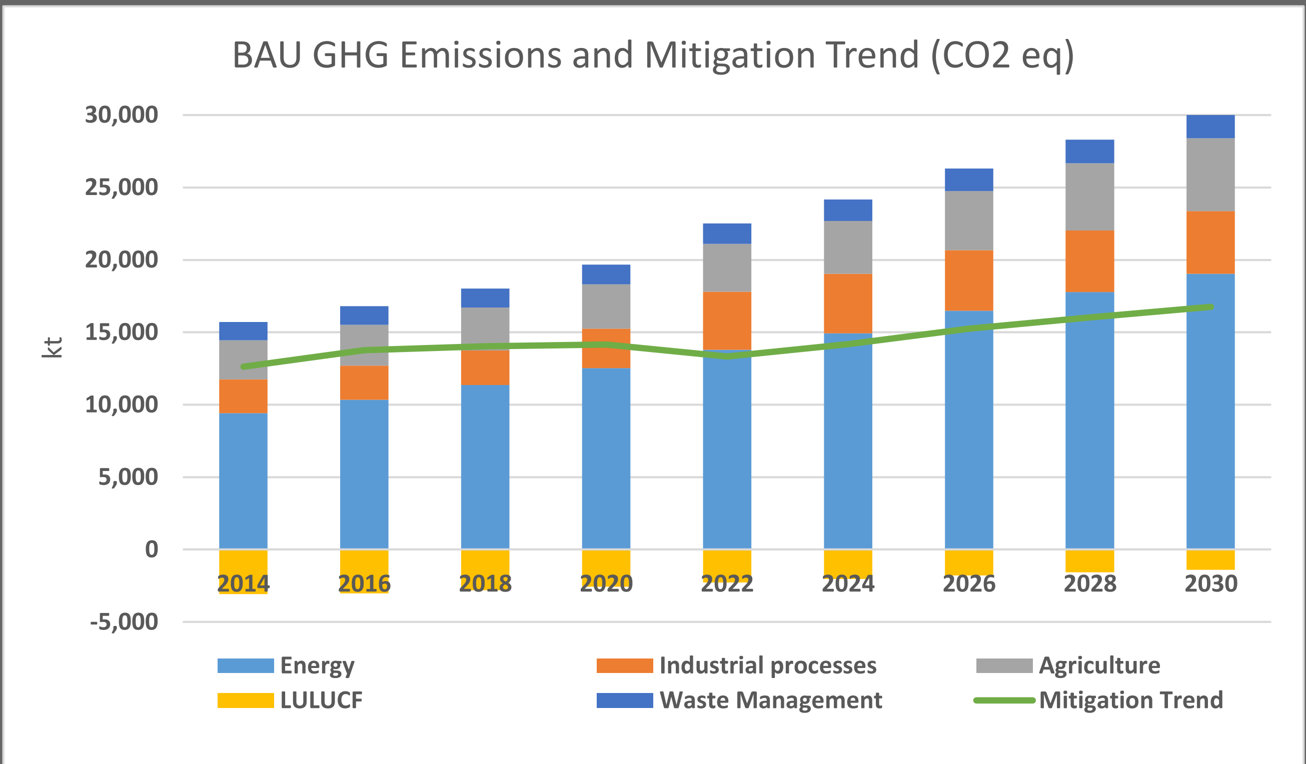
ENHANCING CAPACITY FOR LOW EMISSION DEVELOPMENT STRATEGIES (EC-LEDS) CLEAN ENERGY PROGRAM

COOPERATIVE AGREEMENT NO. 114-A-13-00008

Comprehensive Analysis of LEDS GHG Mitigation Measures using MARKAL-Georgia



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Comprehensive Analysis of LEDS GHG Mitigation Measures using MARKAL-Georgia

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Acronyms

BAU	Business-as-Usual
BEUR	Billion Euro
CH4	Methane
CO_2	Carbon Dioxide
COP	Conference of the Parties
DWG	DecisionWare Group
EC-LEDS	Enhanced Capacity – Low Emissions Development Strategy
GDP	Gross Domestic Product
Gg	Gigagram
GOG	Government of Georgia
GWh	Gigawatt Hours
GHG	Greenhouse Gas
HPEP	Hydro Power and Energy Planning
IEA-ETSAP	International Energy Agency's Energy Technology Systems Analysis Programme
INDC	Indicative National Determined Contribution
Kt	Thousand Tons
LULUCF	Land Use, Land-Use Change and Forestry
MARKAL	MARKet Allocation
MEUR	Million Euro
MoE-AD	Ministry of Energy Analytical Department
MW	Megawatts
N2O	Nitrous Oxide
PJ	Petajoules
RES	Reference Energy System
SC	Steering Committee (LEDS)
TED	Territory Electricity Demand
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development
WG	Working Group (LEDS)

