the updated NDC, the projection where appropriate were conducted using bottom-up approaches (as this allows consistency in the use of methodologies adopted for the ex-post GHG assessment described above).

MRV capacity building for GHG emissions reduction (ER) assessment for energy sector MRV units: In assessing the need for and recommending MRV capacity building activities, the consultants reviewed the current institutional capacity and institutional arrangements for MRV. The need for improving/enhancing effective exchange of data and information between the various implementing and coordinating institutions supporting the MRV processes necessary to assess GHG, as well as non-GHG impacts of mitigation policy and actions were also reviewed. The MRV capacity development need assessment and recommendations were informed by lessons learned and good practices documented in the Handbook on Measurement, Reporting and Verification for developing country Parties[6], and Toolkit for non-Annex I Parties[7]. Under this assignment the focus or target institutions for MRV training and capacity enhancement are the MOWE and EFCC.

[5] For example, CLEER GHG Projections Calculator, and the accompanying Clean Energy Emission Reduction (CLEER) Protocol: Guidelines for Quantifying GHG Emission Reductions from Clean Energy Actions Conducted under the USAID Global Climate Change Initiative May 2019.A methodology and tool that is "Built on GHG Protocol."

[6] Handbook on Measurement, Reporting and Verification for developing country Parties , 2014 United Nations Climate Change Secretariat,

[7] Toolkit for non-Annex I Parties on establishing and maintaining institutional arrangements for preparing national communications and biennial update reports, UNFCCC 2013.

2. GHG emission reduction from policies and actions

2.1 Improved cookstoves

Development and large-scale dissemination of household ICS both in rural and urban areas has been one of the major priority areas identified in the CRGE strategy document (CRGE 2011)[8]. And based on this strategy document, the MOWE had redeveloped the "Fuelwood-Efficient Stoves Investment Plan for 2012-2015[9]. The Investment plan had two phases with the first phase covering the period 2012 to 2015, in which 9 million ICS would be disseminated, and that this action will help the GOE achieve i) a total reduction of 14 Mt CO2 emission at cost of less than USD 3 per tCO2 mitigated, and a corresponding biomass saving of 8 Mt.

In the second phase (2016 -2030), the plan was to reach and help 15.7 million rural households (and 0.3 million urban holds) adopt ICS which will result in gross GHG abatement potential of 34.3 Mt CO2. The plan assumed each household will own two biomass ICS - one for baking and one cooking - with each ICS stove having a minimum fuel saving potential of 50% compared to traditional inefficient stoves. Average service life of the ICS is estimated to vary from 2.5 for cooking stoves made of sheet metal (e.g Tikikil) and 4.5 years or higher for baking stoves such as Mirt or Gonzie.

At household level the benefits of adopting ICS include saving in cost of biomass fuels, reduced fuelwood collection time and reduction in levels of indoor air pollution (IAP), and at local and national levels will contribute to reduction of forest degradation.

The MOWE ICS investment plan provides a detailed national ICS production and dissemination plan including necessary implementation structure to be established, what capacity development needs are and the necessary MRV arrangement required if international financing is to be attracted. Following the release of the ICS investment document, the MOWE had produced a Project Design Documents (PDDs). This document mainly builds on the MOWE Investment document but also include lessons from a detailed market assessment study and a study on results based financing (RBF) on ICS. However, despite these efforts the national ICS dissemination effort was not implemented according to what was planned under the CRGE strategy or MOWE plans and programs.

Still the MOWE as the national coordinating body had provided technical support to and engaged regional energy offices in the planning of a national ICS program within the two GTP planning periods, and the GHG assessment that follows largely depends on ICS dissemination efforts conducted in the regions and the data and information provided by the regional energy offices on number of ICS produced and disseminated in the period 2011 to 2020.

2.1.1 Methodology

Potential effects and action boundary

The major effects of the action is the reduction in the amount of fuelwood consumed in

[8] FDRE, 2011. Ethiopia's Climate-Resilient Green Economy Green Economy Strategy.

[9] MOWE 2012. Fuelwood-Efficient Stoves Investment Plan 2012-2015. FINAL VERSION

households who were using inefficient fuelwood/biomass stoves and are now adopting ICS. The reduction in the amount of fuelwood due to adoption of efficient fuelwood stoves is expected to reduce GHG emissions associated with combustion of fuelwood. The action is also expected to result in lower cost of time and energy expended in collection and transporting of fuelwood (by rural households), and lower cooking and baking cost (for households who purchase fuelwood), and reduction of negative health impacts due to lower indoor air pollutants generated when using ICS. The program is also expected to contribute to reduction of forest degradation both at local and national levels, however this effect would be difficult to assess (quantify). These effects are considered as in-jurisdiction effects.

There could be some up-stream GHG emissions due to use of cement for the production of Mirt injera baking stove and biomass fuels used in firing the Gonzie clay stoves which could be used both for baking and cooking - the two improved stoves considered in the analysis. The magnitude of GHG emissions associated with cement or biomass used for the respective stoves is considered to be relatively small compared to the magnitude of GHG reduced through use of these stoves in their lifetime, and therefore not considered.

The following chart provides the potential GHG and non-GHG effects of the action and the GHG assessment boundary.

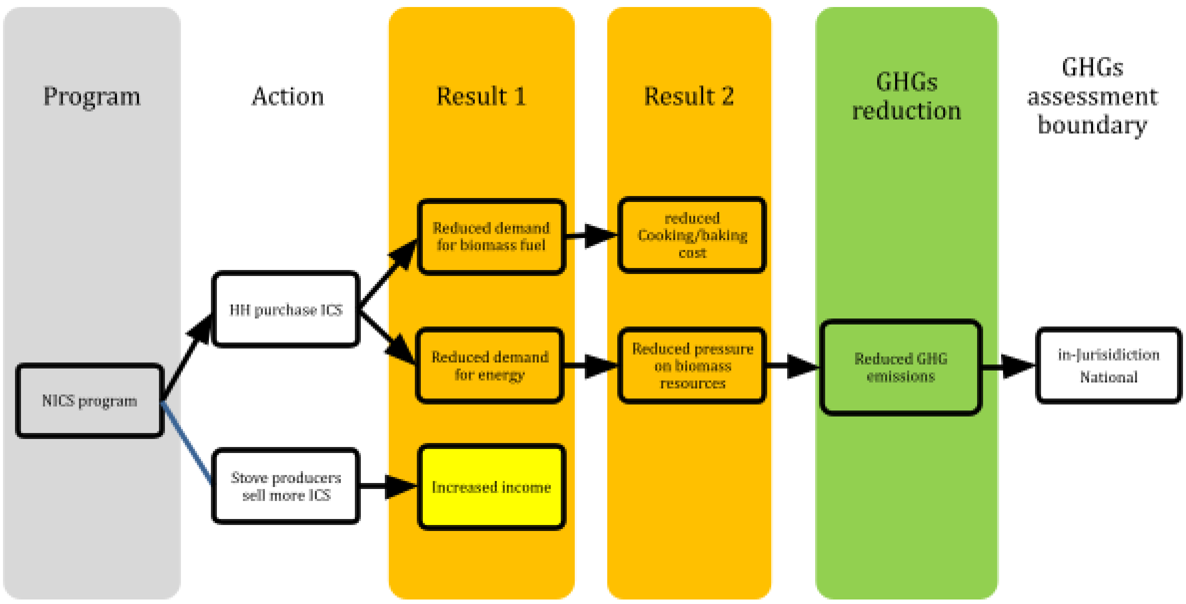


Figure 2.1.1 Causal chain promotion and use of efficient household biomass cooking stoves

<u>Estimating GHG emissions reduction</u>

The total net emission reduction from deployment of ICS to replace inefficient (traditional, baseline stoves) is determined for each project year and for each type of ICS introduced by the project is simply calculated as the difference between the ex-post baseline and ex-post GHG emissions.

ERy = Baseline GHG emissions – ex-post action GHG emissions

*Baseline GHG emissions = Nb,y*Pb,y*(fnb,y*EFb,fuel-CO2+EFb,fuel-non-CO2)*[10]

[10]A more stringent method for estimating the ERy values may include consideration for loss of efficiency of the ICS over the years as well as usage rates as described in the relevant CDM tools (e.g. AMS.II.G Version 8.0). But as data on these factors are not available, and also as there will be several factors that influence the use-efficiency of both baseline stoves and ICS, these factors are not included.

*Action GHG emissions = Np,y*Pp,y*(fnb,y*EFb,fuel-CO2+EFb,fuel-non-CO2)*

Where:

Np,y: *Number of project cookstoves of each age group operational in the year y (number)*

P.y: *Quantity of firewood consumed in year y (ton/hh-y)*

fnb,y: *Fraction of biomass, used in year y for baseline scenario, which can be established as non- renewable.*

EFb,fuel,CO2: *CO2 emission factor of fire wood that is substituted or reduced.*

EFb,fuel,non-CO2: *Non-CO2 emission factor of fire wood that is substituted or reduced*

b and p indicates baseline and action/project cases

The quantity of biomass saved, Py-saved, for baking and cooking is calculated using

Py-baking = Pb-fuel_consumed-baking(1-ηb,stove /ηp-stove) (ton/stove-yr)*

Py-cooking = Pb-fuel_consumed-cooking(1-ηb,stove /ηp-stove) (ton/stove-yr)*

Pb-fuel: *Amount of fuel consumed when using baseline stove (ton/hh-yr)*

ηb,stove: *Efficiency of the baseline stove replaced (fraction)*

ηp-stove: *Efficiency of the project stove (fraction)*

2.1.2 Baseline scenario and ex-post GHG emissions reduction estimates

The following sections provide data and information used for assessing ex-post baseline and ex-post GHG emission estimates (no ex-ante estimates is made since the analysis uses reported ICS dissemination data by the implementing entities and no prior GHG emission projection was available).

<u>Ex-post baseline GHG emissions</u>

In the baseline scenario the assumption was that households currently using traditional inefficient stoves will continue to use these stoves for cooking and baking using firewood, a significant part of which is non-renewable. The key parameters specifying the baseline conditions and sources of information are shown in Table 2.1.1.

The basic assumptions and data used for estimating the ex-post baseline GHG emissions is that in the period covering 2011 to 2020 the number of inefficient fuelwood cookstoves replaced is equal to the number of ICS disseminated in that specific year. However the number of new ICS users are determined and adjusted by subtracting the number of ICS to be replaced from the total number of ICS disseminated in that specific year. Each ICS is estimated to last 5 yrs and that users of ICS will replace their ICS when the ICS reaches it end of lifetime.

Table 2.1.1 Key parameters used to estimate baseline emissions

Parameter	Baseline value(s) applied over the GHG	Methodology and assumptions to estimate	Data source(s)

	assessment period	value(s)	
Efficiency of baseline baking and cooking stove	10%	Laboratory/KPT tests	Studies, EREDPC
Average annual fuelwood consumption per household	2.5 ton/hh-yr[11]	IPCC default and national data	IPCC default and national data
Emission factor of fire wood that is substituted or reduced.	1.747 (t CO2/ton)	Default values	IPCC, 2006
Fraction of biomass, used in year y that is non-renewable	0.76	Calculated according to TOOL30	CDM. ASB0044-2019, Improved Institutional Cookstoves in Ethiopia-Version 01.0.
Non-CO2 emission factor of fire wood that is substituted or reduced.	0.46 (t CO2/ton)	Default value	IPCC, 2006

Ex-post GHG emissions

In assessing the ex-post GHG reduction assessment we have used current ICS production (and dissemination) data provided by MOWE for the year 2011 to 2020 (Annex 2) and the key parameters used are presented in Table 2.1.2.

Table 2.1.2 Key parameters used to estimate ex-post policy emissions

Parameter	Value(s) applied over the ex-post GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Efficiency of project cooking stove (Mirt and Gonzi)	20 to 25% efficiency	MOWE, lab test laboratory/KPT tests	MOWE (2012).
Emission factor of firewood that is substituted/reduced.	1.747 (tCO2/ton)	Default values	IPCC, 2006
Fraction of biomass, used in year y that is non- renewable	0.76	Calculated according to TOOL30	CDM. ASB0044-2019, Improved Institutional Cookstoves in Ethiopia-Version 01.0.
Non-CO2 emission factor of firewood that is substituted or reduced.	0.46 (tCO2/ton)	Default value	IPCC, 2006

GHG emissions reduction estimates

The annual ex-post baseline and ex-post GHG emissions and the estimated GHG emissions reduction is presented in Figure 2.1.2 and Table 2.1.3 The ex-post GHG analysis shows that by 2015 estimated GHG reduction was about 20.6 Mt CO2, and reach a maximum of 20.9 Mt CO2 by 2016. At the end of the period, 2020, the annual GHG emission reduction has declined to 18.5 Mt CO2, and this is attributed to the lower than necessary total number of ICS disseminated that was necessary to keep the number of ICS users increasing (that is some ICS are used as a replacement of ICS by exiting users).

However, it should be noted that the ex-post GHG assessment is based reported ICS production and dissemination data, rather data collected, analysed, and verified by MOWE. And the GHG emission reduction values estimated should be considered only as indicative values.

[11] A default value of 0.5 ton/capita per year is also recommended when using AMS II G, Ver 8.0, section 5.4.

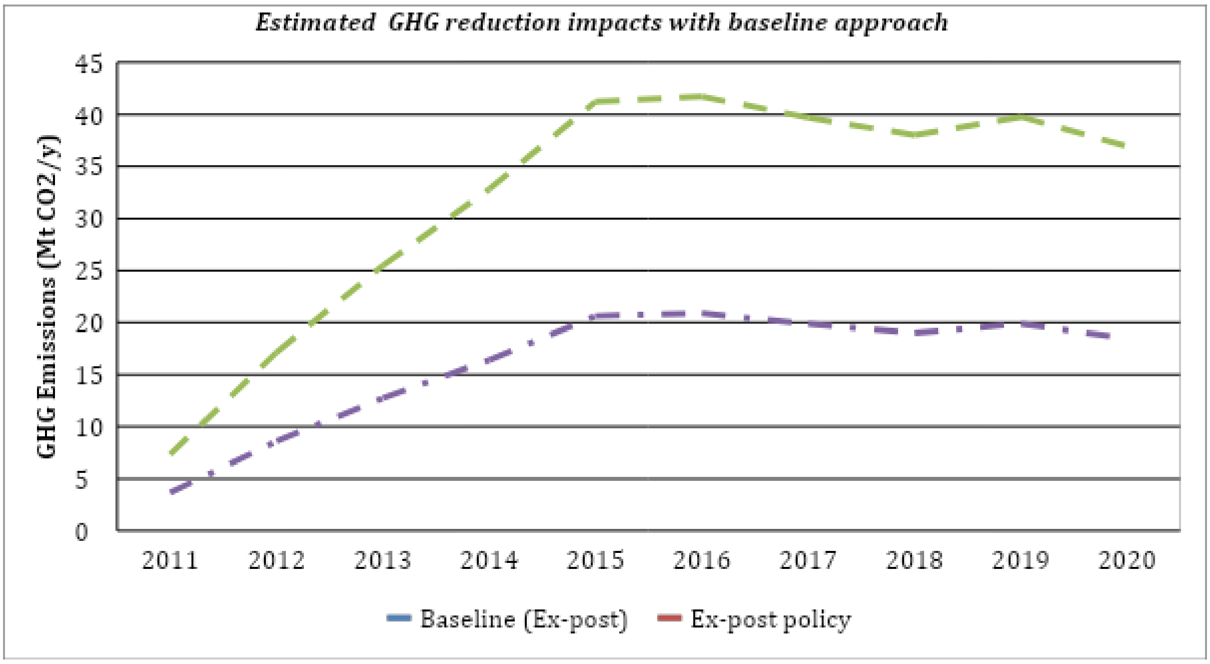


Fig. 2.1.2 Estimated GHG reduction impacts with baseline approach

Table 2.1.3 Ex-post baseline and ex-post GHG reduction estimates (Mt CO2/y)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baseline (Ex-post)	7.3	17.2	25.5	32.8	41.2	41.7	39.7	38.0	39.8	36.9
Ex-post policy	3.7	8.6	12.7	16.4	20.6	20.9	19.9	19.0	19.9	18.5
GHG reduction annual	3.7	8.6	12.7	16.4	20.6	20.9	19.9	19.0	19.9	18.5

2.1.3 Ex-ante GHG emissions reduction: 2021 – 2030

At present, there is no clearly defined program (program document) that provides data and information on the government's plan to disseminate Biomass ICS or "Clean Cook stoves". However, the Updated NDC indicates that to reduce the residential sector demand for biomass fuels: a) efficiency improvement measures that is dissemination of biomass ICS, and b) fuel shift measures - that is move from use of unattainable biomass to electric stoves, and use of renewable biofuels will be undertaken (Updated NDC, 2021).

The plan included in the Updated NDC, are apparently consistent with abatement initiatives identified in the CRGE 2011 document: a) 15.7 million rural households and 0.3 million urban households using fuelwood-efficient stoves resulting in a saving of 34.3 M tCO_2 in 2030, and b) with a cleaner fuels reach of: LPG 0.3 million urban households (Mt CO_2 0.6)- Biogas stoves rural households reach 1 million (Mt CO_2 2.3), and Electric stoves and mitads 1.0 million rural households and up to 4.9 million urban households (Mt CO_2 14.0) by 2030.

The MOWE is currently developing a national "Clean Cookstoves" program. The program mainly focuses on promotion and supporting the adoption of electric cooking (and baking) stoves in rural parts of the country where grid has or is expected to reach in the coming years. It will also promote use of other clear fuels such as biogas (in rural areas) (CRGE, 2011).

Table 2.1.4 Key parameters used to estimate ex-ante policy scenario emissions

Parameter	Value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
LPG (urban-cooking)	0.053 kg LPG/kg fuelwood EF: 2.98 kgCO2eq/kg LPG	calculated	MOWE studies, research papers, IPCC 2006
Biogas (rura -cooking)	0.188 m3/kg fuelwood, EF: 1.092 kg CO2eq/m3	calculated	MOWE studies, research papers, IPCC 2006
Grid elect Cooking / baking	0.833 kWhe/kg fuelwood EF: 0.05 CO2eq/kWhe	calculated	MOWE studies, research papers, IPCC 2006, lighting ETH U4E Country Saving Assessment (EF)
Emission factor of fire wood that is substituted/ reduced.	1.747 (tCO2/ton)	Default values	IPCC, 2006
Fraction of biomass, used in year y that is non- renewable	0.76	Calculated according to TOOL30	CDM. ASB0044-2019, Improved Institutional Cookstoves in Ethiopia-Version 01.0.
Non-CO2 emission factor of fire wood that is substituted or reduced.	0.46 (tCO2/ton)	Default value	IPCC, 2006
Average annual fuelwood consumption per household	2.5 ton/households-yr[12]	IPCC default and national data	IPCC default and national data

<u>Estimating GHG emissions reduction</u>

ER = GHG emissions, baseline - GHG emissions, policy

The baseline GHG emission is computed using the equations presented in estimating baseline GHG emissions in the baseline scenario described above:

Baseline GHG emissions = Nb,y*Pb,y*(fnb,y*EFb,fuel-CO2+EFb,fuel-non-CO2)

And

GHG emissions, policy =Qf fuel/energy* GHG Emission factor, fuel

Where:

Qf[13] = (ηb/ηe)*(NCVb/NCVf)*Pb*Nhouseholds

nb, and ηe are respectively the use efficiency of biomass stove, and the replacement fuel-stove

NCVb and NCVf are respectively the net calorific value (or energy content) of fuel wood and replacement fuel/energy source

Pb is the amount of fuelwood consumed per households consumed under baseline conditions and households is the number of households reached

The assessment shows that due to the limited scale of the action – substitution of fuelwood by LPG and biogas for cooking, and electricity for both cooking and baking, the net total GHG emissions reduction is relatively low. The major contribution will be from the large-scale

[1212]IPCC

[13] The equivalent amount of fuel/energy (Qf) to be supplied to displace Pb kg of fuelwood is computed based on the requirement that the same amount of useful energy will be delivered.

dissemination of fuelwood ICS.

Table 2.1.5 presents the total GHG emissions for the BAU scenario and the projected GHG emissions and emissions reduction estimated to be achieved from implementation of the proposed actions. The contribution of specific options considered is shown in Figure 2.1.3, below.

Table 2.1.5 BAU, ex-ante and GHG emission reduction estimates 2030

	Unit	Amount	GHG (Mt CO2e)
BAU emissions 2030			
Rural	Mton	44.3	78.9
Urban	Mton	11.0	19.6
Total		55.3	98.5
Action emissions (2030)			
LPG (urban-cooking)	Mton	0.02	0.05
Biogas (rural-cooking)	Gm3	0.23	0.26
Grid electricity (rural urban)			
Rural: cooking and baking	GWh	2.1	0.10
Urban: cooking and baking	GWh	8.2	0.41
Fuelwood efficient stoves			
Rural: cooking and baking	Mton	19.6	35.0
Urban: cooking and baking	Mton	0.3	0.53
Total GHG emissions			36.3
GHG emission reduction			62.2

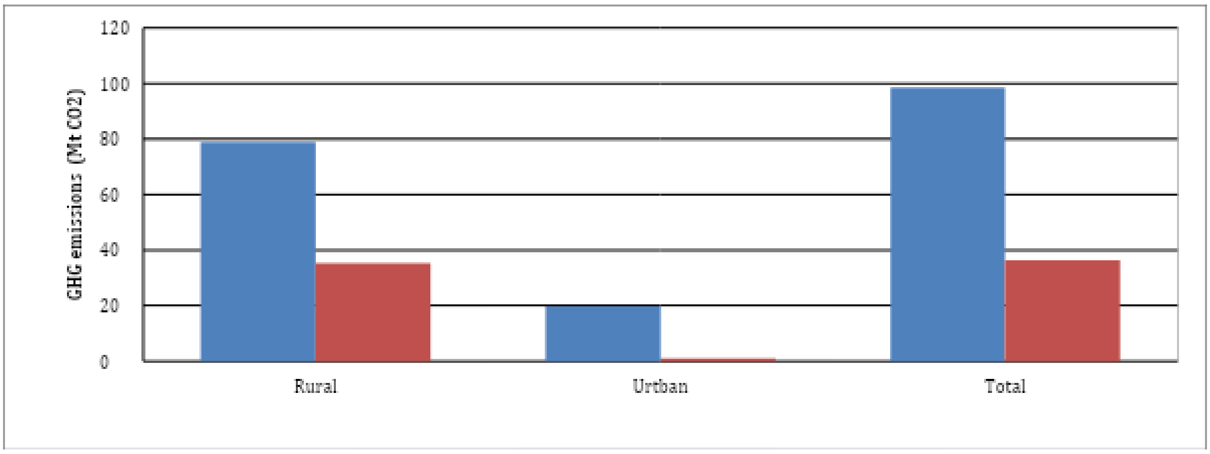


Figure 2.1.3 Baseline and e-ante GHG emissions estimates for 2030

2.1.4 Co-benefits of measure

Large-scale dissemination of efficient and cleaner fuelwood burning ICS will have several positive impacts both at national level and to households using these ICS. At the national level reduced demand for fuelwood implies that pressure on existing forest resources will be reduced and local environment will be improved.

At private level, rural households would be spending less time and labour in gathering and transporting fuelwood, and as these stoves are more efficient and clean burning indoor air pollution is expected to be reduced. For rural residents large-scale ICS dissemination programs provide opportunity for employment as stoves producers and distributors. Urban households will benefit from use of cleaner energy sources and technologies as well as reduce their biomass fuels demand for cooking/baking.

2.2 Standard and labelling for electric Injera mitad

Labelling for efficiency of Electric Injera Baking Mitad is a major component of the energy policy measure on replacement of traditional energy inefficient end-use technologies with new and more efficient ones[14]. To implement this policy measure a directive was passed for setting a performance standard for Electric Injera Mitad in 2016[15]. Following the establishment of Ethiopian standard for electric injera baking mitad, a Minimum Energy Performance Standard (MEPS) was developed[16].

The assumption is that once the MEPS is established, labelling of electric injera mitad promotes use of more energy efficient and low power rating electric mitads which help reduce electricity consumption and peak load demand. This will allow less use of grid connected thermal power plants during peak load hours, and reduction of the frequency and duration of use of individual generator sets by individual or institutional consumers when power shedding occurs during peak load hours.

The Energy Efficiency program, EEA, 2019, under the labelling of electric Injera Mitad measure, aims to reduce the average power rating of electric injera baking mitads from about 3.8 kW to 2.8 kW. Other benefits include a reduction of 2,017GWh grid electricity and power demand of 363 MW by 2030. The document, however, does not provide estimation of GHG emissions reduction due to this action.

The power rating of ordinary electric injera mitads that are widely in use by households in Ethiopia ranges between 3kW and 4kW.[17]The findings of the household survey conducted during this assessment also confirm this. Expected impacts are a reduction in electricity consumption and GHG emissions.

Energy Efficiency Grade	Efficiency Range
1	Eff> 80%
2	78%<Eff<= 80%
3	73% <Eff<= 78%
4	68%<Eff<= 73%
5	60% <Eff<= 68%

[14] National Energy Policy, Article 4.4, Draft, March 2021

[15] Ethiopian Standard Agency, ES ISO 04090:2016, 2016

[16] Minimum Energy Performance Standard (MEPS) and Labeling for Clay plate resistor based electric Injera Mitad, 2020

[17] DANAS, 2015. Project document on Electric Injera Mitad, Energy Efficiency Standards and Libelling

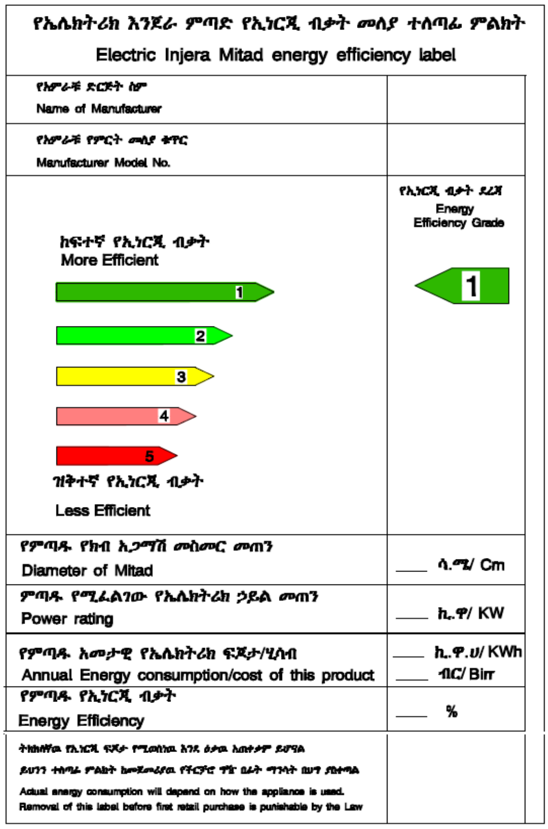


Figure 2.2.1 Electric Mitad Labels and Corresponding Thermal Efficiency Ranges

2.2.1 Methodology

Effects and action boundary

The expected outcome of the labelling of electric injera mitad is to promote use of more energy efficient and low power rating electric mitads which help reduce electricity consumption and the peak load demand. This will allow less use of industrial/commercial back-up diesel generators as well as less use of individual generator sets by consumers as power shedding during peak load hours would be reduced. Expected impacts are a reduction in electricity consumption and GHG emissions. The action boundary included the power generation units, and T&D systems and the end-users. The policy is already in place, but is expected to be fully implemented (enforced) from 2025 and onwards. The assessment period covers the period until 2030[18].

Estimating GHG emissions reduction

A simplified methodology for GHG Emission reduction estimate with the use of Efficient Electric Mitad will be used as outlined in the Policy and Action Standard of the World Resource Institute (WRI, 2014).

Emission reduction = *Number of households who shifted from use of less efficient to more efficient electric mitads*difference of electricity consumption for injera baking between the old and new*

[18]Currently, compliance to the Electric Injera Baking stove standard is on voluntary basis. But from 2025 onwards, it will be mandatory as per the MEPs guideline for Electric Injera Baking Stove.

electric mitad grid emission factor*

Difference of electricity consumption for injera baking between the old and new electric mitads *= (annual electricity consumption of the previously used less energy efficient electric mitads – annual electricity consumption of currently used more efficient electric mitads).*

2.2.2 Baseline and Ex-post GHG emissions 2011-2020

Labelling of electric injera mitad was the outcome of the household end-use energy technology efficiency improvement policy measure. The National Energy Policy, Article 5.5, 2013 states the need to take energy efficiency improvement and conservation measures to reduce GHG emissions. Following the policy statement on energy efficiency, the Ethiopian Standard Agency released the Ethiopian Standard for locally produced electric injera baking mitads in 2016 to set a standard for performance, safety and durability of electric injera mitad[19].

The labelling of electric injera mitad was introduced under the Minimum Energy Performance Standard (MEPS) for 'Clay Plate Single Resistor based Electric Injera Mitad' in June 2020. MEPS for electric injera baking mitad came to an effect for voluntary compliance to the electric injera mitad standard.

Since the implementation of MEPS for electric injera mitad was started in June 2020, only very few electric injera mitad manufacturers have got their products evaluated and labelled by Ethiopian Energy Authority. Until the time that this study was conducted, only a total number of 453 labelled electric injera mitads have been sold. Over 85% of these mitads were label 3 and label 4 with thermal efficiencies ranging between 68% and 78%.

The following table shows the number of electric mitad manufacturers who got their products evaluated and labelled, the number of labelled electric injera mitads sold until March 2022. It also shows the MEPS labelling category and the corresponding efficiency range.

Table 2.2.1 MEPS label and efficiency rating for selected stove producers

No.	Name of mitad manufacturer	MEPS Label and Corresponding Efficiency Values[20]			Number of Labeled Electric Injera Mitads Sold[21]
		Energy efficiency grade label	Efficiency Value (%)	Actual Efficiency Value (%)	
1	Danas Engineering	2	78<Eff<=80	78.02%	0
2	Lejio	3	73<Eff<=78	NA	200
3	Demssie Gobeze	4	68<Eff<=73	64.81%	193
4	Mantegafitote	5	60<Eff<=68	63.29%	30
5	Techno Z	5	60<Eff<=68	60.53%	30

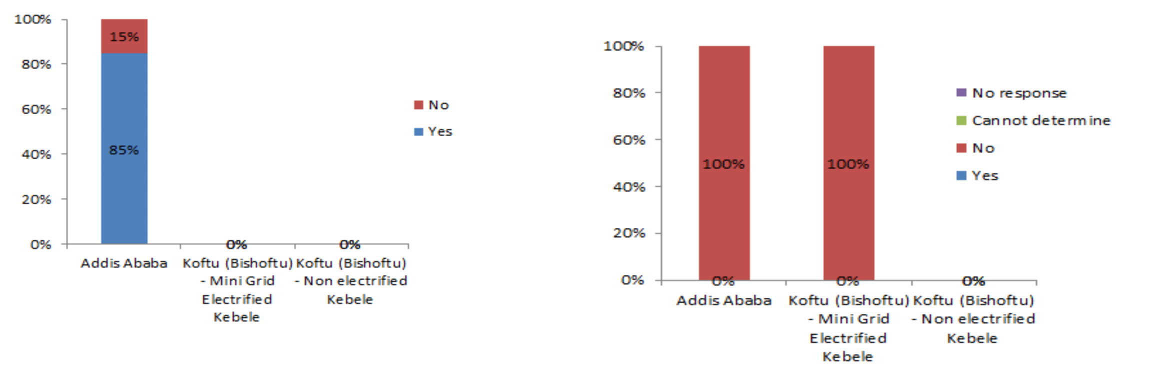
The result of the household survey conducted in February and March 2022 indicated that in Addis Ababa about 85% of households owned and used electric mitad. The mean power rating of

[19] Ethiopian Standards Agency (2016). Electric Power Supply System and Machines - Technical and Performance Requirements For Household Single Plate Resistor Based Electric Injera Mitad - ESA, ES ISO 04090:2016, 2016

[20] Ethiopian Standards Agency (2020). Electric Injera MitadMinimum Energy Performance Standard (MEPS)

[21] Interview with electric injera mitad manufactures who got their products evaluated for performance and got labels for their products from EEA.

the electric mitads used by the households was 3.5 kW[22]. In the rural areas surveyed, none of the surveyed households used electric mitads for baking Injera. For those households that did use electric mitads, none were using electric mitads with labels. This indicates that the number of labelled electric mitads sold was too small to be captured by the survey.



Households who own Electric Injera Mitad

Households response for Labelled Electric Injera Mitad Ownership

Figure 2.2.2Households that own ordinary and labelled electric mitad in the survey areas

Since there was no plan to introduce labelled electric mitad from 2011 to 2020 ex-ante assessment could not be made for this period. Implementation of labelled electric injera mitad was started in June 2020.

However, based on data obtained from the Central Statistical Agency and the household survey conducted during this study period about the penetration rate of electric Injera Mitad in households, ex-post baseline GHG emissions estimate was made for the period 2011 to 2020. Key parameters and the result is presented below.

Table 2.2.2 Key parameters used to estimate baseline and policy scenario emissions

Parameter	Value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Total populations	Number of households	National census	CSA
Electric injera mitad penetration rate	% of households with electric injera mitad, 2011 to 2020	Survey, .Statistics	CSA
Average Elec. Consumption for baking	650 KWh/households-yr	Study estimates	Cooking Efficiency Improvement and New Fuels Marketing Project, Electric Injera stove household assessment, 1996)
Grid emission factor	0.05 kg CO2/kWh (50 t/GWh)	CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies	Lighting ETH U4E Country Saving Assessment Lighting Oct-20

[22]Measured during the sample household survey using the resistance of the mitads and considering the standard 220 volt.

	(IGES) and are assumed constant in future years

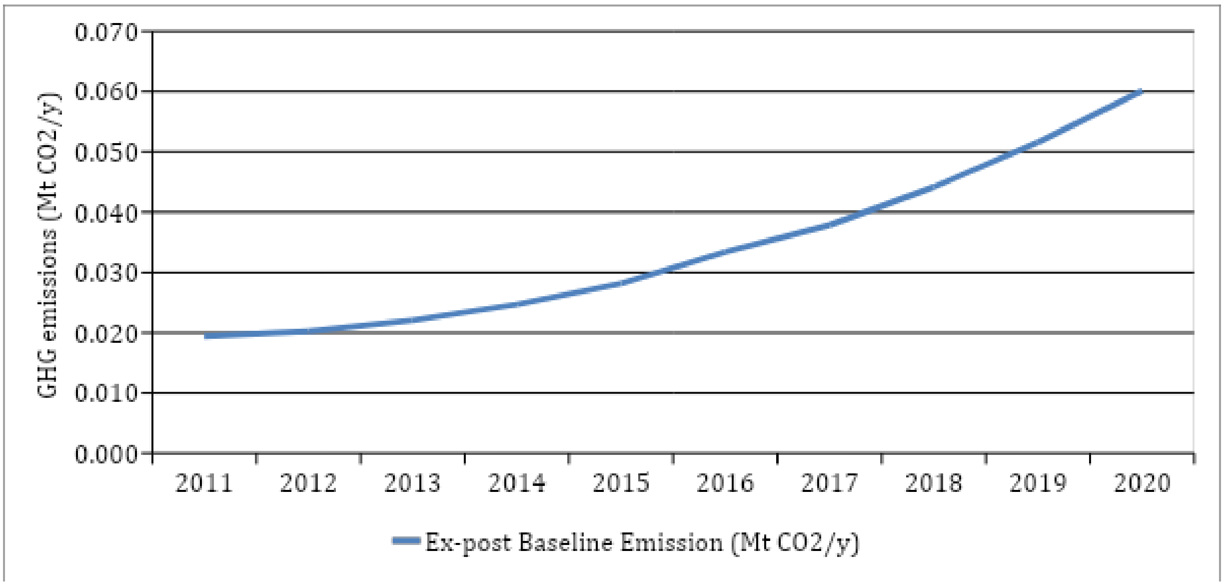


Figure 2.2.2 Ex-Post Baseline GHG Emissions from Electric Injera Baking Mitad (2011 - 2020)

Ex-ante GHG emissions reduction estimates:2021 - 2030

Since labelled electric injera stoves have not been introduced until the end of 2020, electric mitads that are widely produced and sold to users is taken as the baseline technology. The ex-ante assessment is made considering the Ethiopian Standard Authority's plan to make the electric injera mitads MEPS mandatory in five years, and assuming that the proportion of electric injera mitads adopted by users that meet MEPS would uniformly increase to 100% by 2030. Detail assumptions and analysis are shown in the Annex. Based on these assumptions GHG emissions and emissions reduction between 2021 and 2030 is shown in the figure below.

Table 2.2.3 Key parameters used to estimate ex-post baseline and policy scenario emissions

Parameter	Value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Total populations	Number of households	National census	CSA
Electric injera mitad penetration rate	60% of households by 2030	Survey, .Statistics	CSA
Baseline Average Elec. Consumption, baking	650 KWh &households/yr	Study estimates	Cooking Efficiency Improvement and New Fuels Marketing Project, Electric Injera stove household assessment, 1996)
Ex-ante: average efficiency improvement	29% (Percentage of Efficiency improvement from 58% to 75%)	Estimated	Consultants' estimation

Grid emission factor	0.05 kg CO2/kWh (50 t/GWh)	CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years	Lighting ETH U4E Country Saving Assessment Lighting Oct-20

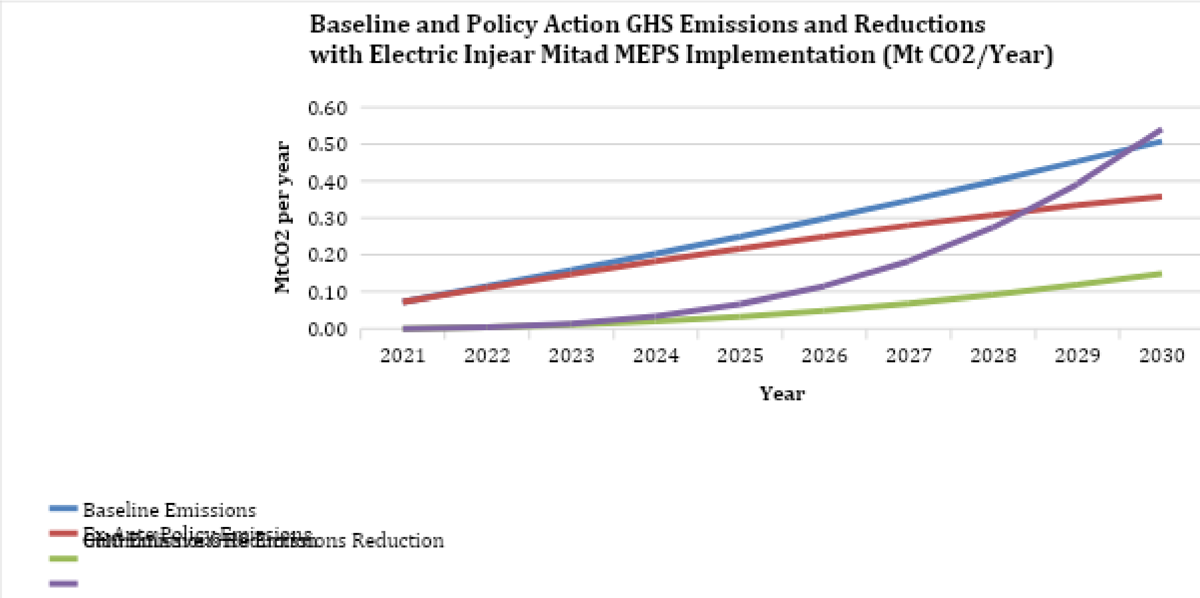


Figure 2.2.3 Baseline and Policy Action GHS Emissions and Reductions with Electric Injera Mitad MEPS Implementation (Mt CO2/Y)

Co-benefits of measure

The promotion of labelled injera baking mitad that meet MEPS standard will support and encourage electric injera mitad producers to progress to quality product manufacturing. The program benefits producers by providing technical skill improvement training.

Households who would adopt better efficiency electric mitads would benefit from savings because of reduced electricity consumption and reduced stove replacement costs because of high durability of the technology.

Lower power rating also means lower peak load demand on the electricity transmission and distribution system. This improved grid efficiency and also avoids the need for additional generation capacity to meet the peak load demand.

2.3 Lighting efficiency improvement

Lighting efficiency improvement is among the most important national - Energy Efficiency Improvement Program areas initiated by GOE in 2009. This first large-scale lighting efficiency improvement program was part of the **Electricity Access (Rural) Expansion Project (EAREP)** implemented between 2009 and 2012**.** In mid-2009 the project had freely distributed 350,000 CFLs to grid connected households mainly in urban areas, and following the initial success, and from July 2011 to January 2012, an additional 4.6 million CFLs were imported and sold at subsidized prices. By end of the project, 31 December 2012, a total of 9.6 million CFLs were distributed[23][24], and 15,000 efficient streetlights were installed (which includes both new and retrofitted lamp posts).

The impact of this lighting efficiency improvement action was assessed in 2013 and later in 2016. These studies have indicated that the CFL distribution under the project has helped households reduce their lighting electric demand and therefore monthly bills, while also helping reduce peak power demand. The 2016 study[25] also showed that most of the households have continued to use CFLs and that the long-term impact of use of CFL in reducing households' electric bill and grid power demand is expected to be sustained.

Policy and strategies: The major policy directions and actions undertaken in supporting lighting energy efficiency improvement include: i) the inclusion of the lighting efficiency and demand side management component under EAREP (which was not part of the initial project objective), and ii) the banning of production and importing of conventional incandescent and halogen lamps effective January 2011 (for Incandescent lamps the regulation applies for lamps with power rating of 15 watts and above[26]).

The Ethiopian Energy Authority (EEA)[27] as the responsible organization for promoting energy efficiency and conservation has issued Energy Efficient Strategy for Ethiopia (2018)[28] and Energy Efficiency Program and Activity plan (2019)[29] document that identified and prioritized programs and projects to address energy efficiency improvement in various sectors and areas including lighting efficiency improvement. Planned activities and results (with timelines) expected to be achieved by developing and enforcing minimum energy performance standards for lighting products is presented in the data sheet "Efficient Electric Lights", Annex A. According to this plan, by 2030 the action will result in reduction of 309 MW of power demand.

While EAREP was initially designed with the main objectives of expanding grid electricity supply to rural towns and villages. To expand grid electricity supply to rural towns and villages a national program (EAREP) – was initiated in 2006 and implemented until 2013**.** The lighting efficiency improvement component of the program project was designed and (later on) incorporated in the project document with the objectives of reducing the peak power demand and electricity energy consumption of inefficient lighting devices used in already electrified households (and other building sectors).

[23]Electricity Access (Rural) Expansion Project. Implementation completion and results report (IDA-4200), August 28, 2013.

[24]Impact evaluation of free-of-charge CFL bulb distribution in Ethiopia (2013) .WB Policy Research Working Paper 6383

[25]Sustainability of a Residential CFL Distribution Program Evidence from Ethiopia. Transport and ICT Global Practice Group, September 2016

[26]Inefficient Lamps that are banned from the Market (Effective from January 6, 2011). EEA web site

[27]The Council of Ministers Regulation No. 308/2014 legally established the Ethiopian Energy Authority (EEA) and laid out its primary objectives, powers and duties include promoting energy efficiency and conservation

[28]Energy Efficiency Strategy for Industries, Buildings and Appliance 2018, Directive 005_2011,

[29]Energy efficiency program and activity plan, directive no 006/2011, EEA Iissued/singed 23 May 2019). The document also provides some information on data collection, monitoring and verification needs and processes to be implemented.

EAREP had financed the acquisition and supported distribution of CFL in already electrified cities and towns[30]. In the first phase of this project - June to August, 2009, Incandescent lamps removed from households were freely exchanged for CFLs. In this phase 350,000 CFL bulbs were distributed free of charge to approximately 90,000 households, mainly in Addis Ababa city. Under phase 2 covering the period July 2011 to Jan 2012, 4.5 million CFLs were sold at a reduced price[31], and by the end of the project period, Dec 2012, a total of 9.6 million CFLs were distributed.

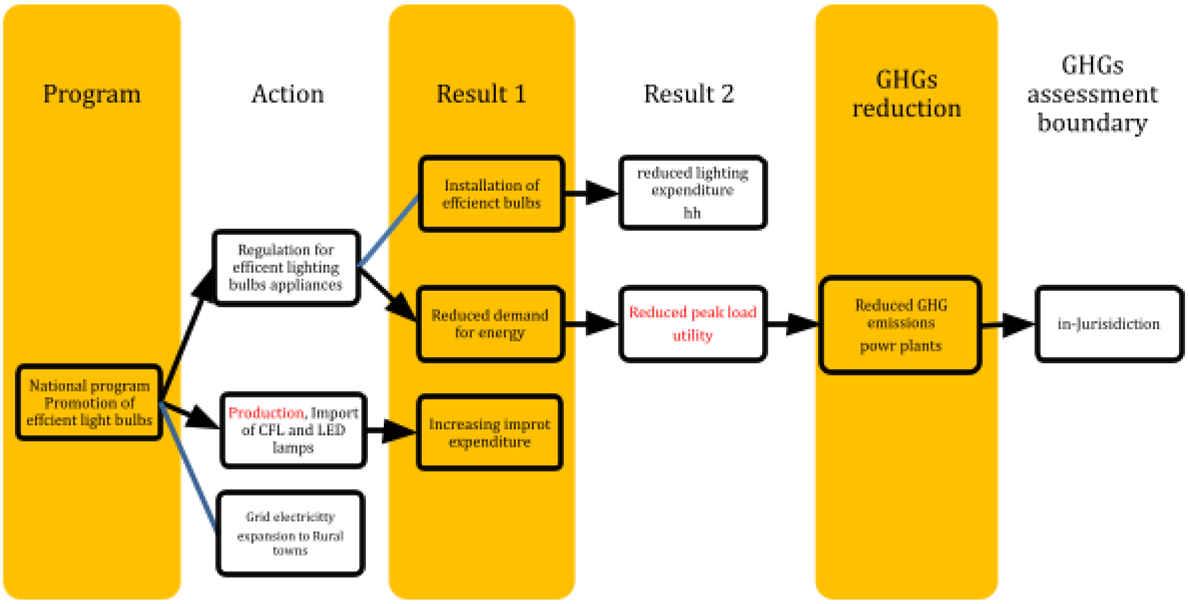
Methodology

- Effects and action boundary

The action would result in significant reduction of grid electric energy demand as well as will contribute to reduction of peak power demand. Households would benefit from lower cost of electric lighting due to less electric energy demand for the same level of illumination that they were receiving at higher cost.

The action boundary includes power generation units, T&D systems and end-users. The assessment period covers the period 2011 to 2020 which includes actual lighting efficiency improvement project, and 2021 to 2030 period for projection of impacts of continued dissemination and use of efficient lighting.

Figure 2.3.1 Causal chain promotion and use of efficient lighting bulbs (CFL)



Baseline scenario and ex-ante GHG emissions

Until 2009, most households, commercial units, and street lights were using Incandescent lamps and linear fluorescent lamps that low efficiency (and efficacy) and hence meeting lighting energy demand in these sectors required the supply of large amount of power from the national grid

[30]Electricity Access (Rural) Expansion Project Implementation completion and results report (IDA-4200), August 28, 2013. Project ID: P097271.

[31]Sustainability of Residential CFL Distribution Program Evidence from Ethiopia Transport and ICT Global Practice Group, September 2016.

(or other systems providing power).

Justification for why it is considered the most likely scenario: The baseline scenario we considered is based on the assumption that EEP which was under pressure to increase its power generation capacity as well as expand the national grid to cover un-electrified town and villages, had responded to the increasing demand by initiating DSM options including the promotion and support for large scale lighting efficiency improvement. The baseline scenario thus assumes that without this DSM option lighting energy consumption would have continued over the next several years (2011 to 2020).

Baseline GHG Emissions = Electricity Consumed × Grid GHG Emission Factor

Where
Electricity Consumed= Number of lamps × Power Rating of lamps × Operating hours per day x 365 days /yr
Electricity demand= Electricity Consumed / (1-T&D losses)

Table 2.3.1 Key parameters used to estimate (ex-post) baseline GHG emissions

Parameter	Baseline value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Number of lamps per households	4	National survey	MTF study 2018
Total number of households targeted (covered)	2.4 million households; 9.6 million CFL, 4 CFL max per households, by end of 2012	No additional CFL rate of dissemination/use	ENERP completion report, WB research report
Power Rating of baseline lamps	40, 60 and 100 W Incandescent lamps	ENERP completion report WB research report	ENERP completion report, WB research report
Operating Hours per day	3.5	National survey	MTF study 2018,
Grid emission factor	0.05 kg CO2/kWh	CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years	Lighting ETH U4E Country Saving Assessment Lighting Oct-20
Grid T&D losses	18.5%	Regional average calculated from electricity production and consumption data published by the IEA.	Lighting ETH U4E Country Saving Assessment Lighting Oct-20

As there were no projects or programs designed for introduction of efficient lighting, the residential sector the assessment did not provide data on potential reduction of potential actions that would have been undertaken to provide both GHG emission reduction potential as well as the various private and utility level co-benefits; accordingly, no ex-ante (or ex-post ex-ante) assessment is made. And since the impact of the action is registered as the difference between the action and baseline, this result is presented in the next section.