1 Executive Summary

This report was prepared under the US Agency for International Development (USAID) Enhancing Capacity for Low Emissions Development Strategy (EC-LEDS) Clean Energy Program for Georgia, which supports increased climate change mitigation by building capacity to stimulate private sector investment in energy efficiency and green buildings, raising public awareness, and strengthening Government of Georgia (GOG) capacity to develop and implement a national LEDS.

The report builds on the energy sector Business-As-Usual (BAU) and LEDS Measures reports[1,2] that describe the energy and emissions aspects of the BAU scenario for Georgia, along with mitigation measures in the energy sector identified as part of analyzing LEDS pathway for the country. This report summarizes the third portion of this analysis with the addition of non-energy Greenhouse Gas (GHG) emissions and mitigation measures to provide a comprehensive view of LEDS for Georgia.

The analyses presented in this report were performed using the MARKAL-Georgia model and the best available local data, augmented by international data for future technology characterizations. As described in the Energy sector Mitigation report, the energy sector LEDS measures were identified by sector-based Working Groups (WG) and represent practical and implementable options for Georgia. Likewise, the non-energy sector emissions baseline and mitigation measures were developed by sector experts as the most practical and implementable options for Georgia.

The report presents the GHG emissions baseline and mitigation options for each non-energy sector:

- Agriculture,
- Land Use, Land-Use Change and Forestry (LULUCF)
- Industrial processes, and
- Waste Management.

To complete the coverage of GHG emissions, BAU projections were developed for the four non-energy sectors, and some fifty eight mitigation measures were identified. The importance of looking at the entire emission profile and mitigation options to get a complete picture for LEDS is evident in Figure 1, which presents the full GHG emissions profile for Georgia under the following 4 scenarios:

- BAU with full GHG accounting;
- All energy sector mitigation measures;
- All non-energy sector mitigation measures
- Combined energy and non-energy mitigation measures.

For the Combined scenario, BAU GHG emissions from the non-energy sectors were added to the BAU scenario from the energy system. Then the non-energy mitigation measures were added to the energy sector mitigation scenario without any interaction to produce an initial comprehensive view of the future possible GHG profile for Georgia. The Combined run is thus a mostly prescriptive (exogenously specified) view of the mitigation potential in Georgia.

The figure shows that nearly equal levels of mitigation will come from the energy and non-energy sectors by 2030. The difference in emission levels and reductions from all measures is clearly seen, pointing out that approximately 25% of emissions arise from the non-energy sector (40% excluding LULUCF sequestration).

[1] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, MARKAL-Georgia LEDS BAU Scenario Report, November 2016.

[2] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, MARKAL-Georgia Mitigation Measures Report, May 2016