<u>Ex-post GHG assessment: 2011 - 2020</u>

The ex-post GHG emission reduction is estimated for a total of 9.6 million CFLs distributed/sold of starting mid-2009 to end of 2012, as shown in Table 2.3.2.

Table 2.3.2 Lamp rated powered and number of CFL distributed/installed

Lamp type and rated power (W)		1st Phase (free CFL)	2nd phase (Subsidized)	Last phase of project	
CFL	IL replaced	2009	Jun –Dec 2011 Jan 2012	Dec 2012*	Total
11	40	192,500	2,802,000	2,942,348	5,936,848
15	60	154,000	1,672,000	1,755,748	3,581,748
20	100	3,500	38,000	39,903	81,403
Total		350,000	4,512,000	4,738,000	9,600,000

(*) The number of CFL by rated power for Dec 2012 is estimated using percentage share of CFL type of distributed in the first two phases.

The assessment provides estimates on change in GHG emissions over the GHG assessment period 2011 to 2020 and provides both annual and cumulative GHG emission reduction estimates. In the process of implementing the action there had been some lessons to be learnt and this includes how burned out CFL are replaced - that is whether, CFLs that have failed are replaced by Incandescent lamps or with CFL of same power rating and quality. Another important finding of a study (Con et al. 2013) was that those using CFL have tended to consume more lighting energy and the saving from use of CFL compared to what it replaced was lower by 20% than was computed based on the net power saving of CFL over IL it replaced. This factor will also be considered to see how the net saving is affected if such rebound effect is to be widespread

GHG emission reduction estimation from use of CFL and displacement of IL is computed using the following relation:

GHG Emissions Reduced = Baseline GHG Emissions – Action GHG Emissions
Action GHG Emissions =Electricity consumed × grid GHG Emission Factor (grid)
Electricity Consumed = Number of lamps × lamp power rating× Operating hours/day x 365/yr

And, Reduction on electricity demand
Electric energy demand = Electricity consumed / (1-TD losses) [kWh/yr]
Electric power demand = Number of lamps × lamp power rating [MW]
Reduction in peak power demand = Electric power demand * Peak coincidence factor [MW]

Table 2.3.3 Key parameters used to estimate ex-post GHG emissions

Parameter	Action value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)

Number of lamps per household	4	National survey	MTF study 2018, ENERP completion report, WB research report
Total number of households targeted	9.6 million CFL , 4 CFL max per households	CFL Procurement data	ENERP completion report, WB research report
Power Rating of CFL lamps	11, 15, 20 W (replacing, respectively: 40, 60 and 100 W incandescent lamps)		ENERP completion report, WB research report
Operating hr/day	3.5	National survey	MTF study 2018, CDM default values
Lamp life (total hrs)	6000 – 15000 (4.7 to 11 yrs)		Accelerating the Global Adoption of Energy-efficient Lighting. Policy guide series united for efficiency, 2017
Grid emission factor	0.05 kg CO2/kWh	IEA methodology	Lighting ETH U4E Country Saving Assessment
Grid TD losses	18.5%	.	Power Africa GMSP System Integration Studies technical review presentation
Peak power coincidence factor	0.56	Computed based on data collected	ENERP completion report, WB research report
Oct-20 CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years			

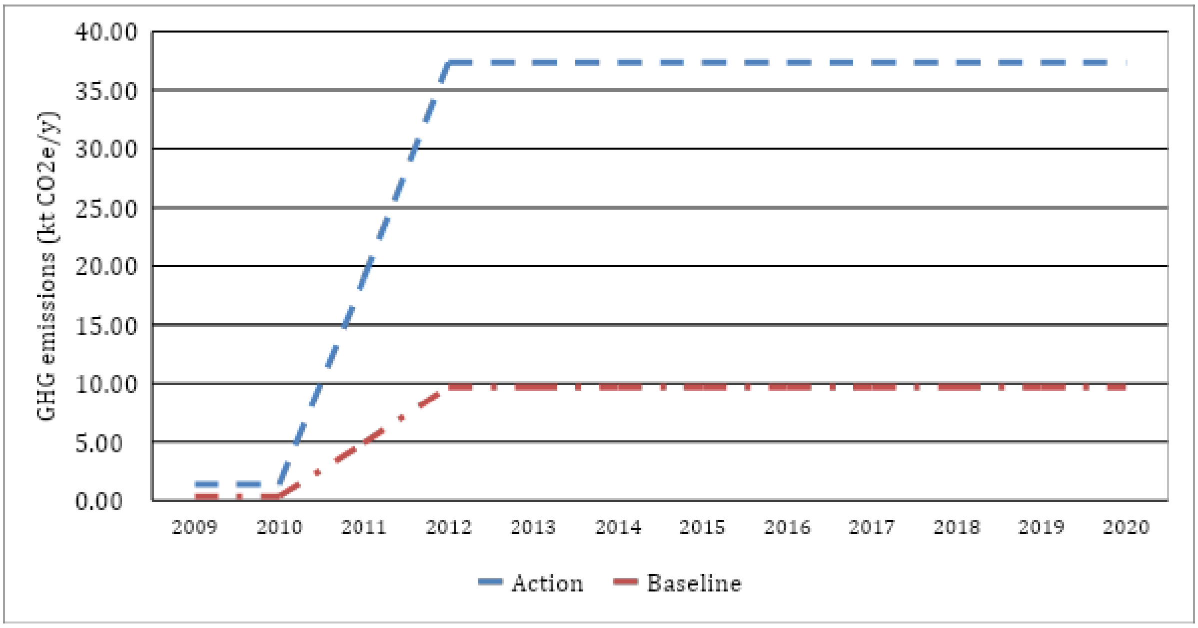


Figure 2.3.2 Baseline and action (impact of CFL distribution) on GHG emission reduction

Table 2.3.4. Summary of GHG emissions reduction estimates (ktCO2e)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baseline	1.41	1.41	18.90	37.33	37.33	37.33	37.33	37.33	37.33	37.33	37.33	37.33
Action	0.36	0.36	4.91	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70	9.70
Annual GHG emissions reduction	1.04	1.04	13.99	27.62	27.62	27.62	27.62	27.62	27.62	27.62	27.62	27.62
Cumulative GHG emissions reduction	1.04	2.09	16.08	43.70	71.32	98.94	126.57	154.19	181.81	209.43	237.05	264.68

Ex-ante GHG emissions reduction estimates: 2021 - 2030

The ex-ante GHG emissions for the period 2021 to 2030 is computed based on projected number of urban households to be connected in this period and assuming that the use of CFL in these households will be gradually replaced with LED lamps providing equivalent lumen. The key parameters used in this analysis are shown in the Table 2.3.4.

Table 2.3.4 Key parameters used to estimate ex-ante policy scenario emissions (2021 – 2030)

Parameter	Action value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Number of lamps per household	4 LED lamps	As replacement for CFL lamps considered in baseline case	ENERP completion report, WB research report
Total number of households targeted	4.82 million households (2921) 6.51 million households (2030)	Projected/calculated data	Power Africa GMSP System Integration Studies technical review presentation, 2018
Power Rating of CFL lamps	5, 10 LED lamps (replacing, respectively: 11 and 15 W CFL lamps)	Based on lumen equivalence	Accelerating the Global Adoption of ENERGY-EFFICIENT LIGHTING.
Operating hr/day	3.5	National survey	MTF study 2018
Grid emission factor	0.05 kg CO2/kWh	IEA methodology*	Lighting ETH U4E Country Saving Assessment Lighting
Grid T&D losses	18.8% to 12.5% (2021 to 2030)	Projected data	Power Africa GMSP System Integration Studies technical review presentation, 2018
Peak power coincidence factor	0.56	Study result calculated	ENERP completion report, WB research report

* CO2 emission factors from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years, Oct-2020 update.

The result presented in Figure. 2.3.3 shows that by 2030, the Action will result in net GHG emission reduction of about 4 kt CO2, and the cumulative reduction by 2030 will reach 20 kt CO2, the result is based on the assumption that in 2021 of the total urban households 50% use CFL and the other 50% LED and LED replacement of CFL will progress at about 7.5 % per year until 2030.

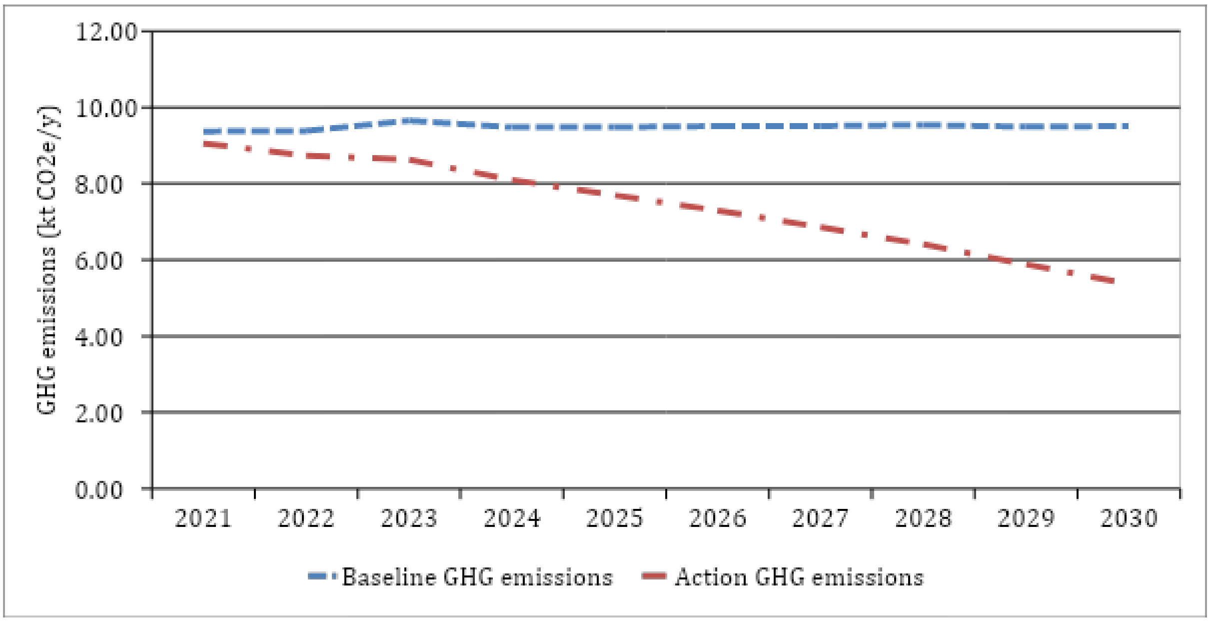


Figure 2.3.3 Baseline and ex-post GHG emissions

Table 2.3.5.Summary of results GHG emissions reduction estimates (ktCO2e)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline GHG emissions	9.37	9.38	9.65	9.48	9.48	9.51	9.51	9.54	9.49	9.51
Action GHG emissions	9.05	8.73	8.62	8.09	7.70	7.30	6.86	6.41	5.88	5.37
GHG emissions reduction - Annual	0.32	0.65	1.03	1.39	1.78	2.21	2.65	3.13	3.61	4.14
Cumulative	0.32	0.97	1.99	3.38	5.16	7.37	10.02	13.16	16.77	20.91

Co-benefits

The most important co-benefits are a reduction of KWh lighting energy consumption for households using efficient lighting bulbs, and at the national level demand for electric energy as well as pick power demand. The former implies that household will reduce their electric bill, and ten later means that the utility (or national grid) will have increased electric supply capability without to add additional power plants.

2.4 Use of bio-ethanol to substitute household cooking fuels and for transportation

The government of Ethiopia developed a sustainable bio-energy policy as an important component of the National Development Program. In 2001, Finchaa sugar factory commenced to produce bio-ethanol using sugarcane molasses - a by-product of the sugar production process. Following the bio-ethanol production in the country, the government promoted the use of bio-ethanol as household cooking fuel and as transport fuel to replace fossil fuel use and contribute to its emissions reduction activities.

Currently, bio-ethanol is produced from sugarcane molasses at two sugar factories in the country, Finchaa and Metahara sugar factories. Ethiopia’s first Growth and Transformation Plan (GTP), 2010/11-2014/15, planned eight bio-ethanol blending facilities and constructed four facilities which blended 50.6 million litres of ethanol with gasoline. Under GTP-II, 2015/16-2019/20, the GOE had planned to develop 14.1 million hectares of land for bio-ethanol production, and construct five bio-ethanol production plants with a total production capacity of 1,288 million litres. GTP-II targeted 442 million litres of bio-ethanol to be blending with gasoline, 120 million litres of bio-ethanol to be supplied for and used by households for cooking, and the rest 713 million litres to be used by other sectors. By using bio-fuels, bio-ethanol and bio-diesel, GTP-II planned to reduce 65 million tons of CO2 emission.

The use of bio-ethanol as a transport fuel blended with gasoline become mandatory in 2007. The program was launched and implemented in Addis Ababa in 2007 with a 5% bio-ethanol blend (E-5) and later increased to 10% blend (E-10). Similarly, legal provisions were made to support the introduction and promotion of bio-ethanol as a cooking fuel.

The use of bio-ethanol for cooking was planned and implemented with the objective of reducing kerosene and biomass fuels demand in the household sector. Private companies and an NGO commenced the introduction of ethanol stoves and fuel-ethanol for cooking in Addis Ababa city and some of the refugee camps in the country. The initiative was started with pilot projects as early as 2006.

Ethanol for household cooking had been continuously supplied between 2012 until 2018, after which it was terminated. In this seven year period, a total of 4,372 thousand litres of ethanol was supplied and used for cooking, of which 88% was supplied to refugee camps and the balance for households in Addis Ababa city. MOWE data on stove use shows that there were 9,465 operational ethanol stoves in the refugee camps, and 4,372 in Addis Ababa. Ethanol blending with gasoline was also interrupted in 2016, resumed in 2017 but only to be terminated again in 2018. Bio-ethanol supply interruption was mainly attributed to shortage of supply and its diversion into other uses.

2.4.1 Methods

<u>Effects and action boundary</u>

When used for displacing fuelwood the action - use of bio-ethanol as cooking fuel will displace non-renewable fuelwood and reduce associated GHG emissions. As a clean burning fuel it also reduces indoor air pollution. As the production of bio-ethanol involves use of chemical fertilizer for sugar cane production and some chemicals for processing of molasses to ethanol that generates GHGs emissions. The action boundary covers both the production as well as the end-use of bio-ethanol.

When used for cooking the boundary includes bio-ethanol production and the different end-user:

- Ethanol production, and end-users switching from non-sustainable fuelwood to cooking with bio-ethanol or bio-ethanol production, and end-users switching from kerosene to cooking with ethanol,

When anhydrous ethanol is used for transportation the boundary includes

- Bio-ethanol production and use of bio-ethanol for transportation (displacing some portion of gasoline used in gasoline vehicles).

For the assessment two periods are considered 2011 to 2020 where there were actual projects that promoted and supported use of bio-ethanol for cooking and transportation. And a second period 2021 to 2030 which is used to project bio-ethanol use in the transport sector (assumptions mainly based on plans that were included in GTP I and II).

Bio-ethanol as household cooking fuel

Bio-ethanol has been used as a household fuel both by households using biomass and kerosene fuels as their main cooking fuel. Based on available data the impact of this action was assessed for the period 2012 to 2018. The methodology employed and key parameters used in the GHGs reduction assessment are presented below.

Bio-ethanol for substitution of transport fuel (gasoline)

Between 2010 and 2018 a total of 604 million litres of bioethanol blended gasoline was sold in Addis Ababa fuel pump stations. Annual supply of bio/ethanol has varied from about 7 million litres in 2010 to as low as 2.6 million litres in 2017, to the largest supply of 15 million litres in 2018, after which the blending activity was terminated.

Baseline and ex-post GHG emissions for bio-ethanol use for cooking: 2011 - 2020

While the GTP I and II both provide infromation on planned bio-ethanol production and use, there was publicly avaiable national program document tha provide data to estimate baseline or ex-ante GHG emision projections in then period 2011 to 2020. However, data on supply of bio-ethanol for household cooking and belending with gasoline was provided by MOWE, and this data and infromation is used to compute ex-post GHG emision reductions as the diffrence between GHG emisions of "ex-post" baseline and action GHG emisions. Data on bio-ethanol supply for houshold cooking was avaiable for 2012 to 2018, and ethanol-gasoline blending from 2010 to 2017. The GHGs emisions and emision reductions achived from use of bio-ethanol is calculated as follows:

Baseline scenario GHGs emissions estimates

a) Refugee camps – Ethanol displacing fuelwood

Baseline GHG Emissions$_{\text{biomass}}$ = $B_y \times f_{NRB,} \times NCV_{biomass} \times EF_{projected\_fossil\_fuel}$
Where,
B_y = Baseline amount of biomass consumed (Number of HOUSEHOLDS reached * Biomass consumption per households)
f_{NRB}: Non-renewable fraction of biomass (fuelwood)
$CV_{biomass}$: calorific value of biomass fuel
$EF_{projected\_fossil\_fuel}$: Emission factor for projected fossil fuel

Table 2.4.1 Key parameters used to estimate policy scenario emissions

Parameter	Baseline & ex-ante value(s) applied over the GHG assessment period	Methodology / assumptions to estimate value	Data source(s)
B_y	4.83 t/households/yr	Study/Survey	A Joint Study report by the UNHCR and the Gaia Association, 2006)
$f_{NRB,y}$	0.76	Calculated TOOL30	CDM. ASB0044-2019, Improved Institutional cook stoves, Ethiopia
$NCV_{biomass}$	0.015 TJ/t	Default	CDM methodology AMS-I.E

$EF_{projected\_fossil\_fue}$	81.6 tCO2/TJ	Default	CDM methodology AMS-I.E
Volume of Ethanol distributed	Amount in litres	official report	Biofuels Directorate of Ministry of Energy
Number of households reached	Annual number of households reached	Official data	Biofuels Directorate of Ministry of Energy

<u>Addis Ababa – bio-ethanol displacing kerosene</u>

The basic assumption is that in Addis Ababa ethanol is used by housholds who were using kerosene as cooking fuel and the baseline GHG emission and emisions reduction due to the substitution of bio-ethanol for kerosene is computed as follows.

ERy = Baseline GHG Emissions$_{\text{kerosene}}$ - Project emissions – Leakage
Baseline GHG Emissions$_{\text{kerosene}}$ = $B_{y\text{-kerosene}} \times NCV_{\text{kerosene}} \times EF_{fossil\_fuel}$

Where,

ERy: Action emission reduction
$B_{y\text{-kerosene}}$: Quantity of Kerosene consumed (ton/households-yr)
NCV_{kerosene} : Net calorific value of kerosene
$EF_{fossil\_}$: Emission factor of kerosene
By is computed as equivalent amount of Kerosene displaced by Ethanol supplied on a useful energy basis.

Table 2.4.2 Key parameters used to estimate policy scenario emissions

Parameter	Baseline & ex-ante value(s) applied over the GHG assessment period	Methodology / assumptions to estimate value	Data source(s)
Volume of Ethanol distributed to households in year y	litres	Official data	Biofuels Directorate of Ministry of Energy
By	ton	Calculated based on quantity of Ethanol supplied	Biofuels Directorate of Ministry of Energy, for quantity of ethanol supplied
NCV kerosene	43.8 GJ/ton	Default	2006 IPCC Guidelines for National Greenhouse Gas Inventories)
EF kerosene	0.0741 tCO2/GJ	Default	Default values from 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

The baseline and ex-post GHG emissions are presented in Figure 2.4.1. The GHG emission and emission reduction for each year is directly linked to the quantity of bio-ethanol supplied to the refugee camps and households in Addis Ababa. The total quantity of bio-ethanol distributed in the year 2012 to 2018 and the number of stoves that were operational in his period, as well as the estimated GHG emission reduction is shown in Table2.4.3.

The total GHG emission reduction for the period 2012 – 2018 was about 40 ktCO2. The major contribution to the total (and annual) GHG emission reduction was the substitution of bio-ethanol for biomass in refugee camps, which on average accounts to about 80% of the total reductions.

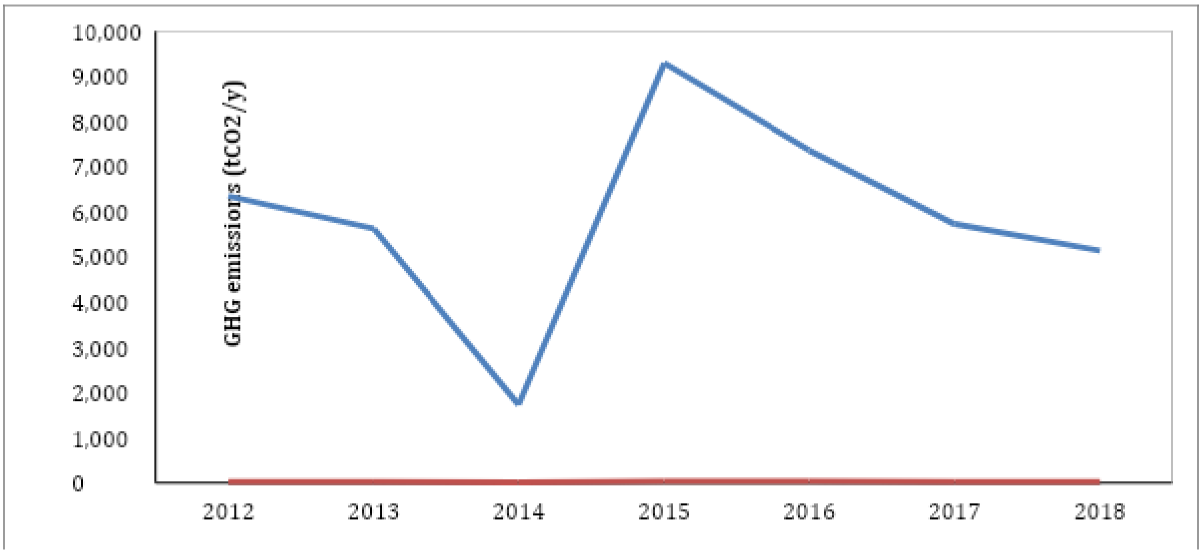


Figure 2.4.1 Baseline and ex-post GHG emissions ethanol substituting cooking fuels

Table 2.4.3 GHG emissions reduction from use of bio-ethanol for cooking

	2012	2013	2014	2015	2016	2017	2018	Total
Baseline emissions(tCO2/yr)	6,352	5,631	1,733	9,293	7,362	5,732	5,143	41,246
Emissions ethanol prod (tCO2/yr)	27	25	9	40	33	27	24	186
ERy - Emission reduction(ktCO2)	6.3	5.6	1.7	9.2	7/3	5.7	5.1	41.1
Total ethanol supply (k litres)	643.8	586.2	221.	950.5	772.4	624.6	573.5	4,372
Fuelwood displaced (t)	5,102	4,484	1,278	7,443	5,849	4,496	4,001	32,653
Kerosene displaced (r)	33	44	52	56	63	71	76	394

<u>Co-benefits of measure for ethanol as cooking fuel</u>

- Environmental Benefits

The program reduces deforestation and forest degradation in areas where non-renewable biomass is used as a source of fuel. This contributes to the overall stability of forest ecosystems, which support biodiversity and maintain the cultural and aesthetic value of forestlands.

- Socio-economic Benefits

The program reduces household air pollution through reduced combustion of non-renewable biomass and fossil fuels in households and communities. According to the WHO, toxic smoke from the combustion of firewood and fossil fuels is responsible for a range of deadly chronic and acute health effects such as child pneumonia, lung cancer, chronic obstructive pulmonary disease, and heart disease, particularly for women and children who spend a large portion of their time near the fireplaces.

The program achieves savings from reduced purchase of biomass and fossil fuels.

The program helps to free time spent in search of wood fuel in places where non-renewable biomass is the fuel of choice. This helps to ensure that household members, particularly women have enough time to care for their children and attend to other responsibilities such as pursuing income-generating activities, education, leisure and rest. According to the Clean Cooking Alliance, lack of access to cooking fuel forces women and children to spend many hours gathering firewood up to 5 hours per day or spend significant household income on fuel purchase.

The program reduces the risks and danger faced by women and girls when collecting firewood for cooking. Women and girls are the primary collectors of firewood. The search for firewood exposes them to the risks of attacks, rape and gender violence as they venture into unsafe territories.

The program contributes to the national hydrocarbon balance by reducing the amount of kerosene imports for cooking purposes at the household level.

<u>Baseline, ex-ante and ex-post GHG emission reduction from bio-ethanol use in transport: 2011-2020</u>

The baseline GHG emissions from use of gasoline in the transport sector is estimated using gasoline import data and the policy/action that is the ex-ante GHG emission reduction from use of gasoline–ethanol blend, E5, in the period 2011 to 2020. The ex-post GHG emission reduction is computed based on actual (reported) volume of ethanol blended with gasoline in the same period (Annex 2). The baseline (BEy) and projected, that is ex-ante and actual ex-post GHG emission reductions (ERy) are computed as follows:

Baseline and ER calculation

BEy = VG * EEP
BEy = Baseline emissions (t CO2e)
VG = Volume of gasoline used for transportation in Addis Ababa (kl)
EEP = Gasoline lifecycle emissions coefficient (t CO2e/kl)

And

ERy = AHy * Q * EEP – Project Emissions
ERy = Net Emissions reduction (tCO2e)
AHy: Volume of anhydrous bio-ethanol used for transportation (kl)
Q: Factor showing volume of gasoline that is displaced by bio-ethanol when bio-ethanol is blended in gasoline
EEP: Gasoline life cycle emissions coefficient. (t CO2e/kl)

Table 2.4.4 Key parameters used to estimate baseline and ex. ante scenario GHG emissions

Parameter	Baseline & ex-ante value(s) applied over the GHG assessment period	Methodology / assumptions to estimate value	Data source(s)
AH	E5,	Reports	Biofuels Directorate, MOWE

VG	(kilo liter, kl)	Official report	Biofuels Directorate, MOWE
EEP	T CO2e/kl	2.26 tCO2e/kl	CDM, UNFCC https://cdm.unfccc.int/Panels/meth/meeting/06/Meth20_repan01_NM0082rev_reformatted.pdf
Q	0.583	ECethanol/ECgasoline (=21/36)	Energy content, IPPC 2006.
EEP	2.26 t CO2e/Kl	Default	(https://cdm.unfccc.int/Panels/meth/meeting/06/Meth20_repan01_NM0082rev_reformatted.pdf
EFethanol	2 g CO2e/MJ	Default	https://theicct.org/sites/default/files/publications/EU-molasses-ethanol-emissions_ICCT-working-paper_27092017_%20vF.pdf

Figure 2.4.2 shows the (ex-post) baseline and ex-ante GHG emissions for Addis Ababa for the period 2011 to 2018, and table 2.4.5. Present baseline and ex-ante GHG emissions and ER estimated to have been resulting from proposed action policy/actions as well as the estimated ex-post GHG emission reduction.

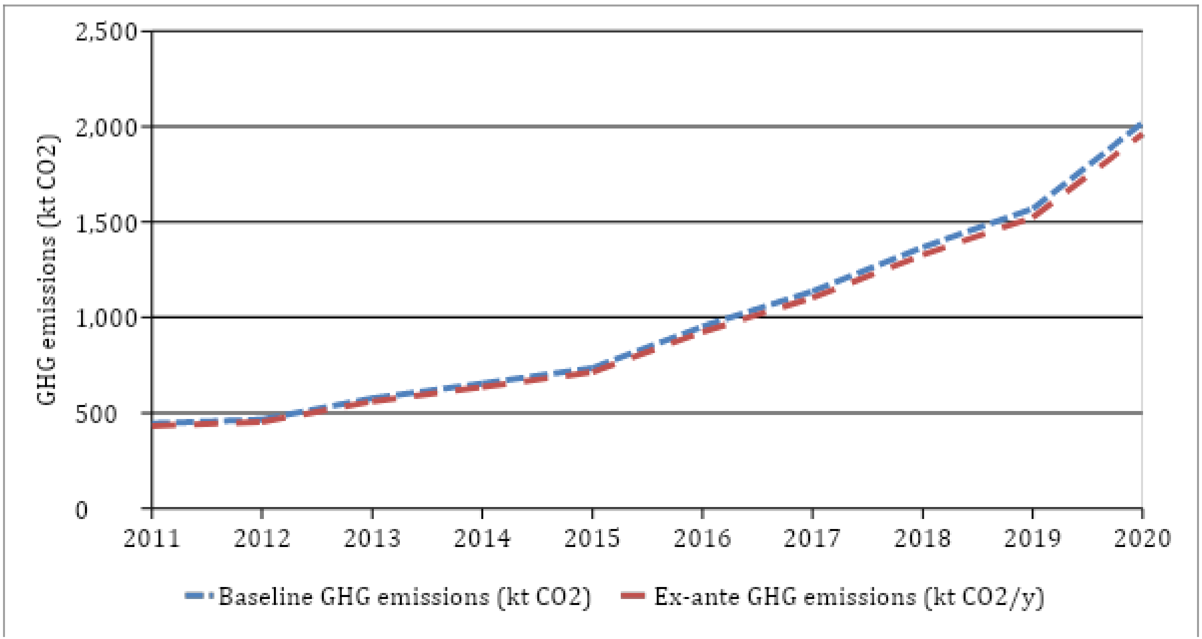


Figure 2.4.2 Baseline and ex-ante GHG emission estimates

Table 2.4.5 Summary of results, baseline, ex-ante GHG emissions and action (projected) and ex-post ER (ktCO2)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Baseline GHG emissions	445	466	577	655	736	953	1,135	1,367	1,569	2,020
Ex-ante GHG emissions	432	453	561	636	715	925	1,102	1,327	1,523	1,961
ER (Baseline-ex-ante)	13.0	13.6	16.8	19.1	21.5	27.8	33.1	39.8	45.7	58.9
ER ex-post	12.5	12.8	10.9	9.1	19.3	-	3.3	-	-	-

<u>Ex-ante GHG emission reduction from bio-ethanol use in transport: 2021 - 2030</u>

The ex-ante emissions and emission reduction for the period 2021 to 2030 are based on the parameters shown in Table 2.4.4, results are presented in Figure 2.4.4.

Table 2.4.4 Key parameters used to estimate policy scenario emissions

Parameter	Baseline & ex-ante value(s) applied over the GHG assessment period	Methodology / assumptions to estimate value	Data source(s)
AH	E5 , E10 , E15	Reports	Biofuels Directorate, MOWE
VG	(kilo liter, kl)	Official report	Biofuels Directorate, MOWE
EEP	tCO2e/kl	2.26 tCO2e/kl	CDM, UNFCC https://cdm.unfccc.int/Panels/meth/meeting/06/Meth20_repan01_NM0082rev_reformatted.pdf
Q	0.583	ECethanol/ECgasoline (=21/36)	Energy content, IPPC 2006.
EEP	2.26 tCO2e/Kl	Default	(https://cdm.unfccc.int/Panels/meth/meeting/06/Meth20_repan01_NM0082rev_reformatted.pdf
EFethanol	2 gCO2e/MJ	Default	https://theicct.org/sites/default/files/publications/EU-molasses-ethanol-emissions_ICCT-working-paper_27092017_%20vF.pdf

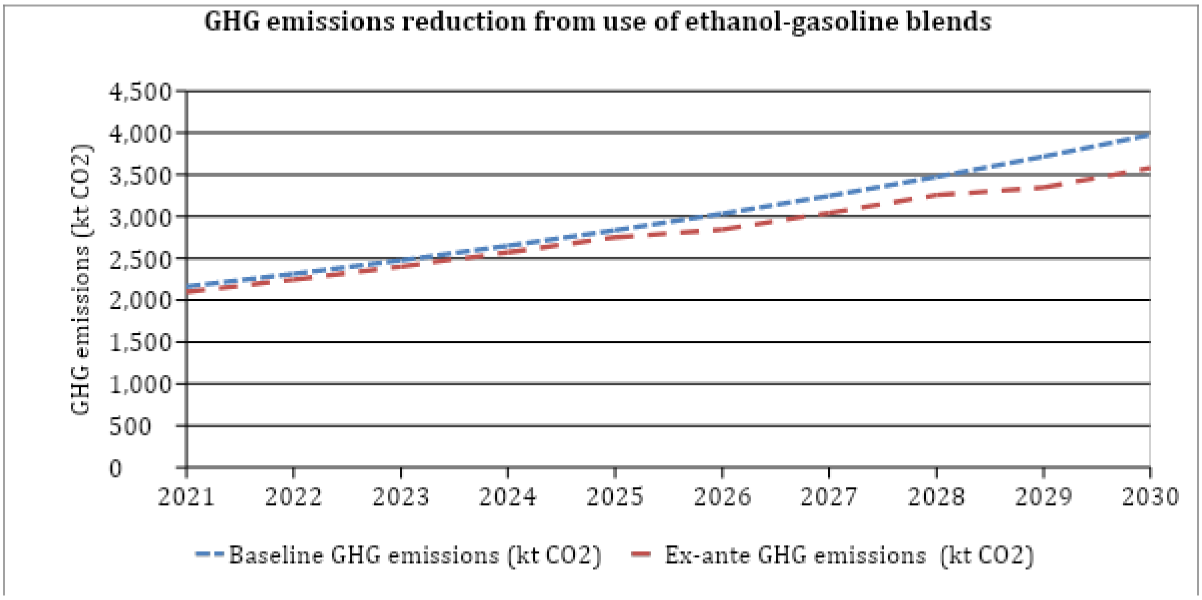


Figure 2.4.3 GHG emission reduction from use of ethanol-gasoline blend

Table 2.4.6. Baseline and ex/ante GHG emissions and GHG emissions reductions due to use of Ethanol gasoline blending E5, E10 and E15.

	E5					E10			E15	
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030

Baseline GHG emissions (kt CO2)	2,162	2,313	2,475	2,648	2,834	3,032	3,244	3,471	3,714	3,974
Ex-ante GHG emissions (kt CO2)	2,097	2,244	2,401	2,570	2,749	2,842	3,041	3,254	3,344	3,578
GHG emissions reduction (kt CO2)	64	69	74	79	84	190	203	218	370	396

Co-benefits of measure from ethanol use in transport

Production and use of bio-ethanol as a transport fuel results multi benefits in addition to its contribution to reduce GHGs. The following co-benefits can be achieved:

- Trade balance: Ethiopia's export earnings are largely taken by hydrocarbon imports. Bio-ethanol blending with gasoline helps to reduce gasoline import and contributes to narrow trade imbalance.
- GDP development and improves agricultural economy: Bio-ethanol production in Ethiopia is based on sugar production and the use of the by-product molasses for bio-ethanol production. The expansion of the agriculture and production activity contributes to GDP development of the country.
- Employment opportunities mainly in rural areas: The sugarcane farms provide large employment opportunities in rural areas of the country.
- Energy security: The global unstable fossil fuel market has been affecting Ethiopia's fragile economy significantly. The use of locally produced renewable energy sources replacing imported hydrocarbon fuels contributes to the energy security of Ethiopia.

2.5 Upgrading of transmission and distribution systems to reduce losses

Transmission and distribution losses of the national electricity grid have been estimated to be over 25% in the early 2000s. Transmission and distribution losses have been recognized in the National Energy Policy of Ethiopia as one of the major energy sector issues that needs to be addressed urgently[32]. This problem has been long recognized and a directive to address it has been set out[33]. Implementation of this policy measure has not been started until 2015. Transmission and distribution of grid electricity are the mandates of the Ethiopian Electric Power (EEP) and The Ethiopian Electricity Utility (EEU). The role of EEP is on the generation and transmission of the electricity system while EEU is responsible for the distribution network.

The objective of the upgrading of the T & D system is primarily to reduce electricity losses in the transmission and distribution system which is increasing with the growing demand for electricity whereby the need for additional power plant to meet the peak load demand would be reduced. Peak load demands have usually been met with thermal power plants which increase the overall grid emission factor.

2.5.1 Methodology

Effects and action boundary

The major objective and expected effects of the action are to reduce T&D losses and thereby reduce the total grid electricity energy supply to end-users (without increasing the capacity of existing power plants or installing new generation capacity). The T&D loss reduction measures were expected to reduce T&D loss from 23% in 2014 to 11% in 2020. However, since the planned reduction of T&D losses to 11% by 2020 was not been achieved, the revised plan is to reduce T&D losses from the current 18% in 2021 to 8.3 % by 2030[34]. The action does not address commercial losses[35].

The action boundary includes the national grid T&D systems and the power plants supplying the grid. The assessment covers the period covering 2011 to 2021 where actual historical data are used, and assessment for the period 2022 to 2030 is based on GOE's grid expansion and improvement plan.

- GHG estimation method

Emission reduction *= Baseline GHG emissions - Action GHG emissions*

Where

Baseline Emissions = Electricity generated ex-post * [[(1-TD loss-ex-post)/(1− TD loss bseline)] * EFGrid

Ex-ante Emissions = Electricity generated ex-post * [(1-TD loss-ex-post)/(1− TD loss action)] * EFGrid

Ex-post emissions = Electricity generated * EFGrid

[32] National Energy Policy 2013, Art 2.1, 2.2.1

[33] The Energy Efficiency and Conservation in Electricity T&D System, Directive 006-2011 Energy Efficiency Program and Activity Plan

[34] Power Africa GMSP System Integration Studies technical review presentation, 2018

[35] Commercial losses are broadly grouped into two categories--unbilled energy losses, and billable, but uncollectable energy usage. Unbilled energy losses are typically the result of theft in one form or another.

Baseline, ex-ante and ex-post GHG Emissions estimate: 2011-2020

Information obtained from EEU indicated that the baseline Transmission and Distribution losses of the national electricity grid was 25% in 2021, although in the Second Growth and Transformation Plan target was set to reduce T&D losses from the 23% in 2014 to 11% in 2020[36]. It is also noted that even though the National Energy Policy stated the need for reduction of T&D losses, implementation of the policy measure was not started until 2015/16.

Based on time series data on grid electricity generation and supply for 2011 to 2020, and based on the corresponding T&D losses the ex-post GHG emission is computed. The corresponding baseline GHG emission shown together with the ex-post values is computed considering a fixed 25% T&D loss over the same period. Annual TD losses for the different scenarios is presented in Figure 2.5.1 and the key parameters used to estimate the baseline and ex-post GHG emissions is presented in Table 2.5.1.

Table 2.5.1 Key parameters used to estimate policy scenario emissions

Parameter	Value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Electricity generated and delivered to end/users (GWH	Data for 2021 to 2020	National time-series data provided by EPE	EEU, 2021
Grid TD losses *		.	
Baseline	25%	Fixed to be equal to the TD loss in 2011 (ex-post data)	EEU
Ex-ante	25% in 2011 to 11% in 2020	GOE plan on TD reduction,	GTP
Ex-post	25% in 2011 to 18% in 2020	Calculated using above electricity generated and delivered data for each year from 2011 to 2020	EEU, 2021
Grid emission factor	0.05 kg CO2/kWh (50 t/GWH)	CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years	Lighting ETH U4E Country Saving Assessment Lighting Oct-20

[36]Growth and Transformation Plan 2, 2015/15 – 2019/2020), Vol. 1, National Planning Commission, May 2016

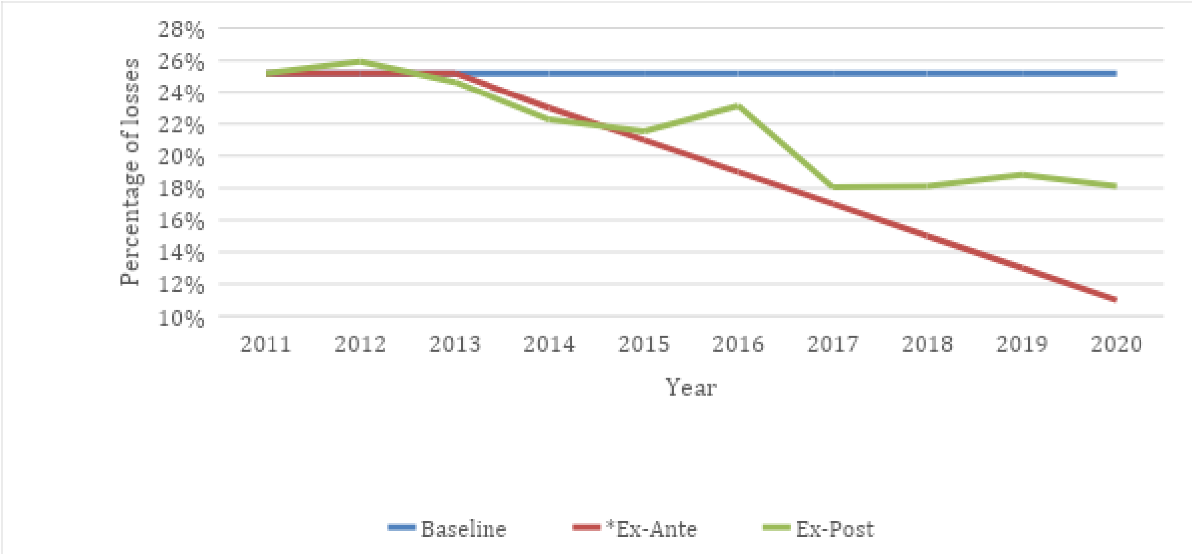


Figure 2.5.1 Percentage of transmission and distribution losses of the national electricity grid

GHG emissions estimates for the baseline, ex-ante and ex-post cases are presented in Figure 2.5.2. The ex-post GHG emissions compared to the baseline case shows the (actual) implementation of TD loss reduction measures had resulted in a steady reduction of GHG emissions, and by 2020 the annual reduction has reached about 0.17MtCO2. However, given the more ambitions TD loss reduction plan compared to was achieved, the ex-post GHG reduction achieved within this period has been considerably lower.

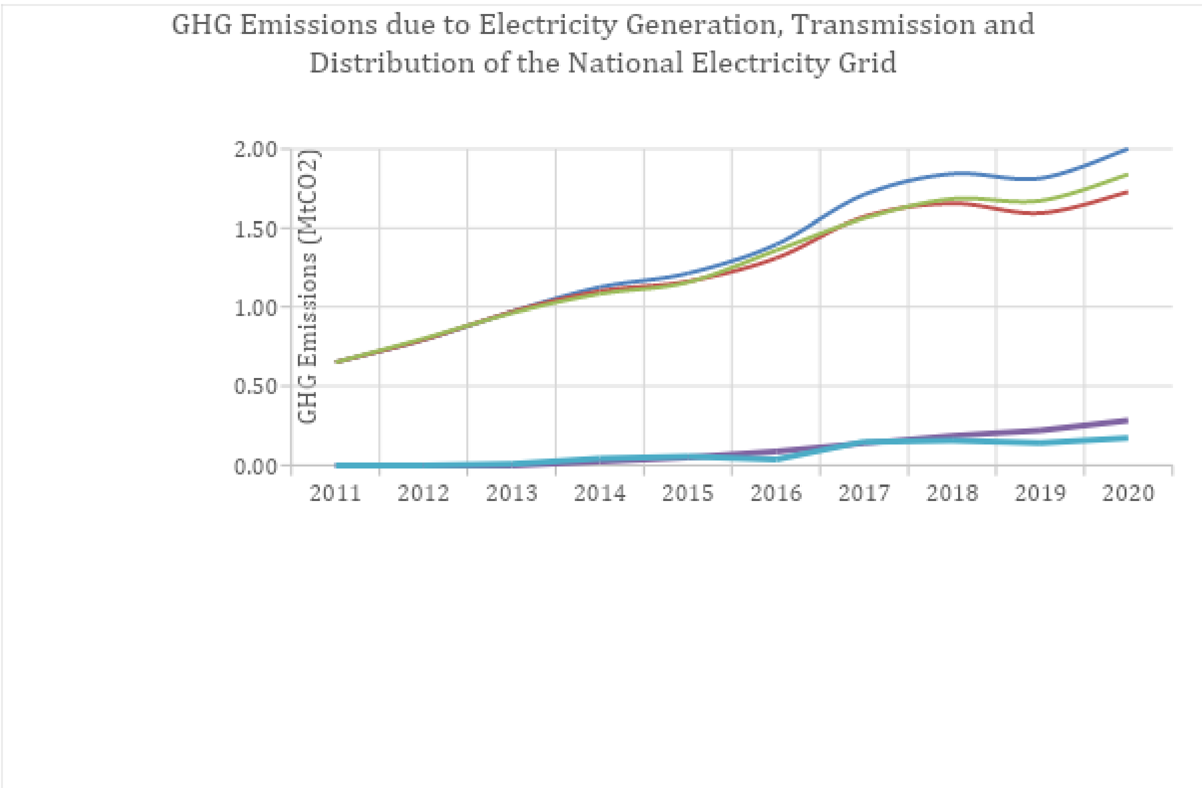


Figure 2.5.2 Baseline, ex-ante and ex-post GHG emission estimates

Ex-ante GHG Emissions: 2021 to 2030

The ex-ante GHG emission for electric power generation and the national grid is computed based on projected data provided in the study Grid Management Support Program. System integration study, (GMSP-SIS) Power Africa, 2019, the Ten-Year Strategic Plan (MoWE), and the Ten-Year Development Plan, 2021.

The baseline scenario GHG emissions are computed based on the assumption that the 2021 T&D loss will remain throughout the assessment period. The Figure below shows the baseline and ex-ante GHG emissions. The analysis shows that by 2030 about 0.89MtCO2 will be reduced if the proposed T&D measures are implemented.

Table 2.5.2 Key parameters used to estimate policy scenario emissions

Parameter	Value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Projected Electricity generation and delivered to end/users (GWh)	Data for 2021 to 2030	Projected, data	-Grid Management Support Program. System integration study, (GMSP-SIS) Power Africa, 2019. -Ten-Year (2021-2030) Strategic Plan, MoWE,2021 -Ten-Year Development Plan, Jan.2021
Grid TD losses	Estimated based on above data	.Calculated	(GMSP-SIS) Power Africa, 2019 -Ten-Year (2021-2030) Strategic Plan, MoWE,2021 -Ten-Year Development Plan, Jan.2021
Grid emission factor	0.05 kg CO2/kWh (50 t/GWh)	CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant	Lighting ETH U4E Country Saving Assessment Lighting Oct-20

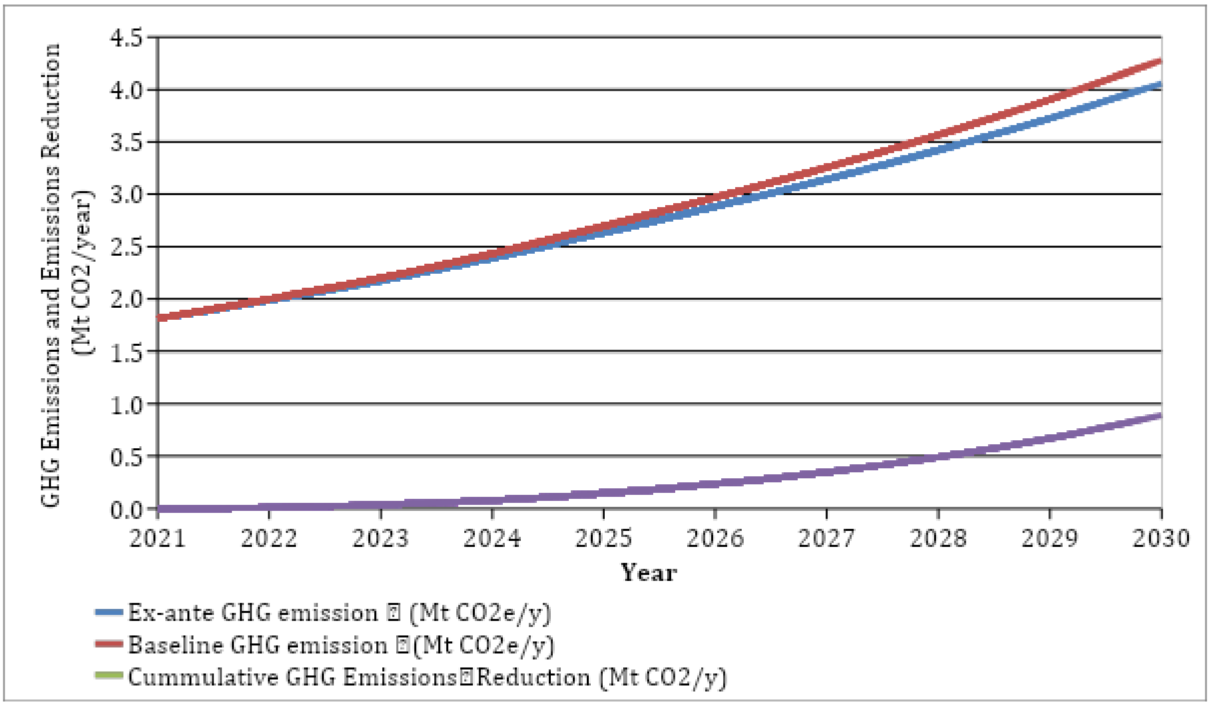


Figure 2.5.3 Baseline and ex-ante GHG emissions (2021-2030), MtCO2

Table 2.5.3 Estimated GHG emission savings: baseline – action: 2021 - 2030 (Mt CO2/Year)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline	1.8	2.0	2.2	2.4	2.7	3.0	3.3	3.6	3.9	4.3
Ex-ante	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.4	3.7	4.1
Saving	0.00	0.01	0.04	0.08	0.14	0.23	0.35	0.49	0.67	0.89

Co-benefits of measure

Reduction of T&D losses means making more electricity available in the grid to meet growing demand. This helps reduce or avoid the need for additional power plant earlier than the planning period.