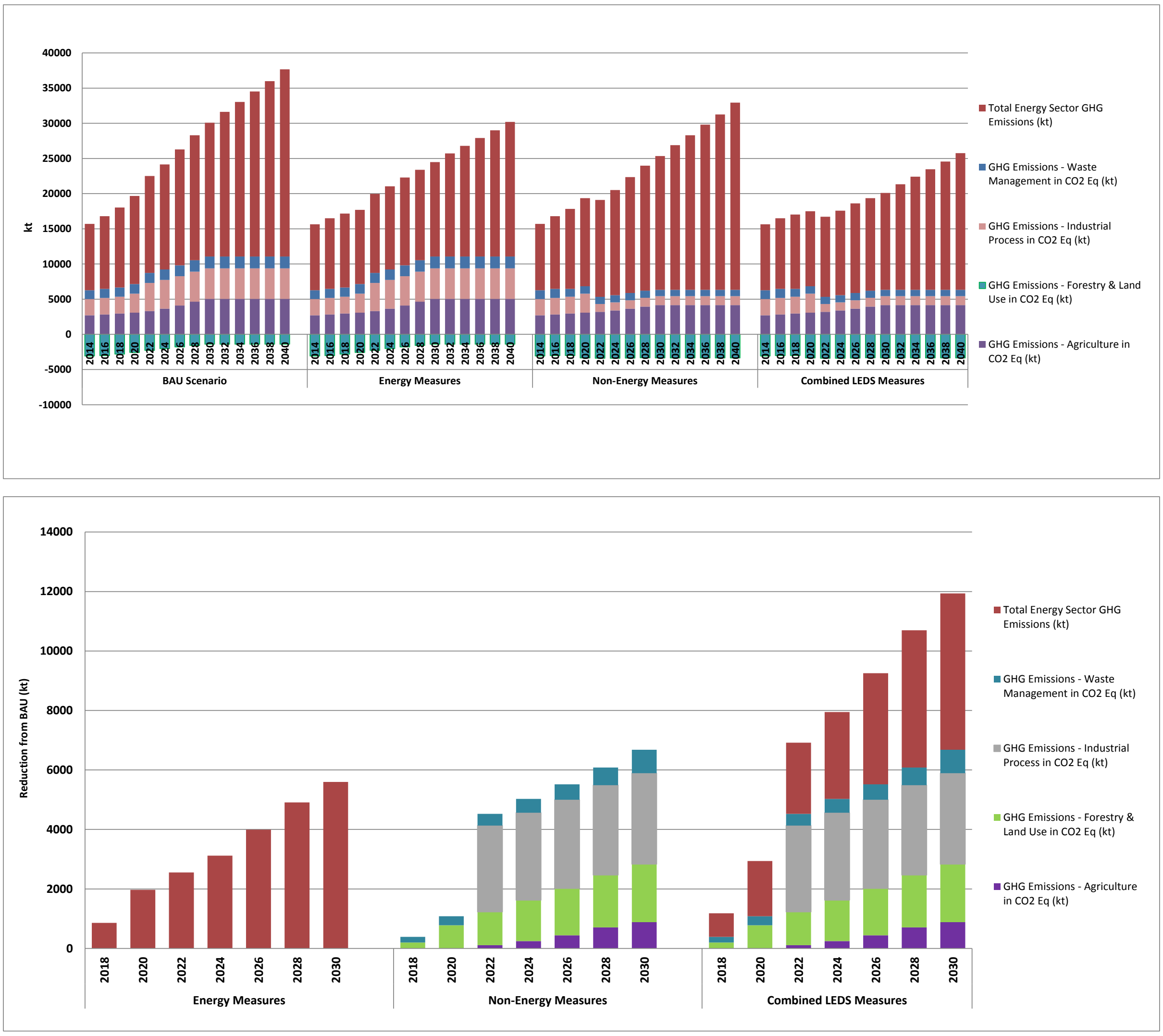

Figure 1: BAU GHG Emission Levels and Mitigation Reductions (CO2 eq)

In Appendix C the United Nations Framework Convention on Climate Change (UNFCCC) emissions and removals reporting table summarizing the mitigation potential from each source is present for the BAU and Combined scenario.

In addition to the non-energy sector baselines and mitigation measures, this report provides a short summary of the energy sector BAU and mitigation analysis along with the analysis of the aggregate energy and non-energy mitigation measures results. Together with the earlier reports, this report is intended to provide the analytic underpinning of a LEDS roadmap for Georgia. It has been developed as part of advising the LEDS Steering Committee (SC) and WGs, along with non-energy sector experts, and continues the process of enhancing the local capacity to identify the most effective policies for LEDS implementation.

2 Introduction

The USAID EC-LEDS Clean Energy Program for Georgia supports increased climate change mitigation by building capacity to stimulate private sector investment in energy efficiency and green buildings, raising public awareness, and strengthening Government of Georgia (GOG) capacity to develop and implement a national LEDS. Under Component 3, the EC-LEDS Clean Energy Program is supporting the National EC-LEDS Steering Committee (SC) and associated technical working groups (WGs) by providing advisory assistance to the GOG to articulate concrete actions, policies, programs and implementation plans under the US-Georgia bilateral EC-LEDS initiative, including supporting Georgia's preparation of policy measures needed to achieve their Nationally Determined Contribution (NDC) to the UNFCCC 21st Conference of Parties (COP-21) as approved by the government in May 2017.

This report documents work performed by DecisionWare Group (DWG) and Sustainable Development Center Remissia in cooperation with Winrock International, leader of the EC-LEDS Clean Energy Program, the Ministry of Energy Analytical Department (MoE-AD) and the Climate Change Office of Ministry of Environment and Natural Resources (MoENR) to develop the BAU and mitigation measures for the non-energy sectors, which were then integrated into the updated MARKAL-Georgia energy system planning model used to analyze a large number of energy policy measures. In this latest phase, the non-energy sector BAUs and mitigation measures were added to the overall LEDS analysis.