2.6 Power factor correction (PFC)

The basis for promotion of Power Factor (PF) correctors in industries is the National Energy Policy 2013, Art 3.1 which underlines the necessity of taking energy efficiency measures in industries to reduce electricity losses. Next to the households sector, the industry sector in Ethiopia is the second largest electricity consumer. About 36% of electricity consumption is by the industry sector. Power Factor Correction (PFC) is a relatively easier and less costly measure which improves efficiency at a factory level and also benefits to reduce the load on the distribution grid.

Induction motors and transformers are the main causes for reactive power. Industrial electric motors are one of the main consumers of electricity in both small and large industries. Induction motors are the most widely used motors in industries. The increase in inductive power drawn from the grid increases power loss in the transmission and distribution systems. Regulators usually penalize industries where power factor levels get below certain levels (e.g. 0.8 or 80%), usually a low power factor charge to the industry tariff. Industries are advised to install power factor correction equipment (usually a capacitive element(s)/ bank connected to the motors to increase the power factor). Power factor correction will have benefits in reducing power drawn from the grid therefore reduces losses in transmission and distribution, increases power available from the grid, and reduce energy/power costs to industries.

In the EEA's Energy Efficiency Program and Activity Plan (2018), improving energy efficiency of industrial motors is said to have the highest contribution among the 10 energy efficiency measures evaluated at nearly a third of all savings (1,900MWh for motors from a total of 6,100MWh).[37]

However, implementation of PFC in industries has been delayed until recently mainly for lack of suppliers for proper PFC equipment. Recently EEA collected data from six industries that installed PFC devices into their systems. These industries were pilot trials.

Table 2.6.1 PF correction devices installed in pilot factories and impacts of measures on KVA demand

No.	Name of Industry	Without PFC			With PFC		
		Avg. PF	KVA	Remaining KVAR demand	Avg. PF	KVA	Remaining KVAR demand
1	Chamber Printing Press	0.86	74	56	0.92	47.2	18.1
2	ELFORA	0.85	39	20.7	0.92	31.8	12.7
3	Yekatit Pulp and Paper Factory	0.61	124	97.6	0.97	97.7	24.9
4	Pepsi Soft Drink Factory	0.89	332	153	0.94	329	114
5	Artisitc Printing Press	0.62	54	41.2	0.94	38.8	23.6
6	Mulege Coffee Decorticating	0.84	66	38.9	0.99	45.0	1.96

2.6.1 Methodology

Effects and action boundary

The major effects of PF correction measures include reduction of T&D losses by reducing factory/industry level reactive power demand. The reduction in reactive power demand decreases the total electric current demand and hence current – related transmission and distribution losses but without reducing active power supply to factories (or other end-users) implementing PFC measures.

This measure also reduces the amount of energy power plants should supply through the T&D systems. At a factory level the impact of PFC measures include less overloaded internal distribution system with high internal power losses.

The action boundary includes the power plant, the national grid (T&D systems) and the factory employing PF correction measures. Given that there is no publicly available national PF correction plan, it was not possible to make specific GHG emissions or co-benefit assessment for any particular period.

GHG reduction from installation of capacitors to correct/improve powered factor involves

[37]Note that the Ethiopian Energy Authority (EEA) has another policy measure regarding motors, specifically setting and regulating standards for electric motors (NOT power factor correction for motors in industry).

estimation of energy losses from cables and transformers before installation of capacitors. The GHG reduction is then determined by multiplying the energy loss reduction by the average grid EF.

GHG reduction due to PF Correction = Energy loss reduced (KWh)*EFgrid (t CO_2/kWh)

where,

Energy loss reduced = Cable and Transformer losses* $[1-(PFold/PFnew)^2]$ [kWh)

Associated with energy consumption reduction and depending on the level of power factor improvement, factories implementing PFC may reduce or totally eliminate power factor penalty imposed by EEU for PF lower than 0.9. The power factor penalty is computed using the following relations:

Power factor penalty = (KWbilled – KW actual)*Birr/KW, Where, KWbilled = KWactual* 0.9/PF

2.6.2 Baseline, ex-ante and ex-post GHG emissions estimates

For action involving PF correction measures the baseline GHG emissions is the sum of cable and transformer energy losses before PF correction multiplied by the grid emission factor. For the ex-ante case, the GHG emission estimation will be the sum of these losses estimated after a proposed PF correction measure is employed multiplied by the same grid emission factor as used for the base case.

Ex-post GHG Emissions reduction from PF correction measures would be more difficult to estimate as estimation of ex-post impacts would involve measuring, collection and analysing of actual operational ex-post factory level data and information relevant to assessing GHG reductions. Key information collected and analysed shall provide estimates on changes (reduction) in power loss, electricity energy bill, and reduction or elimination of power factor penalties.

Apparently, there appears to be limited baseline data and information on current PF of the various categories of factories and the necessary information need to be collected either as part of an overall energy audit exercise or activity that target in assessing PF. The ex-ante scenario shall then be developed based on various considerations but mainly considering engineering (technical viability), and financial feasibility of undertaking PF correction measures. At country level this scenario shall be developed by aggregating potential PF correction measures developed for selected number of factories, or, for a category or sub-category of one or more types of industry where PF is generally expected to be low, and opportunity for improvement is higher.

<u>Impact of PF correction devices installed in pilot factories</u>

Based on data provided in Table 2.6.1 above the impact of PF correction measures on power (energy) loss reduction is estimated from about 10% to 60% relative to powered demand before the PF correction measures (or relative to the “baseline”). As would be expected the highest relative power (energy) loss reduction is achieved for the factories that had very low PF (61%-62%) and have improved their PF to over 90%. However, as the KVA or power demand of these factories is relatively low (less than about 100 KVA, Except for one), the actual saving in terms of GHG or energy cost will be very low.

2.6.3 Co-benefits of measure

PFC measures have multiple benefits to both the utility and consumers as well. PFC would help reduced the reactive power in industries so that more energy would be available in the grid to provide to other customers. Because of less current requirement at the consumers' side, it improves the voltage level at the consumers' service point. PFC also improves grid T&D losses which ultimately reduce GHG emissions.

2.7 Grid connected waste to energy project

A Waste-to-Energy project is part of Ethiopia's broader strategy which intends to address pollution and expand renewable energy sources in the mix of Ethiopian electricity grid. The government of Ethiopia took an initiative to introduce a project to better manage solid wastes in some of the major cities and avoid methane release from anaerobic decay of organic waste using alternative waste treatment processes.

The Reppi waste dump site has been a major landfill site that for decades was (and still is) receiving solid waste generated in Addis Ababa city. Reppi has stored large amount of solid waste, and as an open dump site releases large amount of methane gas in to the atmosphere.[38]The Reppi waste to energy project is therefore intended to avoid (reduce) methane emissions while generating electricity by burning solid waste. This thermal electric generating plant was installed and commissioned in 2019, has a daily solid waste incineration capacity of 1,400 tons (about 80 % of solid waste generated in Addis Ababa city), and installed electric power generation capacity of 50 MW (2 turbines of 25 MW each). For Ethiopia this plant is the first of its kind.

2.7.1 Methodology

Potential GHG and non-GHG effects and action boundary

The Reppi waste-to-energy project is expected to significantly reduce the amount of methane emissions generated at the Reppi landfill site. The project activity, by incinerating the solid waste, avoids the open disposal and therefore anaerobic decay of the waste to CH4. The major non-GHG emission reduction effects are the generation and supply of renewable electricity into the national grid, and reduce the amount of spaces needed for storing solid wastes at landfill sites. The plant is expected to operate for 25 to 30 years and hence the emission reduction effects are expected to be extended through the next 30 years.

The methodology applied for the assessment is the CDM methodological tool (Tool04) recommended for assessing emissions resulting from solid waste disposal in landfill sites. The tool provides procedures to calculate baseline, project or leakage emissions of methane from solid waste disposed or prevented from disposal at a solid waste disposal site (SWDS). The key parameters used in computing the baseline and avoided methane emissions are shown in Table 2.7.1.

2.7.2 Baseline scenario and ex-post GHG emission estimates: 2011-2020

In the baseline scenario it is assumed that organic waste deposited on the MSW landfill site is left to decay and methane is generate and is emitted into the atmosphere. In the project or action

[38]Methane emission from solid waste generated in Addis Ababa was estimated at 836,120 tCO2 in 2016 (and was about2.6 times more than was estimated for 2012). Addis Ababa City 2016 Greenhouse Gas Emissions Inventory Report Version v8.0.

scenario methane emissions will be avoided through controlled combustion (incineration) of solid organic wasted to produce electricity that will be fed to the national grid (the assumption is that the electricity generated complements grid electricity supplied from hydropower units, and no consideration on displacement of GHG-intensive power generation is considered).

The plant has been operational since May 2019, and till end of 2020 has incinerated 595 thousand tons of solid waste and generated 251GWh of electricity. GHG emission reduction in this period is estimated at 41 ktCO2e. GHG emission reduction for 2019 (8 months of operation) and for 2020 are shown in Table 2.7.2. In 2020 due to the low quality of SW supplied, for most of the period only one of the plants was operational.

Table 2.7.1 Key parameters used to estimate policy scenario emissions

Parameter	Value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data source(s)
Specific solid waste consumption	2-36 tons per MWh generated	Plant operation data for 2019 and 2020	Calculated
Solid waste incinerated	Quantity of solid waste incinerated (ton/y)	Plant operation data for 2019 and 2020	EEP
Electricity generated and fed to the grid	Quantity of electricity generated average of two year values	Plant operation data for 2019 and 2020	EEP
Grid emission factor	0.05 kg CO2/kWh (50 t/GWH)	CO2 emission factors come from the IEA and the Institute of Global Environmental Strategies (IGES) and are assumed constant in future years	Lighting ETH U4E Country Saving Assessment Lighting Oct-20

Table 2.7.2 Amount of waste incinerated and corresponding GHG emission reduction for 2019 and 2020

	Energy generated (MWh)	Waste incinerated (ton)	Degradable organic C in waste (ton)	Emissions reduction (kt CO2e/y)
2019	123,912	313,028	6,871	21
2020	127,767	281,477	6,179	20
Cumulative	251,679	594,505		41

2.7.3 Ex-ante GHG assessment: 2021 - 2030

In estimating the ex-ante GHG emissions reduction we have used the parameters indicated for the baseline case but also have made the following assumption: that in 2021 the quantity of SW incinerated is close to its corresponding value of 2020, but will grow by about 10% per year until 2030, reaching about 90% of the total incineration capacity of the plan[39]. The result shows that in 2030 the GHG emission reduction would reach close to 48Kt CO2, and the cumulative reduction to 326 ktCO2. The annual estimated quantity of MSW incinerated and electric energy produced with the corresponding GHG emissions reduction is shown in Table 2.7.3.

[39] The total quantity of SW projected to be incenerated in 2030 is computed based on average specfic SW consumption of 2.36 tons per MWh generated (see operational data, table 2.7.2), and assuming a plant capacity factor (CF) of about 75%. Based on these considerations the plant is assumed to operate a single unit (25 MW) at 75% CF until 2024, but will need to bring on-line the 2nd unit starting 2025 to reach the projected maximum SW incineration capacity of about 700 tons by 2030 (Table A2.12, annex).

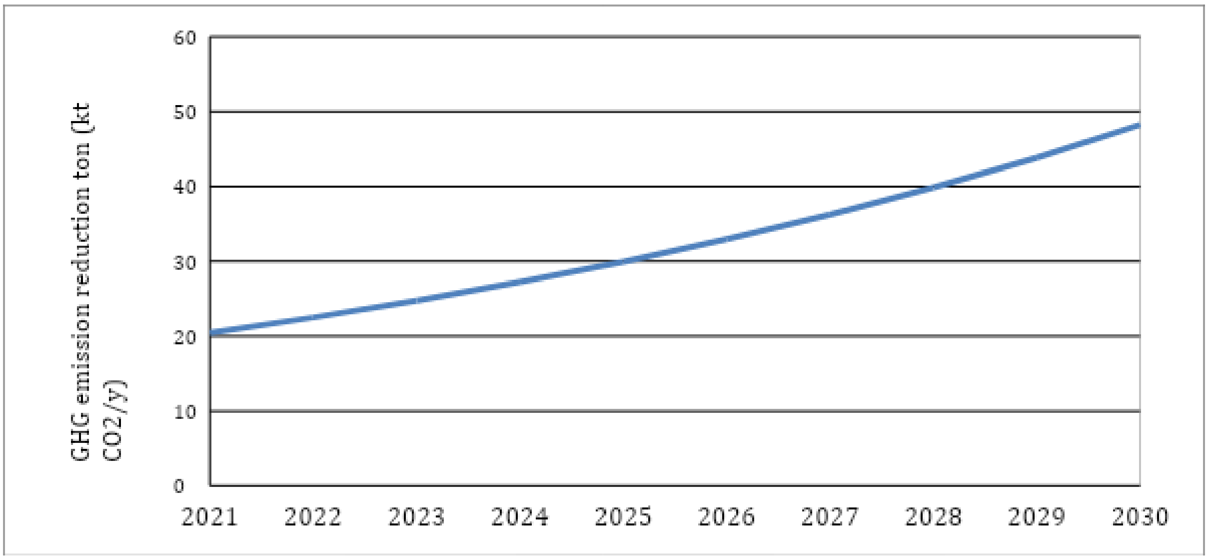


Figure 2.7.1 GHG emission reduced from incineration of solid waste at Reppi (ktCO2e)

Table 2.7.3 Electricity generated, quantity of SW incinerated and GHG emissions reduction (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy generated (GWh)	127	140	154	169	186	204	225	247	272	299
Quantity of SW incinerated (k ton)	300	330	363	399	439	483	531	585	643	707
GHG emissions reduced (kt CO2e)	20	22	25	27	30	33	36	40	44	48

2.7.4 Co-benefits of measure

This project reduces municipal solid waste that otherwise would be land filled, contributes to the beautification of the city and providing source of income for youth while providing clean energy through the national power grid.

2.8 Introduction of mini grids in off-grid rural areas

Electrification of off-grid communities through solar PV and hybrid powered mini grids is part of the off grid component of the national electrification program (NEP 2.0, 2019). The NEP 2.0 has identified 1,160 potential sites within 2.5-25km from the existing grid, 134 sites within 25-100km from the existing grid, and 151 sites are beyond 100km from the exiting grid that may be suitable for development of such mini grids (NEP 2.0, p. 73, p. 78).

Public, private, cooperative, and public-private partnership models are proposed for mini grids. Public financing will be the main model for deep rural areas, and private and cooperative models will be promoted for those within 2.5 – 25km.

Implementation of the mini grid component of the NEP started with piloting of public owned (EEU owned) PV-diesel hybrid mini grids in 37 locations throughout Ethiopia in 2019. About a third of these sites are now operational (early 2022). These pilots were financed by the World Bank (12 sites) and the African Development Bank (25 sites).

The NEP estimates that each of these proposed mini grid sites will have about 700 to 1000 connections (with mean of about 730 connections; p. 79). Total number of beneficiaries (persons, not households) in deep rural areas is estimated between 0.7 to 1 million (NEP 2.0, p. 75). The focus of the mini grid component of the program is to reach the remote sites (or what are called deep rural) first, and then move inwards.

The investment for implementation of the NEP 2.0 is specified in the financing agreement between the Government of Ethiopia and the World Bank in the program called *Access to Distributed Electricity and Lighting in Ethiopia* (ADELE). Total investment for the mini grid component is USSD 300 million (for both public and non-public; NEP 2.0, p. xxxi). The mini grid component of the ADELE program will benefit 240,000 households (1.2 million people), 11,500 businesses (commercial, agricultural and industrial users) (PAD, ADELE, p. 27).[40]

The mini grid component of the NEP will reduce greenhouse gas emissions by replacing petroleum fuel use by off-grid communities, specifically kerosene used for lighting by households, diesel fuel used by grain mills, and diesel fuel used for power generation by commercial entities. However, the PV powered mini grid program is not part of the CRGE or NDC.

2.8.1 Methodology

In rural off-grid areas that will be served with PV/diesel hybrid mini grids the main consumers of energy and the baseline technologies they use that will be replaced by renewable electricity are as follows.[41]

a) Single phase customers: these are mainly households but may also include small commercial entities. The baseline technology that will be replaced by renewable electricity is lighting with kerosene lamps. The ADELE project estimates emission reduction equivalent to.0.374tCO2/year from each household that will be served by mini grids.

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[40]USD 270 million for 251,500 users (equates to USD 1,074/connection).

[41]For a more rigorous assessment of emissions and emission reduction the CDM methodology AMS I..L may be used:
AMS I.L. Electrification of rural communities using renewable energy (applicable for renewable energy powered mini grids and solar home systems; other condition is that 75% of the consumes must be residential)
AMS I.L. Validation parameters are number of facilities served by the renewable electricity by the project (households, SMMEs, public)
AMS I.L. Monitored parameters are net amount of renewable electricity delivered to all end use facilities, and installed capacity of renewable electricity generating facility

- Single phase customer ER/year = 0.374tCO2e//household/year * number of single-phase connections

b) Three phase customers: these consist of mainly grain mills but also other large commercial entities. The baseline technology is a diesel powered engines (running the grain mill and other such equipment). This will be replaced by electricity from the PV/hybrid mini grid.

- Three phase customer ER/year = 1.0tCO2/MWh * MWh consumption three-phase connection * number of three-phase connections

2.8.2 Ex-ante GHG emission and emission reduction: 2021 – 2030

The NEP was first issued in 2017 and its update, the NEP 2.0, in 2019. Mini grids constitute a sub-component of the off-grid component of the NEP. Under the NEP 2.0, mini grids were, expected to be implemented starting 2019 but the first mini grid developed by the EEU came online only in 2021.

Table 2.8.1 Key parameters, baseline values and data sources

Parameter	Baseline and ex-ante values	Methodology and assumptions	Data sources
Single phase customers			
Mean annual electricity consumption	48 kWh/y	Project assumption	ADELE project document
Emission reduction per household connected	0.374tCO2e/y*	Project assumption	ADELE project document
Number of household connections	240,000 (total in 2027)	Project plan	ADELE project document
Three phase customers			
Mean monthly electricity consumption	6, 056kWh/m	Project assumption	ADELE project document
Emission reduction per customer	1.0 tCO2/MWh	Project assumption	AMS-I.L
Number of three phase connections	14,840 (total in 2027)#	Project plan	ADELE project document

*This is based on 6.8tCO2/MWh @ 55kWh/y, from AMS-I.L.
This is calculated as number of mini grids (265) times 3-phase customers per mini grid (56).

The national mini grid development program is expected to reduce GHG emission by 5.9 MtCO2e over the 2021-2030 period. Nearly all of the emission reduction (97%) will be from substitution of diesel use by three-phase customers (those that were using diesel engines for grain mills and diesel generators). Because the mini grids are powered by PV-diesel hybrid systems there will still be some GHG emission.

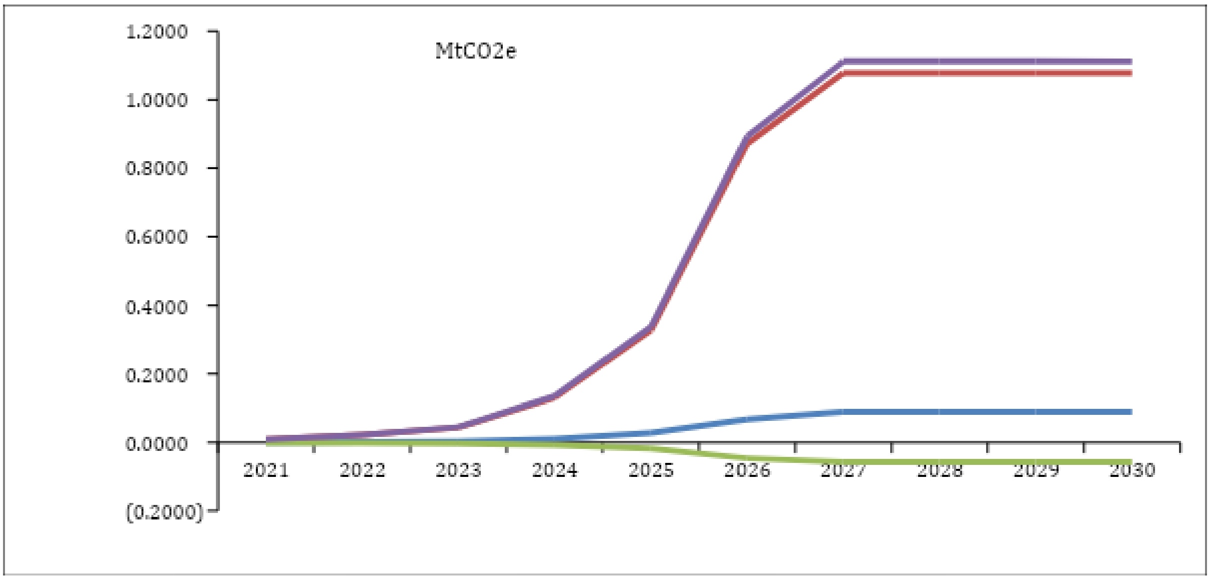

Figure 2.8.1 Emission reduction from the national PV/hybrid mini grid sub- program

2.8.3 Co-benefits of measure

The mini grid sub-program of the ADELE will provide electricity access to 240,000 households (1.2 million people) and will improve productivity, sustainability and profitability of 14,840 enterprises and social services. It will serve remote off-grid areas that will have little opportunity for electrification; these areas are also disadvantaged in terms of access to other economic and social infrastructure and services because of their remoteness. Electrification through mini grids will benefit these communities through:

- Productivity and income gains for rural population; linked with this increased employment opportunities and increased (or new streams of) income
- Better social services (water supply, schools and health posts and centres, churches and mosques)
- Improved living standards (or quality of life) of households
- Removal of household air pollution from homes from kerosene lamps
- Better access to information and better communication for the community (due to reliable access to electricity in the home to charge mobile phones, for TVs, radios)

It is also recommended to conduct periodic sample surveys of selected mini grid development sites to ascertain the assumption in the plan (ADELE). These include the types and number of customers served by the mini grids (residential, industrial, commercial), kWh consumption by customer type (in the ADELE plan these were put as 48kWh/y for single phase customers and 6056kWh/m for three-phase customers), and diesel fuel consumption of the diesel generator.

2.9 Promotion of standalone photovoltaic systems in off grid areas

This set of policies contains actions based on standalone solar systems including solar home systems (and solar lanterns), solar water pumping systems, and solar systems for schools and health centres. Solar home systems and standalone solar systems for schools and health centres are part of the ADELE program (SHS under 3 and solar for schools and health centres and Component 4). Solar water pumping is not included under the ADELE project.

Emission reduction from these policies is mainly due to replacement of fossil (petroleum) based energy sources by solar electric systems. These include replacement of kerosene lamps by solar home systems, replacement of diesel water pumping systems (for potable water supply and for irrigation) by PV pumps, and replacement of diesel generators used by schools and health centres.

The solar lighting (SHS and SL) interventions have been strongly promoted since 2011 (World Bank/IFC support, government support). Regulations related to tax reduction and exemption for Lighting Global approved solar systems have been one of the major drivers. Another driver has been the WB/IFC supported financing in hard currency for importer/suppliers (and also consumer finance through MFIs)

Solar water pumping for potable water supply has been promoted by the government (for example, through the AfDB supported program) and by international development organizations (including UN organizations and others) since 2010. Solar water pumping for irrigation is a new area of interest for the government and donors and there are now projects promoting solar irrigation for smallholder farmers by the government (e.g. through the ATA) and by (e.g. GIZ, SNV).

Standalone solar systems for schools and health centres have been promoted (and piloted) by the government (MOWE, MOE, MOH) and NGOs (GIZ and others) since 2005. The ADELE program is building on these pilots to electrify 1000 schools and 400 health centres in off-grid rural areas throughout the country by 2027.

2.9.1 Methodology

These set of measures reduce greenhouse gas emissions by replacing fossil fuels with electricity from solar systems. Emission reduction coefficients are taken from the project documents where project specific rates available (e.g. for solar home systems); the distribution (or reach) of the intervention is taken from project documents (ADELE for all except for the water pumping technologies).

a) Home systems: baseline technology that will be replaced by renewable electricity from the home systems (and solar lanterns) is lighting with kerosene lamps. The ADELE project estimates emission reduction equivalent to.0.374tCO2/year from each household that will be served by mini grids.

- Emission reduction= 0.374tCO2e//household/year * No. of SHS/SL distributed

b) Potable water pumping: the baseline technology is diesel engine powered water pump. Solar PV replaces the diesel pump and removes emission from diesel fuel consumed in the diesel engines. Emission and emission reduction is estimated from mean annual volume of diesel consumed per pump, emission factor for diesel fuel used in engines.

- Emission reduction= annual diesel fuel consumption per pump (l/y) * emission factor for diesel (74,100 kgCO2/TJ) * calorific value of diesel (36.12 MJ/l) * number of pumps replaced

c) Irrigation water pumping: the baseline technology is diesel and petrol powered irrigation pump. Solar PV replaces the diesel/petrol pump and removes emission from diesel/petrol consumed for the pump.

- Emission reduction= annual diesel fuel consumption per pump (l/y) * emission factor for diesel (74,100 kgCO2/TJ) * calorific value of diesel (36.12 MJ/l) * number of pumps replaced

d) Off-grid schools: 1,000 off-grid schools will be powered by standalone solar system by 2027 according to the ADELE plan. Solar PV will replace diesel self-generation in these schools.

- Emission reduction= Annual electricity consumption per school (MWh) * emission factor for diesel self-generation (0.65 tCO2e/MWh) * number school systems installed

e) Off-grid health centres: 400 off-grid health centres will be powered by standalone solar system by 2027 according to the ADELE plan. Solar PV will replace diesel self-generation in these health centres.

- Emission reduction= Annual electricity consumption per health centre (MWh) * emission factor for diesel self-generation (0.65 tCO2e/MWh) * number health centre systems installed

2.9.2 Ex-ante GHG emission and emission reduction: 2021 – 2030

The ADELE program has specified the number of entities that will be served with distributed solar systems during 2021 to 2027. These plans are used to estimate ex-ante emission reductions for three of the five interventions (solar home systems, solar systems for schools, and solar systems for health centres). For the other two interventions (potable water pumping and irrigation pumping) estimates of annual fuel consumption and systems that will be installed in 2030 are based on recent studies.

Table 2.9.1 Parameters, baseline values and data sources

Parameter	Baseline & ex-ante values applied	Methodology and assumptions	Data sources
Solar home systems (and solar lanterns)			
Emission reduction per household connected	0.374tCO2e/y	Project assumption	ADELE PAD
Number of SHS/SL distributed	750,000 (2027)	Project plan	ADELE PAD
Potable water pumping			
Annual diesel fuel consumption per pump	6,136liter/y		MOWIE, 2017
Emission factor for of diesel	74,100 kg CO2/TJ	Default	https://ghgprotocol.org
Calorific value of diesel	36.12 MJ/liter		https://ghgprotocol.org
Number of diesel pumps replaced	5,000 (2030)	Based on MOWE plan for 30,000 pumps by2030	https://www.concordia.net/solar-water-pumps-in-ethiopia/
Irrigation water pumping			
Annual diesel fuel consumption per pump	118 liter/y		MOA, 2019
Emission factor for of diesel	74,100 kg CO2/TJ	Default	https://ghgprotocol.org
Calorific value of diesel	36.12 MJ/liter		https://ghgprotocol.org
Number of diesel/petrol pumps replaced	70,000 (2030)	Based on GIZ est. of 220,000 pumps in 2021	GIZ Ethiopia, 2021
Off-grid schools			
Average monthly electricity use per school	164kWh/m	Project estimate	ADELE PAD
GHG emission factor for diesel self-generation	0.65 tCO2e/MWh	Project estimate	ADELE PAD
Number of off-grid schools connected	1000	Project plan	ADELE PAD
Off-grid health centres			

Monthly electricity use per health centre	821kWh/m	Project estimate	ADELE PAD
GHG emission factor for diesel self-generation	0.65 tCO2e/MWh	Project estimate	ADELE PAD
Number of diesel/petrol pumps replaced	400	Project plan	ADELE PAD

- MOWIE, 2017. Assessment of the Governing Factors which Affect the Scaling-Up and Sustainability of Solar and Wind Water pumping Systems
- MOA, 2019. Service Delivery Implementation Strategy for Small Scale Irrigation Technologies and Related Services
- GIZ Ethiopia, 2021. Solar irrigation market analysis in Ethiopia
- https://ghgprotocol.org/sites/default/files/Emission_Factors_from_Cross_Sector_Tools_March_2017.xlsx

The standalone solar programs will result in emission reduction of 2.2 M tCO2e during 2021-2030. Solar home systems and solar potable water pumps account for 77% and 19% of this total. The other interventions (solar irrigation pumps, solar systems in schools and health centres) contribute just 3% of the total emission reduction.

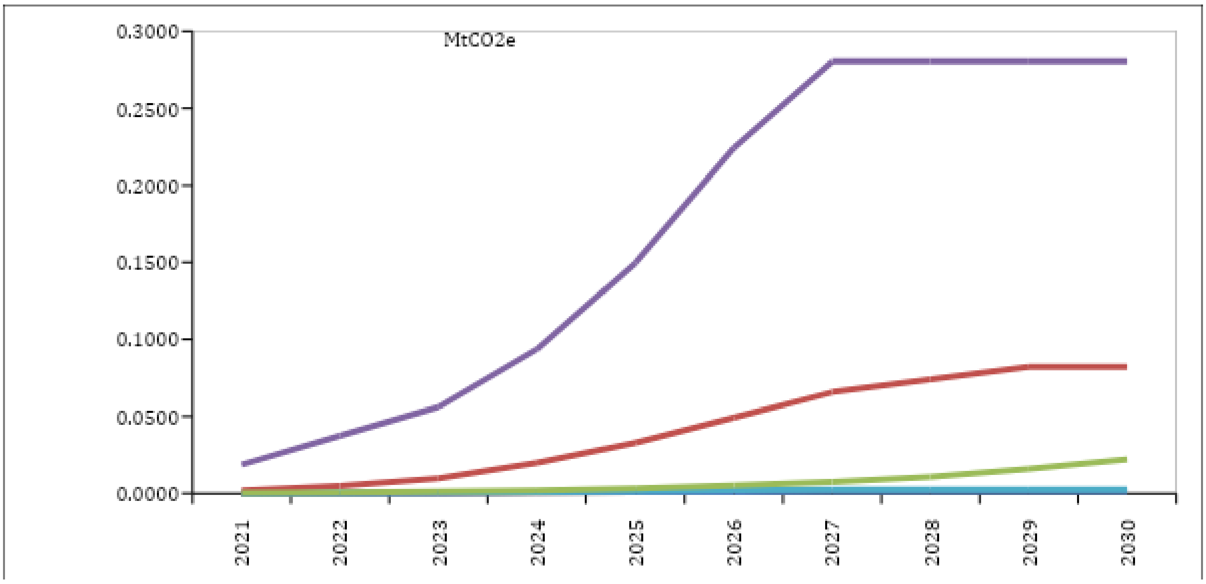

Figure 2.9.1 Emission reduction from national PV standalone system distribution sub-program

2.9.3 Co-benefits of measure

The standalone systems promoted under this set of policies will increase access to electricity to improve living conditions of households, increase sustainability of water supply and irrigation systems, and improve the quality of service for off-grid schools and health posts. The main co-benefits are as follows:

- electrification of 750,000 households during 2021-2027 with SHS and SL. High quality light for homes and access to basic services from electricity including mobile phone charging, electricity to run radios and TVs
- substitute imports with domestic energy (kerosene, diesel and gasoline with electricity from solar PV)
- air pollution mitigation through the removal of kerosene lamps
- low cost of energy service for households and communities; more reliable service because of reduced demand for O&M
- lower cost of water supply (for both potable and irrigation water) – compared to the baseline technology of diesel and petrol pumps, solar pumps will have lower life cycle costs for owner.

They also require much less O&M expenses making them suitable for remote rural areas where technical service and parts are not easily accessible

- more sustainable access to electricity and the services it can support for schools and health posts

3. Considerations for MRV

Implementation plans and quantified targets or expected outputs were relatively easily accessed for some policies and actions but similar information were not available for others. Key monitoring and evaluation issues identified related to the specific policies and actions assessed include:

- Improved cook stoves: ICS are mainly produced and disseminated with support from and coordinated by regional energy offices. These offices are responsible for collecting ICS production sales data for their respective regions. Where data is available the authenticity of the data could not be verified, and/or the data lacks important details such as the disaggregation of ICS produced by type of stove (cooking, baking, Mirt or Gonzie, or Tikikil, etc.). Apparently, at present there is a general lack of strong communication and linkages between MOWE and institutions implementing and/or overseeing planning and implementation of the policy and actions assessed.

- Labelling of electric injera baking mitad: is implemented by EEA. EEA monitors the quality and performance of electric injera mitads produced and approves the labels. As program has only recently started there is only very limited data but EEA appears to have developed effective data collection method. EEA needs to conduct periodic sample surveys (which might not necessarily be representative of the country) but indicative enough to get information on some of the key parameters.

- Efficient lighting: annual data on number of imported CFL (or LED) lamps is not available particularly for the period 2011 to 2020. This limitation however is being addressed by the customs office as it had started to provide specific data by type of lighting bulbs.

- Grid T&D losses: currently, losses are estimated based on comparison of gross electricity generation and the amount sold. However, since consumer meter reading and bill collection rate is less than 100% this method could possibly affect the accuracy of the analysis. It is recommended that EEU needs to install several meters at the main distribution gateways.

- Power factor correction: EEA is the mandated government organization to regulate energy efficiency in industries, while the EEU has the mandate to oversee the implementation PFC measures. We have found very limited (or no documented data) on projects or programs designed for assessing and implementing PFC measures in factories.

- Reppi MSW electric generation: detailed data is made available by EEP and the plant management – with key performance data documented for each months of operation. The data collected includes solid waste receive and incinerated, and power generated. This provides a good example for documentation of key performance information.

- The mini grid sub-program under ADELE: this project is implemented by the EEU. Monitoring of the ER and impacts of the sub-program entails getting annual sub-program progress data from the EEU including number of mini grids developed, kWh consumed by consumer category and installed PV and diesel capacity. It is also recommended to conduct periodic sample surveys of selected mini grid development sites to ascertain the assumption in the plan (ADELE).

- The standalone component of the ADELE program: this component is implemented by the EEU, MOWE, and MOA (for irrigation pumps). The MOWE Environment and Climate Change Directorate should work with these to collect key parameters annually.

At the organizational level there is need to strengthen the climate and environment unit under MOWE. First, the unit should be placed in the organization to serve all sub-sectors, it should be staffed adequately, and then its MRV capability should be built. A key concern is that the climate and environment unit which was until the recent re-organization of the ministry handled both the water and energy sub-sectors is now placed under the water supply and sanitation sub-sector which will limit its mandate to that sub-sector alone. It is recommended that the climate and environment unit be placed in its prior position to serve both sub-sectors.

This assessment has shown inadequacy in program documentation, including in some cases complete lack of documentation for policies and actions that are promoted by the government. Therefore, the climate and environment unit of MOWE needs to collect program and supporting documents, and then collate key performance indicators for all the policy and actions assessed; these should then be used to regularly monitor performance to achieving the targets. Where program documents are not available MOWE should support the relevant agencies prepare these documents. Existing program documents and documents that will be prepared in the future should provide sufficient information to show conditional and unconditional commitments for GHG mitigation (because the NDC specifies such conditional and unconditional commitments) to source the required financing from the internal and external sources.

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Annex 1 Datasheets for policies and actions

The title of the policy or action	National Program for Improved Household Biomass Cook Stoves Development & Promotion
Type of policy or action	Alternative Energy Development and Promotion Program
Description of specific interventions	Support over 7,000 new cook stoves entrepreneurs Produce and disseminate different types of improved biomass stoves (3,5 million Mirt; 1.3 million Gonziye; 3 million Closed stove, 1 million Opesi, and 60 thousand Daily cooker)
The status of the policy or action	Partly implemented
Date of implementation	January 2013
Date of completion (if applicable	January 2018
Implementing entity or entities	Ministry of Water and Energy
Objective(s) of the policy or action	Support the dissemination of 9 million improved cook stoves in Ethiopia up to January 2018 through building a sustainable and vibrant market for improved cook stoves and institutional capacity
Geographic coverage	Urban and rural areas in the 11 regions of Ethiopia
Primary sectors, subsectors, and emission source/sink categories targeted	Residential energy use, households using improved biomass cook stoves and displacing traditional biomass cook stoves
Greenhouse gases targeted (if applicable	CO2, CH4, N2O
Other related policies or actions	
Optional information	
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	A carbon savings amounting to 2.1 t/year per household A total abatement potential of 14 Mt of CO2e due to the effect of reduced degradation
Title of establishing legislation, regulations, or other founding documents	N/A
Monitoring, reporting, and verification procedures	Alternative Energy Technology Promotion and Dissemination Directorate of MOWE will be responsible for MRV; procedures for the MRV process are outlined in the program document.
Enforcement mechanisms	It will be a voluntary action
Reference to relevant guidance documents	CRGE, NAMA of Ethiopia
The broader context/ significance of the policy or action	The program is expected to contribute to realization of the CRGE vision of reducing emissions from deforestation and forest degradation and ensuring access to clean energy
Outline of non-GHG effects or co-benefits of the policy or action	Creating 5,000 private sector jobs largely in rural areas Reduce indoor air pollution, and improve health.
Other info / data	
Approach for estimation of Policy/ Action impact: GHG emission reduction	Emission reduction estimate with the TPDDTEC: Emission reduction = Emission reduction by the project device – Leakage emission Emission reduction by the project device = Fuel savings * technology days (no .of installed devices * no. operational days) * usage rate * fNRB * Emission factor * NCV TPDDTEC: Technologies and practices to displace decentralized thermal energy consumption (TPDDTEC), Gold Standard.

The title of the policy or action	Implementation of Minimum Energy Performance Standard (MEPS) for Electric Injera Mitad, June 2020.
Type of policy or action	Energy Efficiency and Conservation (National Energy Policy 2013 (Draft) National Energy Policy, Article 5.5, Draft, 2013 Ethiopian Standard Agency, ES ISO 04090:2016, 2016 Minimum Energy Performance Standard (MEPS) and Labelling for Clay plate resistor based electric Injera Mitad
Description of specific interventions	The objective is to improve energy efficiency and conservation to reduce GHG emissions. Introduced a standard for performance, safety and durability of electric injera mitad. Introduce labelling mechanism to indicate the level of performance/ energy efficiency and aware consumers about the products' energy efficiency levels. Producers are required to voluntarily comply to the standard. It is anticipated that mandatory compliance would come to effect in five years' time.
The status of the policy or action	On-going
Date of implementation	June 2020
Date of completion (if applicable)	2030
Implementing entity or entities	Ministry of Water and Energy, EEP, EEU,EEA
Objective(s) of the policy or action	Expand generation, transmission and distribution of grid electricity to both local customers (residential, commercial, industry sectors) and export of grid electricity to neighbouring countries.
Geographic coverage	All regions and urban and rural parts of Ethiopia
Primary sectors, subsectors, and emission source/sink categories targeted	The domestic and commercial sector are would be able to reduce their electricity consumption. Reduce growing demand for electricity and reduce need for additional power plant construction or avoid use of non-renewable thermal power plants backup sources
Greenhouse gases targeted (if applicable	None
Other related policies or actions	
Optional information	
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	No target set Not Available - estimation of GHG emissions reduction due to the action is not known Cumulative energy savings by 2030: 2,017 GWh Demand reduction in 2030: 363 MW Mitad peak power reduced from 3.8kW to 2.8kW 435 GWh saved per year (Energy Efficiency program, EEA, 2019),
Title of establishing legislation, regulations, or other founding documents	Minimum Energy Performance Standard (MEPS) and Labelling for Clay Plate Resistor Based Electric Injera Mitad, 2020 Electric Power Supply System and Machines - Technical and Performance Requirements For House Hold Single Plate Resistor Based Electric InjeraMitad - ES ISO 04090:2016
Monitoring, reporting, and verification procedures	Ethiopian Energy Authority is the mandated government organization to regulate MEPS for electric injera mitad performance level. It is responsible to monitory, verify and provide appropriate labelling.

	Ethiopian Standard Agency is responsible for developing the verification procedure to determine the performance of electric injera mitads.
Enforcement mechanisms	Initially, compliance to the standard and MEPS will be on a voluntary basis. However, Ethiopian Energy Authority will make it mandatory after five year when a good number of local producers built their technical capacities and consumers' awareness about the labelling is widely reached.
Reference to relevant guidance documents	National Energy Policy 2013 The standard for locally manufactured electric mitads - ES ISO 04090:2016 MEPS and Labelling of Electric Injera Mitad, 2020
The broader context/ significance of the policy or action	Green economy will unlock economic growth, create employment, and provide additional socio-economic benefits. Households would benefit from higher energy efficiency – especially from more efficient cooking/baking and transport – with savings worth up to 10% of household income. This would lead to an increase in domestic savings and hence result in an enhanced investment capacity.
Outline of non-GHG effects or co-benefits of the policy or action	Planned scaling up of domestic power production capacity, combined with a successful implementation of energy efficiency measures, offers opportunities for electric power exports. These exports could reduce neighboring countries' emissions with clean electric power generated in Ethiopia.
Other info / data	
Approach for estimation of Policy/ Action impact: GHG emission reduction	Emission reduction estimate: Emission reduction: 1) The avoided grid emission due to reduction in electricity consumption in the domestic and commercial sectors, and the number of high efficiency electric injera mitads.

Type of policy or action	Lighting energy efficiency improvement
Description of specific interventions	Replacement of inefficient lighting bulbs (incident, halogen lamps.) with CFL and LED lamps
The status of the policy or action	Implemented as projects (continuous)
Date of implementation	Effective 2021[42]
Date of completion (if applicable	No final date is set
Implementing entity or entities	EEU, EEA, MOWE
Objective(s) of the policy or action	Reduce grid electricity energy demand used for lighting, as well as peak power demand .
Geographic coverage	National
Primary sectors, subsectors, and emission source/sink categories targeted	Residential and commercial sectors 8rrenewwable electricity generation off-grid displacing fuel based lighting
Greenhouse gases targeted (if applicable	CO_2, CH_4, N_2O
Other related policies or actions insulation	Import tax reduction on efficient lighting appliances and , solar PV electricity generating units
Optional information	Explanation
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	Cumulative energy savings by 2030: 5,867 GWh Demand reduction in 2030:309 MW (specified in document EEA , issued/singed 23 May 2019, below) 98% of new lighting with LEDs by 2030.
Title of establishing legislation, regulations, or other founding documents	"Energy efficiency program and activity plan, directive 2006/2011, EEA (issued/singed 23 May 2019).
Monitoring, reporting, and verification procedures	The document "Energy efficiency program and activity plan, directive 2006/2011, EEA (issued/singed 23 May 2019). Provides some information on data collection, monitoring and verification needs and processes to be implemented.
Enforcement mechanisms	Importation of incandescent and halogen lamps is banned, 2011.
Reference to relevant guidance documents	The document "Energy efficiency program and activity plan, directive 006/2011, EEA (issued/singed 23 May 2019)., EEA website
The broader context/ significance of the policy or action	Reduced load demand on the national power grid – increased power supply reliability, reduced power shading
Outline of non-GHG effects or co-benefits of the policy or action	Private cost saving (reduced monthly electric bill)
Other info / data	
Approach for estimation of Policy/ Action impact: GHG emission reduction	AM0113, Large-scale Methodology, Distribution of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps to households, and b) Standard for Sampling and Surveys for CDM Project Activities and Programme of Activities(Annex 4).

[42]Effective from January 6, 2011 Inefficient lamps (conventional incandescent bulbs and conventional halogen lamps) are banned. EEA web site.

Title of the policy or action	Bio-ethanol use as a household fuel to replace biomass and fossil fuels
Type of policy or action	Access to clean energy program
Description of specific interventions	Ethiopian government developed a sustainable bioenergy policy as an important component of the National Development Program Strategy. Legal provisions for distribution and use of bio-ethanol are made to replace fossil and biomass fuels use for cooking and support climate change mitigation activities. Toward this, ethanol cookstoves were disseminated in Addis Ababa city and refugee camps.
The status of the policy or action	Implemented
Date of implementation	2009
Date of completion (if applicable	
Implementing entity or entities	Ministry of Water and Energy, private companies and NGO
Objective(s) of the policy or action	Provide access to clean cooking energy and reduce CO2 emissions by replacing fossil fuels and biomass fuels use for cooking with clean and renewable bio-ethanol fuel.
Geographic coverage	Addis Ababa city and refugee camps
Primary sectors, subsectors, and emission source/sink categories targeted	Household/cooking energy
Greenhouse gases targeted (if applicable)	CO2
Other related policies or actions	
Optional information	
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	Emissions reduction of up to 6 t/year per household
Title of establishing legislation, regulations, or other founding documents	N/A
Monitoring, reporting, and verification procedures	Ministry of Water and Energy is responsible for MRV
Enforcement mechanisms	Voluntary action
Reference to relevant guidance documents	CRGE, NAMA of Ethiopia
The broader context/ significance of the policy or action	The project is expected to contribute to realization of the CRGE vision of reducing emissions and ensuring access to clean energy
Outline of non-GHG effects or co-benefits of the policy or action	Provision of access to clean household energy and reduce an economic and health burden on citizens, mainly women and children
Other info / data	
Approach for estimation of Policy/ Action impact: **GHG emission reduction**	Emission reduction estimation for ethanol cookstove displacing biomass fuel is done by CDM's methodology, Switch from non-renewable biomass for thermal application by the user (AMS-I.E). Emission reduction = Quantity of biomass fuel substituted* fraction of non-renewable biomass * Calorific value of the biomass fuel * Emission factor – Project emissions – Leakage emission Emission reduction estimation for ethanol cookstove displacing fossil fuel (kerosene) is done by CDM's methodology for Biogas/biomass thermal applications for households/small users (AMS-I.I). Emission reduction = Quantity of renewable fuel used * Ratio of efficiencies * Calorific value of the biomass fuel * Emission factor – Project emissions – Leakage emission

<table>
<tr><td>The title of the policy or action</td><td>Grid Transmission and Distribution Loss reduction
Under the Grid Management Support Program System Integration Study, (GMSP-SIS). Nexant, Inc. Jan 2019.</td></tr>
<tr><td>Type of policy or action</td><td>National grid electricity generation and expansion plan</td></tr>
<tr><td>Description of specific interventions</td><td>The objectives of System Integration Study (SIS) are to examine the state of the current grid and planned additions and comprehensively evaluate the technical and operational aspects needed to ensure that the future power system is planned and developed to be able to operate harmoniously, reliably and efficiently (GMSP-SIS) .
In the study - each year T&D losses reflect individual distribution and transmission loss reduction targets aimed to reach the defined end year target set by GOE.
<table><tr><td>Year</td><td>Distribution Loss</td><td>Transmission Loss</td></tr><tr><td>2017 (historical data)</td><td>16.2%</td><td>5.4%</td></tr><tr><td>2020 (estimates)</td><td>14.6%</td><td>5.0%</td></tr><tr><td>2030 (estimates)</td><td>9.0%</td><td>3.5%</td></tr></table></td></tr>
<tr><td>The status of the policy or action</td><td>Ongoing</td></tr>
<tr><td>Date of implementation</td><td>2020</td></tr>
<tr><td>Date of completion (if applicable)</td><td>January 2030</td></tr>
<tr><td>Implementing entity or entities</td><td>Ministry of Water and Energy, EEP, EEU,EEA</td></tr>
<tr><td>Objective(s) of the policy or action</td><td>Expand generation, transmission and distribution of grid electricity to both local customers (residential, commercial, industry sectors) and export of grid electricity to neighbouring countries.</td></tr>
<tr><td>Geographic coverage</td><td>All regions and urban and rural parts of Ethiopia</td></tr>
<tr><td>Primary sectors, subsectors, and emission source/sink categories targeted</td><td>The plan does not directly address GHG emission reduction either in general or though any specific actions
Partly because all power development expansion plans are based on either hydro or other renewable energy sources</td></tr>
<tr><td>Greenhouse gases targeted (if applicable</td><td>None</td></tr>
<tr><td>Other related policies or actions</td><td></td></tr>
<tr><td>Optional information</td><td></td></tr>
<tr><td>Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).</td><td>No target set</td></tr>
<tr><td>Title of establishing legislation, regulations, or other founding documents</td><td>Ethiopian Power System Expansion Master Plan Study. 2014. Parsons Brinckerhoff for the Ethiopian Electric Power.</td></tr>
<tr><td>Monitoring, reporting, and verification procedures</td><td>The document, GMSP-SIS, provides no specific MRV procedures for GHG emissions assessment and reporting</td></tr>
<tr><td>Enforcement mechanisms</td><td>NA</td></tr>
<tr><td>Reference to relevant guidance documents</td><td>GTP II</td></tr>
<tr><td>The broader context/ significance of the policy or action</td><td>The program is/was expected to contribute to realization of GTP II.</td></tr>
</table>

Outline of non-GHG effects or co-benefits of the policy or action	A significant percentage of Ethiopia's rural and urban population will be provided with electricity - a clean lighting and cooking /baking fuel – that reduces GHG emissions health effects associated with use of (non-) renewable fuelwood and other biomass fuels.
Other info / data	
Approach for estimation of Policy/ Action impact: GHG emission reduction	Emission reduction estimate: Emission reduction: 1) The avoided grid emission due to transmission and distribution lossreduction Or, where applicable (1) plus emission reduction by the project will be measured by the magnitude of fossil fuel based electricity generation avoided.