The BAU GHG projection for the Agriculture and Industrial Processes sectors were prepared by the Climate Change Office, Winrock experts supplied the mitigation measures for those sectors, and the Waste and LULUCF sector BAUs and mitigation measures were developed by Remissia.

This report summarizes the details of how the non-energy sector baseline and mitigation measure information was integrated into the MARKAL-Georgia model and presents the results of the analysis, both in terms of the impact of individual non-energy measures, as wells as the aggregated impact of the energy and non-energy measures. The analysis approach was to initially add all the non-energy mitigation measures to the run with all the energy sector mitigation measures, but without any interaction based on relative cost-effectiveness. This is labelled the "Combined LEDS" run).

This report builds on the BAU scenario and energy sector Mitigation Measures analysis reports that describe the energy and emissions aspects of the BAU scenario for Georgia and the actions to reduce those emissions. Therefore, this report only summarizes the energy sector BAU scenario and mitigation analysis results to set the context for the comprehensive GHG analysis. Thus the combined energy/non-energy platform provides complete GHG coverage so that this report can further serve to provide the analytic underpinnings to advise the SC and WGs as they look to develop a robust effective LEDS roadmap for Georgia.

3 MARKAL-Georgia Overview

The MARKAL-Georgia model has been developed over several years with the support of a series of USAID regional and national projects designed to better inform policy making and assess future energy investment options. It is built using the MARKAL integrated energy system modeling platform, developed under the auspices of the International Energy Agency's Energy Technology Systems Analysis Program (IEA-ETSAP, www.iea-etsap.org). The MARKAL-Georgia model has been used to examine the role of energy efficiency and renewable energy in meeting anticipated Energy Community commitments and European Union accession directives. The model was also used for energy strategy analysis as part of the USAID Hydro Power and Energy Planning (HPEP) project. Most recently under this EC-LEDS project, the model was used to develop the BAU trajectory for the energy sector for Georgia's submission to COP-21 and subsequently an in-depth analysis of the mitigation measures that can be undertaken the curb the emissions growth from the energy sector.

The key features of a MARKAL model are:

- Encompasses the ***entire energy system*** *(and in this case the non-energy GHG sources as well)* from resource extraction through to end-use demands as represented by a Reference Energy System (RES) network (see the example in Figure 2);
- Employs least-cost ***optimization;***
- Identifies the most ***cost-effective*** pattern of resource use and technology deployment over time;
- Provides a framework for the evaluation of mid-to-long-term ***policies and programs*** that can impact the evolution of the energy system;

- Quantifies the ***costs and technology choices***, and the associated emissions, that result from imposition of the policies and programs, and
- Fosters **stakeholder buy-in** and consensus building.