The title of the policy or action	Power Factor Correction Measures
Type of policy or action	Grid electricity - demand side management
Description of specific interventions	Apparently EEU with support from the then METEC (now Ethio Engineering Group) was to install capacitors in selected Industries with the objective of improving PF and hence – reduce reactive power demand from the gird (reduced load on the grid), as well as reduce cost of electricity for the Industry (due to pick power demand penalty).
The status of the policy or action	Planned but not implemented except for some piloting
Date of implementation	NA
Date of completion (if applicable)	NA (Expected to be reinitiated and continue for some years)
Implementing entity or entities	EEP Corporation, EEU and Industries
Objective(s) of the policy or action	Reduce load on the grid, reduce pick power demand penalty, release grid power and energy to expand grid electricity coverage (supply new customers).
Geographic coverage	National
Primary sectors, subsectors, and emission source/sink categories targeted	Industries – high voltage and medium voltage
Greenhouse gases targeted (if applicable)	CH4
Other related policies or actions	Upgrading of T&D lines for reduction of T&D losses
Optional information	
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	
Title of establishing legislation, regulations, or other founding documents	
Monitoring, reporting, and verification procedures	
Enforcement mechanisms	Voluntary action
Reference to relevant guidance documents	
The broader context/ significance of the policy or action	
Outline of non-GHG effects or co-benefits of the policy or action	Reduce grid technical losses, reactive power demand, and through loss reduction expand grid electricity services
Other info / data	
Approach for estimation of Policy/ Action impact: GHG emission reduction	GHG reduction from installation of capacitors to correct/improve powered factor involves estimation of energy losses from cables and transformers before installation of capacitors. The GHG reduction is then determined by multiplying the energy loss reduction by the average grid EF.

The title of the policy or action	Grid connected waste to energy projects in Addis Ababa (and other cities)
Type of policy or action	Waste-to-Energy projects
Description of specific interventions	A Waste-to-Energy project is part of Ethiopia's broader strategy which intends to address pollution and expand renewable energy sources in the mix of Ethiopian electricity grid. The first of its kind, Reppi Waste-to-Energy project, located at Koshe dump site two 25 MW power plants are installed and conne4cted to the grid, The plants have started operation in 2019, have a capacity to incinerate 1,400 tons of waste every day, roughly 80 % of Addis Ababa city's rubbish/.
The status of the policy or action	Implemented
Date of implementation	2014
Date of completion (if applicable)	2019
Implementing entity or entities	Ethiopian Electric Power Corporation
Objective(s) of the policy or action	Avoid methane emissions from anaerobic decay of organic waste using alternative waste treatment processes, incineration of the waste, and generate electricity to feed into the national grid.
Geographic coverage	Addis Ababa city
Primary sectors, subsectors, and emission source/sink categories targeted	Waste dump sites and landfills in cities
Greenhouse gases targeted (if applicable)	CH4
Other related policies or actions	
Optional information	
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	Waste treatment of 1,400 tons/day and generation of 25 to 50 MW electricity
Title of establishing legislation, regulations, or other founding documents	N/A
Monitoring, reporting, and verification procedures	Ethiopian Electric Power Corporation is responsible for MRV
Enforcement mechanisms	Voluntary action
Reference to relevant guidance documents	CDM waste to energy (solid waste management)
The broader context/ significance of the policy or action	The project is expected to contribute to realization of the CRGE vision of reducing emissions and ensuring access to clean energy
Outline of non-GHG effects or co-benefits of the policy or action	Generation of 25 to 50 MW electricity to the grid
Other info / data	

Approach for estimation of Policy/ Action impact: GHG emission reduction	Emission reduction estimate with the methodology for alternative waste treatment processes (ACM0022) and Emissions from solid waste disposal sites (Tool04): Emission reduction = Baseline emissions – Project emissions – Leakage emission Baseline methane emissions = Model correction factor * (1-Fraction of methane captured at the SWDS and flared, combusted or used) * Global Warming Potential of methane *(1 - Oxidation factor) *16/12 Fraction of methane in the SWDS gas * Fraction of degradable organic carbon in the waste * Methane correction factor * ΣxΣj(Amount of solid waste type j disposed or prevented from disposal in the SWDS in the year x * Fraction of degradable organic carbon in the waste type *e -kj×(y-x) × (1-e-kj)

The title of the policy or action	Introduction of mini grids in off-grid rural areas ER through substitution of kerosene used for lighting by residential, commercial and social/pubic consumers ER through substitution of diesel used for grain milling and other agro-industrial appliances ER through substitution of diesel electric generators from commercial service consumers
Type of policy or action[43]	Infrastructure program (for the public component through the EEU); Regulations and standards (for the non-public, private and cooperative led, component of the program)
Description of specific interventions	Renewable energy powered mini grids (more specifically solar PV powered) were proposed as one option of electrification for off-grid communities in the National Electrification Program 2.0 (2019). 1,160 sites within 2.5-25km from existing grid (NEP 2.0, p. 73) 285 sites beyond 25km (deep rural, NEP. 2.0, p. 78); 151 sites are beyond 100km, 134 sites are within 25-100km. Each of these deep rural sites is estimated to have about 700 to 1000 connections (with mean of about 730 connections; p. 79) Total number of beneficiaries (this is persons, not households) in deep rural areas is estimated between 0.7 to 1 million (NEP 2.0, p. 75) The focus of the mini grid component of the program is to reach the remote sites first, then move inwards. Public/government financing will be the main model for deep rural areas; private and cooperative models will be promoted for those within 2.5 – 25km. Total investment for the mini grid component is USSD 300 million (for both public and non-public; NEP 2.0, p. xxxi) The mini grid component of the ADELE program will benefit 240,000 households (1.2 million people), 11,500 businesses (commercial, agricultural and industrial users) (PAD, ADELE, p. 27).[44]
The status of the policy or action	Under implementation 2018 – 2030 (NEP 2.0) 2021 – 2027 (ADELE, 2021)
Date of implementation	2018 – 2030 Mini grid infrastructure is designed for 20 year lifetime The NEP was first issued in 2017

[43]Type of policy instruments (World Resources Institute (WRI), 2014. Climate Policy Implementation Tracking Framework):

1. Regulations and standards
2. Taxes and charges
3. Subsidies and incentives
4. Tradable permits
5. Voluntary agreements or measures
6. Information instruments
7. RD&D policies
8. Public procurement policies
9. Infrastructure programs
10. Financing and investment

- RD&D policies are policies aimed at supporting technological advancement, through direct government funding or investment or facilitation of investment, in technology RD and deployment activities
- Regulations and standards – regulations that specify abatement technologies (technology standard) or minimum requirements for energy consumption, pollution output, or other activities (performance standard)

[44]USD 270 million for 251,500 users (equates to USD 1,074/connection).

	The NEP update, NEP 2.0, was issued in 2019 The ADELE was issued in 2021 The policy has been in implementation since 2019 (with the public sector investment in solar powered mini grids by the EEU)
Date of completion (if applicable	2030
Implementing entity or entities	EEU Private enterprises, energy service cooperatives
Objective(s) of the policy or action	Electrification of off grid rural areas through solar powered mini grids Residential, public, commercial, industrial and agricultural consumers are expected to benefit from the project
Geographic coverage	National
Primary sectors, subsectors, and emission source/sink categories targeted	Sector: energy Beneficiaries: rural/off grid, residential, public, commercial, industrial, agricultural Emission sources/sinks: kerosene lighting (residential and other), diesel consumed in diesel engine mills, diesel consumed in diesel generators used by commercial and other consumers
Greenhouse gases targeted (if applicable	CO2
Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	2.96 Mt CO2e (over 20 years)[45][this is for all 5 components] Other target (number of mini grids): 1,445 mini grids (1,160 mini grids within 2.5-25km from the existing grid, 285 mini grids beyond 25km from existing grid) Other target (number of connections/user entities): 210,000 households for deep rural areas (210,000 households in 285 mini grids or 730 household connections per mini grid) (NEP 2.0, p. 79) Other target (number of connections): 240,000 households (1.2 million people), 11,500 businesses (commercial, agricultural and industrial users) (PAD, ADELE, p. 27) Other target (renewable energy generation capacity of mini grids): 35MW Other target (number of greenfield mini grids supported (EEU led and private sector led): 255 (PAD, ADELE, p. 74) Number of hybridized mini grids: 10 (PAD, ADELE, p. 74) Solar panel capacity: 289kWp (PAD, ADELE, p. 74); capacity factor solar panel: 18.5% Annual solar power generation: 458,288 kWh (PAD, ADELE, p. 74) [based on 4.44h/d of sunlight or 1620 annual peak hours, as calculated from 18.5% capacity factor, i.e. 18.5% of 8760 hours)

[45]PAD, ADELE, p. 50). 138. Climate change.The investments under the proposed project will rely on clean energy sources, including the grid investments under component 1 to enhance reliability of grid electricity (largely hydropower), as well as components 2, 3, and 4, which will be fully powered by distributed solar PV generation in the case of components 3 and 4, and largely solar based in the case of component 2, with a small percentage, less than 1 percent of investments used for diesel generation to improve the availability of power. GHG accounting has also been undertaken for this project. The project will result in significant GHG emission avoidance by replacing household usage of candles, kerosene, and charcoal fuels as well as diesel consumption in public facilities and productive uses. As outlined previously, most of the activities will not directly emit GHG due to the use of solar technologies. A total of 2.96 million tCO2e is avoided throughout the project's lifetime (assumed 20 years).

PAD, ADELE, p. 56. 156. Mitigation. Overall, the project has strong contribution to climate change mitigation. The grid investment under component 1 will carry 100 percent renewable energy-based (largely hydropower) grid electricity in Ethiopia. Solar home and institutional systems under components 3 and 4 are fully powered by distributed solar PV generation. Mini-grid investments under component 2 are expected to be largely solar based, but approximately US$3 million out of the component is expected to be used for diesel generation to hybridize mini-grid systems in combination with solar PV to improve the availability of power. Technical assistance under component 5 will support the delivery of other components.

	Diesel generation capacity: 50kVA; capacity factor for diesel: 9.3% Annual diesel power generation: 40,119kWh CO2 emission per kWh consumed from mini grid: 0.052 kgCO2e/kWh Diesel generation as percentage of total generation: 8% Single phase customers per mini grid: 370 Average yearly power consumption single phase customer: 48kWh/y Annual increase in power consumption for single phase customers: 1% WTP of single phase customers: 72 USD/y Annual increase in WTB of single phase customers: 6.8% Three phase connections per mini grid: 56 Three phase connection average monthly power consumption: 6,056kWh
Other related policies or actions	The Mini Grid Directive (EEA, 2020)
Approach for estimation of Policy/ Action impact: GHG emission reduction	AMS I.L. Electrification of rural communities using renewable energy (applicable for renewable energy powered mini grids and solar home systems; other condition is that 75% of the consumes must be residential) AMS I.L. Validation parameters are number of facilities served by the renewable electricity by the project (households, SMMEs, public) AMS I.L. Monitored parameters are net amount of renewable electricity delivered to all end use facilities, and installed capacity of renewable electricity generating facility Emission by households: 0.374tCO2/y/household (WB factor) * No. of household connections (emission from kerosene lamps by households) Emission by diesel grain mills: annual diesel fuel consumption per grain mill * emission factor per liter of diesel for engines * number of grain mills replaced (5.1kg diesel/h for the 20kW/27HP Andoria engine at rated capacity) Emission by commercial entities using diesel generating sets: annual diesel fuel consumer per diesel generator * emission factor per liter (kg) of diesel * number of diesel generators replaced Emission factor for diesel engine: 74 tCO2/TJ * 45.5e-6TJ/kg * x kg/y diesel
Optional information	
Title of establishing legislation, regulations, or other founding documents	FDRE, 2019. The National Electrification Program 2.0 World Bank, 2021 (8 March). Project Appraisal Document on a Proposed Credit in the Amount of SDR 347.1 million (US$500 million equivalent) to the FDRE for the Access to Distributed Electricity and Lighting in Ethiopia (ADELE) Project
Monitoring, reporting, and verification procedures	ADELE targets for mini grids EEU five year and annual plans for mini grids
Enforcement mechanisms	Monitoring as above
Reference to relevant guidance documents	NEP 2.0 ADELE EEU, DOE five year and annual plans (if these are available)
The broader context/ significance of the policy or action	Electricity access; productive use of energy, raise productivity, incomes, jobs
Outline of non-GHG effects or co-benefits of the policy or action	Electricity access (population/households, SMEs, social institutions gaining access)
Other info / data	

The title of the policy or action	Promotion of standalone PV systems (water pumping, home systems, street lighting, water heating, refrigeration, water purification) [9]
Type of policy or action	Regulations and standards Taxes and charges Information instruments Financing and investment
Description of specific interventions	This contains a diverse set of interventions based on standalone solar systems. The interventions that have (and will have) significant impact are solar home systems (including solar lanterns) and solar water pumps (including irrigation pumps). These two are addressed under this intervention (or policy). The solar lighting (SHS and SL) interventions have been strongly promoted since 2011 (World Bank/IFC support, government support). Regulations related to tax reduction and exemption for Lighting Global approved solar systems have been one of the major drivers Another driver has been the WB/IFC supported financing in hard currency for importer/suppliers (and also consumer finance through MFIs) Solar water pumping for potable water supply has been promoted by the government (for example, through the AfDB supported program) and by international development organizations (including UN organizations and others) Solar irrigation is a new area of interest for the government and donors and there are now projects promoting solar irrigation for smallholder farmers by the government (e.g. through the ATA) and by (e.g. GIZ, SNV)
The status of the policy or action	The solar lighting program (for SHS and SL) started in 2011 (the WB/IFC supported program) The program for solar water pumping for potable water supply since 2013? Studies and pilots for solar powered irrigation started in 2018 (the ATA project) Are these part of the CRGE or the NDC?
Date of implementation	Solar lighting: 2011 – 2030 Solar potable water pumping: 2013 –XXXX Solar irrigation pumping: 2018 -- XXXX
Date of completion (if applicable	Not applicable
Implementing entity or entities	Ministry of Water and Energy (MOWE)
Objective(s) of the policy or action	Access to energy/electricity (electrification) – solar lighting Sustainable operation of potable water supply systems (traditionally such systems are powered by diesel engines that have high requirements for operation and maintenance; fuel costs are very high, maintenance requirements are frequent and expensive) For solar irrigation systems the objective is to increase productivity of smallholder farmers through small scale irrigation from shallow wells and streams
Geographic coverage	National
Primary sectors, subsectors, and emission source/sink categories targeted	Energy and water Rural and off-grid Emission sources are kerosene lamps for solar lighting, diesel engines for potable water pumping and for smallholder irrigation Solar (PV) will remove the need for kerosene for lighting; PV systems will replace diesel engines used for water pumping (potable and irrigation)
Greenhouse gases targeted (if applicable	CO_2 (from kerosene, diesel)

Intended level of mitigation to be achieved and/or target level of other indicators (if applicable).	The ADELE program envisions reduction 2.96 $MtCO_2e$ for all components under the program. The share of standalone PV systems may be estimated based on WB estimates for individual interventions: ER from households [0.374 tCO_2/y] ER from displacement of diesel self-generation [0.65 kg CO_2e/kWh]
Other related policies or actions	
Approach for estimation of Policy/ Action impact: GHG emission reduction	AMS I.L. Electrification of rural communities using renewable energy (applicable for renewable energy powered mini grids and solar home systems; other condition is that 75% of the consumes must be residential) Check if AMS I.L. can be used for replacement of diesel mills with electricity from a renewable mini grid Emission and emission reduction to be calculated as follows: SHS: number of SHS distributed * 0.374tCO_2/y PV water pumps: number of diesel pumps * liter/y/pump (mean for population/sample) * tCO_2/liter of diesel The number of SHS/SL units distributed annually will be collected from past distribution statistics (e.g. GOGLA statistics for SHS/SL or import data from ERCA). SHS/SL distribution in the future will be used to estimate ER ex ante (for the ADELE program, for example) The number of PV pumps distributed in the past may be available from the relevant Directorate at MOWE
Optional information	
Title of establishing legislation, regulations, or other founding documents	These policies are contained in national strategies and programs: NEP 2.0 ADELE
Monitoring, reporting, and verification procedures	Monitoring is carried out for program impacts, outcomes and outputs These indicators are contained in the program documents
Enforcement mechanisms	Annual plans of the relevant government agencies (the Department of Electrification or DOE under MOWIE for SHS/SL Annual plans of the water sub-sector for potable water supply and irrigation with solar PV
Reference to relevant guidance documents	ADELE Five year strategic plans, and annual implementation plans of the relevant government agencies
The broader context/ significance of the policy or action	Electricity access (0.75 million households by 2025?) Sustainable potable water supply for rural areas (target?) Raising smallholder productivity, incomes, nutrition through irrigation
Outline of non-GHG effects or co-benefits of the policy or action	(To be extracted from the relevant documents) Electricity access (for residential and non-residential consumers) Reduction of air pollutants from kerosene lamps Productivity gains and higher incomes through smallholder irrigated farming Sustainable operation of potable water supply (many diesel powered potable water supply units cease operation because users cannot afford the cost of fuel and maintenance of the diesel engines).
Other info / data	

Annex 2 Data used in the policy analyses

<u>Policy/action: Improved cookstoves (ICS)</u>

Table A2.1 Number of Stoves disseminated in the period 2010 - 2020

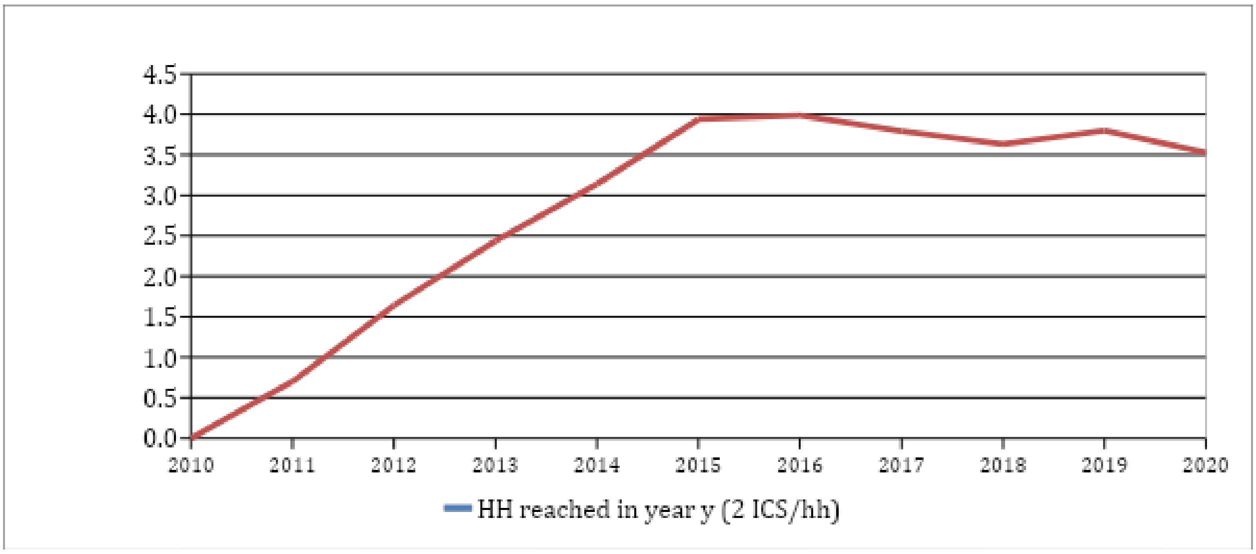
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total (2010 - 2020)
Oromia	529,744	613,245	1,491,263	892,861	886,082	685,259	707,139	791,221	682,030	692,535	686,655	8,658,034
Amhara	598,747	419,831	80,769	93,583	104,879	255,256	205,736	314,769	248,923	516,160	129,805	2,968,458
Southern	106,366	124,616	122,374	135,457	80,485	133,439	124,401	139,027	151,298	260,901	139,481	1,517,845
Tigray	16,488	34,420		82,605	103,789	140,517	130,413	96,475	77,074	162,423		844,204
Benshangul	5,685	2,895	2,971	4,170	2,809	7,993	10,615	17,948	17,995	24,378	14,765	112,224
Afar	-	-				1,523	3,500	3,016		4,500	7,001	19,540
Somali	113	35				1,500	1,500	2,500	2,000	2,982	2,081	12,711
Gambella									3,800	1,185		6,049
Dire Dawa	800	4,654				3,200	13,741	7,380	871			31,184
Harari	-	-				4,682		1,095	785	1,154	3,025	11,341
Addis Ababa	60,885	199,147	182,498	383,183	223,470	373,149	296,500	119,518	84,009	71,240	83,734	2,077,333
Total (annual)	1,318,828	1,398,843	1,879,875	1,591,859	1,402,052	1,606,942	1,494,145	1,493,589	1,268,785	1,737,458	1,066,547	16,258,923
Cumulative		1,398,843	3,278,718	4,870,577	6,272,629	7,879,571	9,373,716	10,867,305	12,136,090	13,873,548	4,940,095	

Source: MOWE 2022

Table A2.2 Net number of households adopting ICS ('000): replacement ICS and number of new households adopting ICS

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Replacement stoves yea	-	-	-	-	-	1,399	1,880	1,592	1,402	1,607
Total replacement ICS	-	-	-			1,399	1,880	1,592	1,402	1,607
New HOUSEHOLDS reached in ea	1,399	1,880	1,592	1,402	1,607	1,494	1,494	1,269	1,737	1,067
HOUSEHOLDS reached in year y **	1,399	1,880	1,592	1,402	1,607	95	(386)	(323)	335	(540)
Cumulative HOUSEHOLDS reached *	-	3,279	4,871	6,273	7,880	7,975	7,589	7,266	7,601	7,061
HOUSEHOLDS reached in year y **	699	1,639	2,435	3,136	3,940	3,987	3,794	3,633	3,800	3,530

*(one ICS /households), ** (2 ICS/households



Policy/action: Efficient lighting

Table A2.3 Residential and small businesses / commercial units

Power rating and number of CFL distributed/installed (Watt)	Year - implementation period 2009	2010	2011	2012
11	192,500		2,802,000	2,918,129
15	154,000		1,672,000	1,779,430
20	3,500		38,000	40,442
Total Annual	350,000	-	4,512,000	4,738,000
Cumulative				9,600,000
Street lighting				15,000

Source: EAREP, 2013

Table A2.4 Bulbs distributed, saving per bulb and operating hours

	Incandescent Bulbs replaced baseline lamps	Type of CFL bul distribut Project/acti lam	Saving per bulb (watt)	Operating hrs/day	Operating hrs/yr
Residential	40	11	29	3.5	1,278
Residential	60	15	45	3.5	1,278
Commercial	100	20	80	10	3,650

Policy/action: TD loss reduction

Table A2.5 National Grid electricity power generation, electric energy delivered, and system losses (2001 to 2020)

	Peak demand (sent out)	Load factor	Gross generation	Auxiliary + own consumption	Generation (sent out)	Exports	Total national energy sales	Losses	Losses
Year	MW	%	GWh	GWh	GWh	GWh	GWh	GWh	% of incoming energy
2001	352	64%	1,976	3	1,973	-	1,388	585	30%
2002	391	64%	2,192	3	2,189	-	1,597	592	27%
2003	405	63%	2,249	3	2,246	-	1,678	568	25%
2004	454	63%	2,527	5	2,522	-	1,817	705	28%
2005	521	62%	2,816	5	2,811	-	2,033	778	28%
2006	587	61%	3,155	6	3,149	-	2,316	833	26%
2007	623	66%	3,625	7	3,619	-	2,558	1,061	29%
2008	675	66%	3,884	7	3,877	-	2,795	1,082	28%
2009	673	69%	4,064	7	4,057	-	2,906	1,151	28%
2010	767	65%	4,375	6	4,369	-	3,247	1,122	26%
2011	914	68%	5,493	15	5,478	17	4,081	1,380	25.0%
2012	1,125	68%	6,771	34	6,737	332	4,659	1,746	26.0%
2013	1,437	64%	8,136	42	8,093	563	5,537	1,994	25.0%
2014	1,643	63%	9,148	49	9,100	730	6,343	2,027	22.0%
2015	1,965	56%	9,770	54	9,716	762	6,862	2,092	22.0%
2016	2,204	59%	11,478	61	11,418	564	8,213	2,641	23.0%
2017	2,491	60%	13,185	70	13,116	1,305	9,445	2,365	18.0%
2018	2,588	62%	14,211	64	14,147	1,345	10,238	2,564	18.0%
2019	2,773	58%	14,115	69	14,046	844	10,558	2,644	19.0%
2020	2,634	67%	15,528	78	15,450	1,488	11,166	2,796	18.0%

Source. Ethiopian Electric Utility (EEU) 2022.

Table A2.6 Total distribution base case forecast for 2021 to 2030 (GWh)

Year	Domestic	Commercial	Street lighting	Low voltage Industrial	Distribution loss	Total including losses	Grid Distribution losses (%)
2021	5,294	3,209	49	4,092	1,770	14,414	12.3%
2022	5,880	3,571	52	4,452	1,876	15,831	11.9%
2023	6,531	3,974	56	4,806	1,981	17,348	11.4%
2024	7,255	4,422	61	5,254	2,096	19,088	11.0%
2025	8,059	4,922	65	5,782	2,217	21,045	10.5%
2026	8,884	5,442	70	6,310	2,324	23,030	10.1%
2027	9,776	6,003	75	6,858	2,422	25,134	9.6%
2028	10,751	6,617	80	7,437	2,516	27,401	9.2%
2029	11,823	7,292	86	8,057	2,605	29,863	8.7%
2030	13,001	8,035	92	8,723	2,687	32,538	8.3%

Source: EEA. Power Africa GMSP System Integration Studies technical review presentation, 2018

Policy/action: Bio-ethanol

- Cooking

Table A2.7 Ethanol Stoves distributed and volume of ethanol supplied to refugee camps (substituting biomass)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Stoves operational	-	3,869	4,211	4,211	6,821	8,815	9,465	9,465	-	-	46,857
Fuel ethanol utilized (lit)	-	598,782	526,240	150,000	873,488	686,372	527,587	469,508	-	-	3,831,977

Source: MOWE and Gaia Clean Energy 2022

Table A2.8 Ethanol Stoves distributed and volume of ethanol supplied to Addis Ababa Households (substituting Kerosene)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Stoves operational	-	2,200	2,700	3,315	3,315	3,315	3,315	3,315	-	-	21,475
Fuel ethanol utilized (lit)	-	45,000	60,000	71,000	77,000	86,000	97,000	104,000	-	-	540,000

Source: MOWE and Gaia Clean Energy 2022

- Transport

Table A2.9 Data on imports of gasoline national level, original data in (MT)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
MT	143,878.8	150,619.1	186,517.5	211,598.0	237,773.0	307,817.0	366,659.0	441,542.0	506,739.0	652,573.0
m3	197,094.2	206,327.5	255,503.4	289,860.3	325,716.4	421,667.1	502,272.6	604,852.1	694,163.0	893,935.6

Source: MOWE and Gaia Clean Energy 2022

Table A2.10 Projection of gasoline consumption national level

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
MT	698,253	747,131	799,430	855,390	915,267	979,336	1,047,890	1,121,242	1,199,729	1,283,710
m3	956,511	1,023,467	1,095,110	1,171,767	1,253,791	1,341,556	1,435,465	1,535,948	1,643,464	1,758,507

Assumed growth rate: 7%
Density of gasoline: 0.73 kg/lit

Policy/action: Grid connected waste to energy projects

Table A2.11 Energy generated quantity of SW incinerated and GHG emission reduction: Reppi SW landfill site

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total
Energy generated (000 MWh)	127	140	154	169	186	204	225	247	272	299	2,022
Quantity of SW incinerated (k ton)	300	330	363	399	439	483	531	585	643	707	4,781

GHG emissions reduced (kt CO2e)	20	22	25	27	30	33	36	40	44	48	326

Source: EEP 2002

Table A2.12 Data and assumption: Power generation capacity and expected and estimated MSW consumption per MWh generated

1. Given data and Assumptions

Power Generation Units		Two units	One unit
Units	MW	50	25
Operating hrs	hrs/y	6570	6570
@ plant factor	75%		
Annual energy generation	MWh/y	328,500	164,250
Nominal SW consumption	ton/day - design value	1,400	700
Annual SW consumption	ton/y	383,250	191,625
SW consumption / MWh (theoretical)	ton/MWh	1.17	1.17

2. Actual operational data only one unit operating at a time due to boiler capacity limits

SW consumption / MWh (2019 data)	ton/MWh	2.53	2.53
SW consumption / MWh (2020 data)	ton/MWh	2.20	2.20
Average	ton/MWh	2.36	2.36
Annual SW consumption	ton/y	776,781	388,391

Annex 3 Sample household energy survey methods and results

As part of the greenhouse gas emission reduction assessment for the energy sector a small (non-representative) sample survey of households was carried out to collect data that will complement data from official sources and other reports. This primary data collection exercise was made primarily as a technical capacity measure to illustrate how such data may be collected by MOWE where data from other sources are either not available or adequate. This section provides an overview of the methods and tools used to carry out the sample survey.

Data for impact assessment of GHG mitigation policies may be obtained from published official sources, data from sector agencies (that may be gathered for program development, implementation and monitoring), and from primary surveys.

a. Published reports from official sources: these include, for example, the Welfare Monitoring Survey (WMS) and the Household Income Consumption and Expenditure Survey (HICES) from the CSA, and the Multi-Tier Framework (MTF) survey by the World Bank and CSA. These provide user adoption of renewable energy (RE) and energy efficient (EE) technologies including biogas stoves, electric stoves, electric Injera mitad, and solar lighting devices. Another source is import statistics from the Ethiopian Revenue and Customs Authority (ERCA) where import data for electric appliances, solar energy products is available.

b. Data collected for development, management and operation of actions from sector agencies: examples include data on power generation from the waste-to-energy facility of the EEP, and transmission and distribution loss records from the EEP and EEU. Sales data from manufacturers and distributors, such as improved stove suppliers for solar home system distributors, is another source of data of this type.

c. Primary data collection where the above two are not available: data that is not available from either of the above sources may be collected directly for impact assessment. Data that may not be available from the above sources include energy consumption of RE and EE technologies and their useful life (e.g. stoves, CFL and LED lamps). While nationwide data collection (on a representative scale) may not be feasible to conduct at the sector level, smaller scale sample surveys will provide useful data that will complement data that may be available from the other two sources.

The policies (actions, measures) that are evaluated fall under the following three categories: a) those that are implemented at consumer level, (ICS for households, power factor correction in factories), b) those that are implemented at community level (e.g. solar mini grids), and c) those that are implemented at central level (e.g.. renewable power generation on the grid). Primary surveys may be required for the first type of policies (unless such data is available from other sources such as sales data for improved cookstoves). Data requirement for assessment of such policies include technology penetration levels (e.g. improved stove ownership/use), technology use (hours of use for improved stoves), and other technology specific data (e.g. energy saving by device, useful life of device). Five of the nine policies under review may require data from surveys as shown below.

P	*Policy*	*Data requirement*

#		
1	Improved Cookstoves (ICS)	Technology penetration level, device life, energy use
2	Distribution of CFL/LED lamps	Technology penetration level, device life, energy use
3	Power Factor correction	
4	Energy efficiency labelling of Electric Injera mitad	Technology penetration level, device life, energy use
5	Renewable energy powered mini grids	
6	Transmission and distribution loss reduction	
7	Waste to energy production	
8	Ethanol fuel use for cooking	Technology penetration level, device life, energy use
9	Standalone solar PV promotion in off-grid areas	Technology penetration level, device life, energy use

Sampling

Although the parameters we like to know are for the population as a whole (of say households in a specific area), it is seldom possible to collect data from the total population due to cost and other considerations. For this reason surveys are almost always conducted in a sample of the population. But it is critical how samples are taken from the population if the data gathered from the sample is to be considered to represent the larger population from which it is drawn. Estimates derived from samples represent the population they are drawn from only if they are taken through *probability sampling*; otherwise the estimate from the sample may provide useful information about the population but it cannot be considered to represent the population.[46]

- *Probability sampling* involves random selection, allowing you to make strong statistical inferences about the whole group.
- *Non-probability sampling* involves non-random selection based on convenience or other criteria, allowing you to easily collect data.

Probability sampling ensures that estimates from the samples are unbiased and reliable.[47]

- *Unbiased* indicates that the sampling will not systematically underestimate or overestimate the mean value determined. *Reliability* of a parameter value estimate, determined via sampling, is typically expressed in terms of the probability that the sample-based parameter value estimate falls within a specified interval around the population's true parameter value.

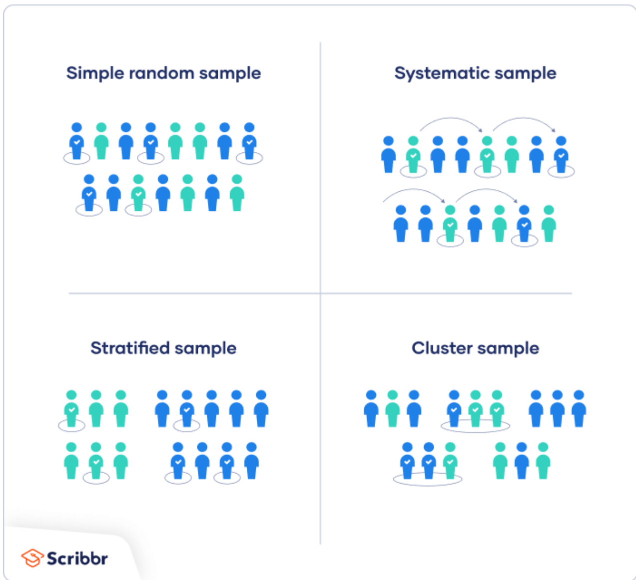
There are four methods of probability sampling (extracts from www.scribbr.com):

- *Simple random sampling*: In a simple random sample, every member of the population has an equal chance of being selected. Your sampling frame should include the whole population. To conduct this type of sampling, you can use tools like random number generators or other techniques that are based entirely on chance.
- *Systematic sampling*: Systematic sampling is similar to simple random sampling, but it is usually slightly easier to conduct. Every member of the population is listed with a number, but instead

[46] https://www.scribbr.com/methodology/sampling-methods/#:~:text=Probability%20sampling%20involves%20random%20selection,you%20to%20easily%20collect%20data.

[47] Concise explanation of sampling is provided by the UNFCC guideline for sample surveys: UNFCCC, 2009. General Guidelines for Sampling and Surveys for Small-scale CDM Project Activities, Version 1.0, EB 50, Annex 30.

of randomly generating numbers, individuals are chosen at regular intervals.



- *Stratified sampling*: Stratified sampling involves dividing the population into subpopulations that may differ in important ways. It allows you draw more precise conclusions by ensuring that every subgroup is properly represented in the sample. To use this sampling method, you divide the population into subgroups (called strata) based on the relevant characteristic (e.g. gender, age range, income bracket, job role). Based on the overall proportions of the population, you calculate how many people should be sampled from each subgroup. Then you use random or systematic sampling to select a sample from each subgroup.
- *Cluster sampling*: Cluster sampling also involves dividing the population into subgroups, but each subgroup should have similar characteristics to the whole sample. Instead of sampling individuals from each subgroup, you randomly select entire subgroups. If it is practically possible, you might include every individual from each sampled cluster. If the clusters themselves are large, you can also sample individuals from within each cluster using one of the techniques above. This is called *multistage sampling*. This method is good for dealing with large and dispersed populations, but there is more risk of error in the sample, as there could be substantial differences between clusters. It's difficult to guarantee that the sampled clusters are really representative of the whole population.

Purpose of the survey

The purpose of the sample survey was to collect data on households' adoption of energy efficient (EE) and renewable energy (RE) technologies and other related parameters. As explained previously five of the nine policies required such data. The survey was a very small sample survey intended only to illustrate how such surveys may be carried out by the Climate/Environment unit at MOWE if there is need and resources are available. For illustrative purposes we chose to conduct the survey in one urban area (Addis Ababa) and one rural area (a rural Kebele close to Bishoftu town).

Sampling for the survey

Surveys may be made at a local (e.g. for an ICS promotion project in just one Wereda) or national levels. For this assessment the requirement is to get EE and RE technology adoption and other related parameters at the national level.

Because some of the policies are directed mainly at rural households while others are directed toward urban households, and also because technology adoption drivers may be different between rural and urban areas, the sample survey is first stratified by settlement typology into rural and urban households (but this stratification may go further and divide urban areas into several typologies, for example, capital city, secondary cities, and tertiary or small towns).

Once the survey is stratified by settlement types (urban, rural), several stages of cluster sampling is carried out to reach to the final cluster of Kebeles (or geographic areas) from which the final sample households will be randomly selected. This means the sampling method we applied was multi-stage stratified cluster sampling. For our survey this entailed, for urban areas:

- selecting the city (a cluster) – chose to do only Addis Ababa as illustration
- from the city randomly selecting 2 Sub-Cities (sub city as cluster) – selected Yeka and Bole sub-cities
- from each sub-city randomly selecting 1 Wereda (Wereda as cluster) – selected Wereda 1 in Yeka, Wereda 12 in Bole
- from each Wereda randomly selecting 2 blocks as shown in the following figure (block as cluster)
- finally randomly sampling 30 households from each block selected

Similar steps will be taken to select the final cluster for rural areas. For example, if the survey is to be conducted in one regional state, the first step will be to randomly select a number of Weredas from the region, then from each Wereda selected, randomly select a number of rural Kebeles, and finally select a pre-determined number of households (say, 30 households) within these Kebeles to conduct the survey).

Figure A.1 Blocks for Wereda 1 in Yeka Sub-City

- Example of application for Addis Ababa
- Sub city sampled = Yeka
- Wereda sampled = Wereda 1
- Two blocks selected

The survey tool (questionnaire)

The survey was conducted to evaluate the impact of selected energy sector policies (for 5 of the 9 policies listed in the previous page). Parameters that are required include RE and EE technology penetration for the selected policies (e.g. improved cookstove and CFL penetration levels), frequency of use of these technologies, their useful life, and their failure rate.

A household questionnaire was prepared to collect the above data for all the relevant policies. Data was collected through a digital data collection tool (kobotoolbox) using a team of enumerators overseen by a supervisor.

Some of the data collected for each of the relevant policies are shown below. The full online questionnaire is available at https://kf.kobotoolbox.org/#/forms/afyanHkoYavdtA6vPpnFVs/landing

2/19/22, 4:28 PM Ministry of Water and Energy - GHG ER Impact Assessment of the CRGE for the Energy Sector | KoboToolbox

Ministry of Water and Energy - GHG ER Impact Assessment of the CRGE for the Energy Sector

Household survey to evaluate the adoption and use of clean cooking and renewable energy technologies by households
(ERG, v. 1.0, 4.00p, 19 feb 22)

Improved Cookstoves (ICS)

Ethanol fuel use for cooking

- Types of cooking and baking stoves used by the household (including ICS, ethanol stove, others)
- Amount of fuel consumed for each fuel used by the household
- Frequency of use of the stoves (days in a week, hours in a day)

Distribution of CFL/LED lamps

- CFL and LED lamps installed in the household
- Power rating for CFL and LED lamps (in Watt)
- Hours of operation for CFL and LED lamps

Energy efficiency labelling of electric cook stoves and electric Injera stoves/mitads

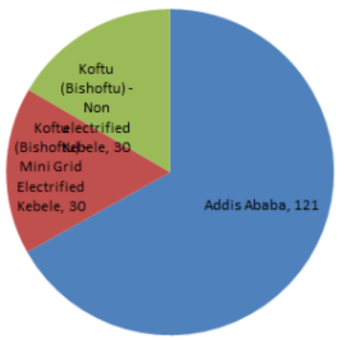
- Does your electric stove have an efficiency label (for electric cooking stoves)
- If your electric stove has an efficiency label, what is the grade/label?
- Frequency of use the electric stove (days in a week, hours in a day)
- What times of the day is the electric stove used

Standalone solar PV promotion in off-grid areas

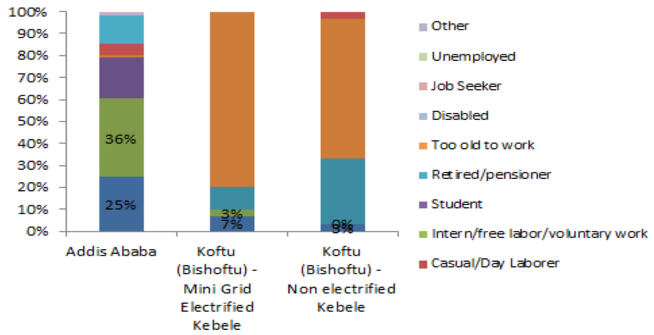
- Does the household use standalone solar systems for lighting (solar home systems or solar lanterns)?
- What type of solar home systems are used (how many lighting, power for other devices)?
- What has the solar system replaced?

Findings from the survey

The household energy survey was made in Addis Ababa and a rural area close to Bishoftu town. The rural survey covered two Kebeles, one of which has recently been electrified with a solar powered mini grid by the Ethiopian Electricity Utility (EEU). A total of 181 households were surveyed, 121 of them in Addis Ababa.



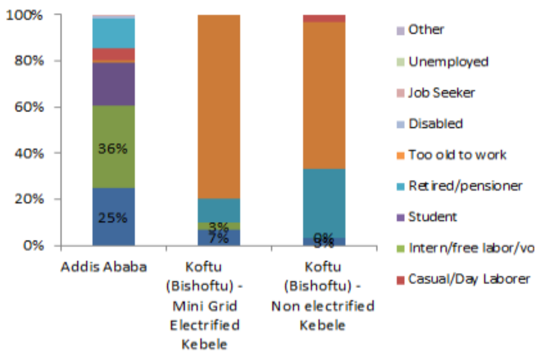
Sample distribution



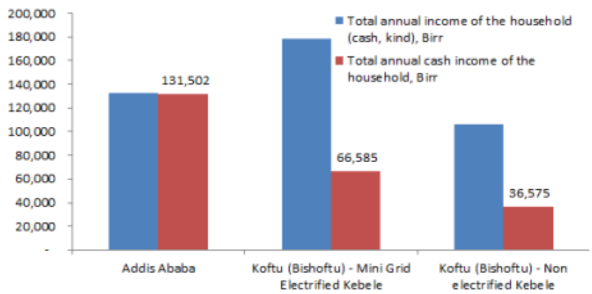
Sources of livelihood for households

The main sources of livelihood for rural households are agriculture (crop and livestock production) which is reported for 90% of households. For households in Addis Ababa the main sources of livelihood are diverse and include wage employment (25%), self-employment in non-farm activities (55%), retired (13%), casual labour (5%), and others.

The mean total income for households in Addis Ababa is ETB 133,000 that for rural areas is between ETB 105,000 and 179,000. In Addis Ababa income is exclusively in the form of cash income whereas in the rural areas cash incomes account only for about a third of the total income.

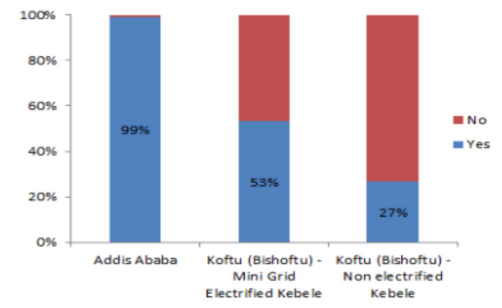


Sources of livelihood for households

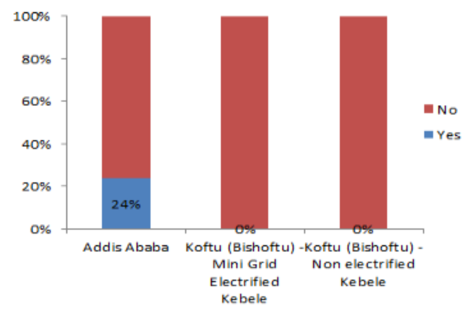


Annual total & cash income of households (Birr)

Virtually all households in Addis Ababa have at least one finance account from a formal institution such as a bank or micro finance institution (MFI). In rural areas households that have such accounts ranged from 27% to 53% (the higher percentage for those that live in the electrified rural area). Mobile money accounts are held by about a quarter of households in Addis Ababa but no households hold mobile money accounts.

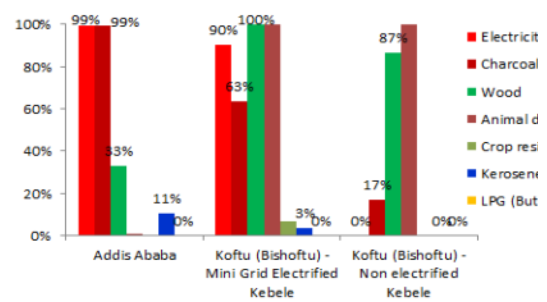


Bank account in a formal institution

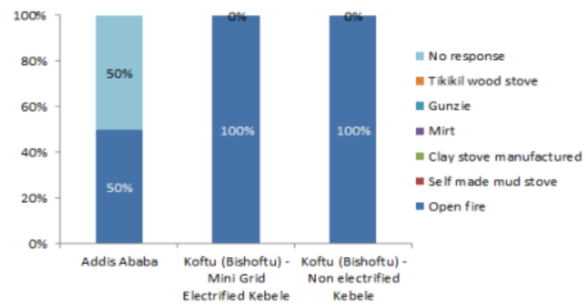


Mobile money account

The main cooking (and baking) fuels used by households in Addis Ababa are electricity and charcoal (used virtually by all households). In the electrified rural area electricity and wood are the main cooking fuels. In the non-electrified rural area the main cooking fuels are wood and charcoal. In all the settlements surveyed the open fire is the dominant stove used for cooking with wood.

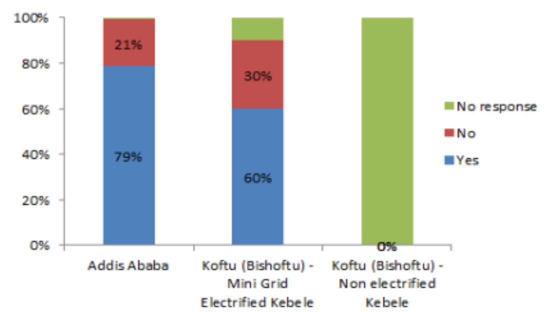


Fuels and energy used for cooking and baking in households

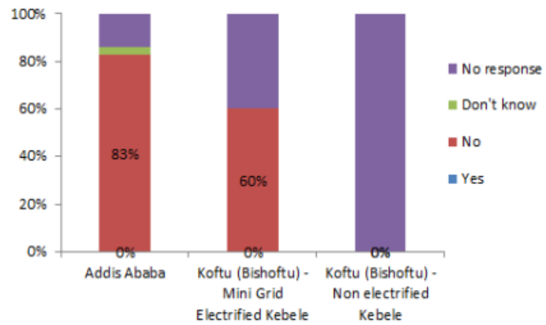


Cooking stoves (non-baking) used for wood by households

Nearly 80% of households in Addis Ababa cooked (excludes baking Injera) with electricity while in the electrified rural Kebele 60% of households cooked with electricity. None of the households that cooked with electricity owned an electric stove with labels.

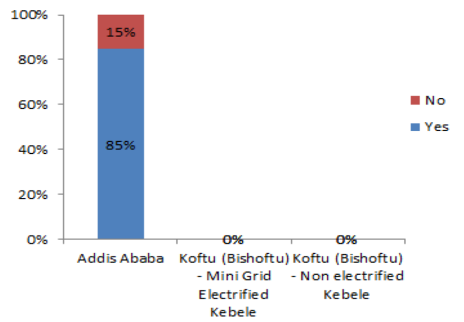


Households that cook with electricity

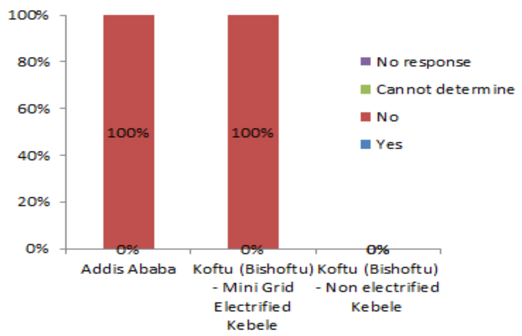


Electric cookstove has label?

In Addis Ababa 85% of households owned and used the electric mitad. The mean power rating of the electric mitads used was 3.5kW (measured for the sample using the resistance of the mitads). In the rural areas surveyed non used electric mitads for baking Injera. For those households that did use electric mitads, none were using electric mitads with labels.



Households that own electric mitad



Does the electric mitad has a label?