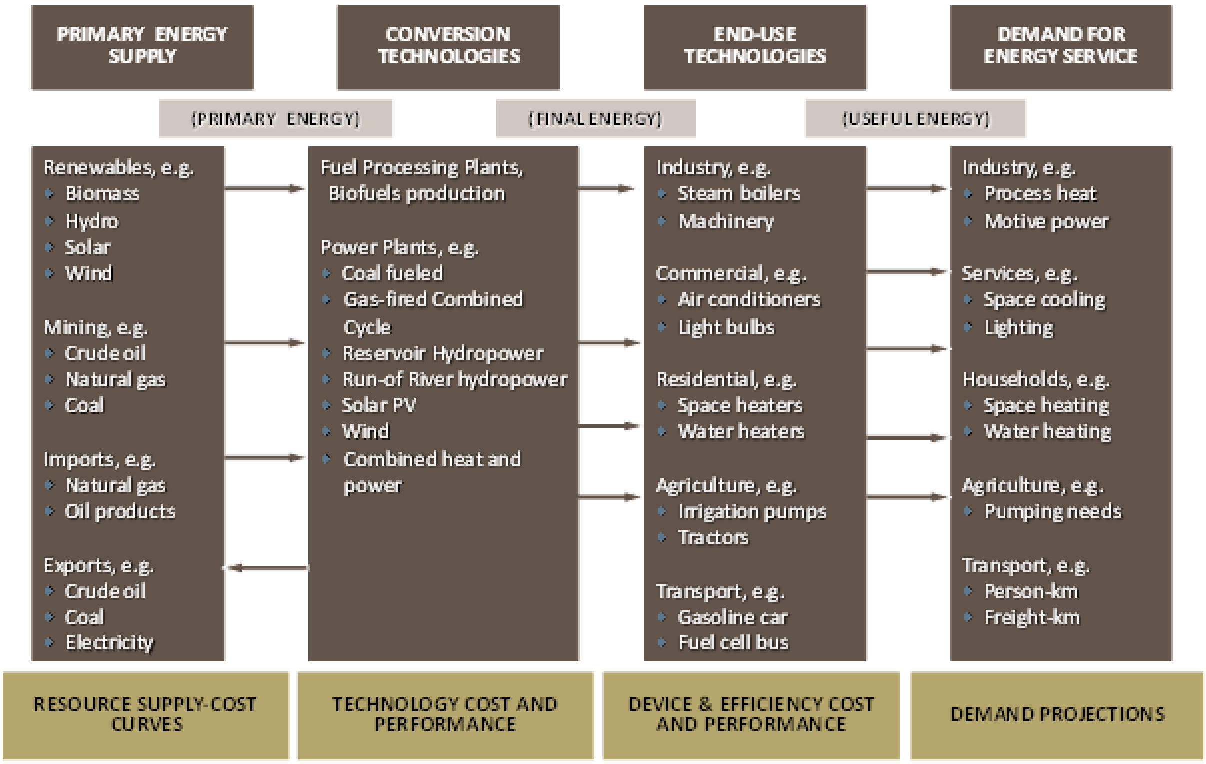

Figure 2: Simplified Reference Energy System

Under the previous phase of EC-LEDS project the MARKAL-Georgia model was substantially revised and updated. The major change involved moving the model's Base Year to 2014 and calibrating the model to the 2014 Geostat energy balance, which is an improvement over the 2012 and 2013 energy balances. In addition, the model was restructured into 2-year periods out to 2040, compared to 3-year periods out to 2036 in the previous version. Furthermore, all input data were reviewed and updated where appropriate. A summary of these changes may be found in Appendix A of the BAU Report.

Based on 2014 Geostat energy balance, there are 25 different forms of energy currently used in Georgia, each fully depicted in the model. These energy carriers are utilized in the following demand sectors:

- Agriculture;
- Commercial;
- Industry;
- Residential;
- Territory Electricity Demand (TED), representing the electricity consumption in Abkhazia, and
- Transportation.

In addition, there is a separate sector representing the non-energy demands to fully represent all the entries in the 2014 Geostat energy balance.

The power sector describes Georgia's existing and planned power plants, including the three thermal plants currently in operation, the Enguri and Vardnili regulating hydro plants, other regulating hydro plants, run of river hydropower plants, as well as potential renewable and new coal and natural gas-fired power plants.

The scope of coverage was expanded for this undertaking to capture all sources of GHG emissions in the country including those from the Agriculture, LULUCF, Industrial Processes and Waste Management sectors.

4 LEDS Business-as-Usual (BAU) Scenario

In this analysis the MARKAL-Georgia BAU scenario has been expanded to represent the expected evolution of the Georgia energy sectors and non-energy sectors under current policies and practices. The BAU scenario does not represent a forecast of evolution of the system; rather it serves as the comparison scenario for quantifying the costs, benefits, technology changes, fuel switching, emissions and other impacts of potential measures that collectively will shape the LEDS strategy for Georgia. GHG emissions from the energy sectors are calculated endogenously in the MARKAL-Georgia model, but the non-energy sector BAU emissions are an exogenously prepared projection by sector experts based on the anticipated growth of GHG emissions from the four non-energy sectors.

4.1 Non-Energy Sector BAU Emissions

The non-energy sectors consist of:

- Industrial processes[3,4,5];
- Agriculture[6,7,8];
- Waste Management[9,10,11], and
- Land Use, Land-Use Change and Forestry[12,13,14].

Each sector is fully described in the referenced USAID reports that provide a detailed description of the sector, the expected BAU GHG emissions profile, and the potential for emission reductions in the sector. Table 1 summarizes the non-energy sector data with a short description of each GHG producing activity.

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[3] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Overview of Industry Sector in Georgia, April 2017

[4] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Non-energy Related GHG Emissions Inventory and BAU Scenario for Industrial Sector, March 2017

[5] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Industry: Mitigation Measures (Non-energy Related Emissions), April 2017

[6] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Overview of Agriculture Sector in Georgia, April 2017

[7] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Greenhouse Gas Inventory and Business as Usual Scenario for Agriculture Sector, March 2017.

[8] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Mitigation Measures for Agriculture Sector, April 2017

[9] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Overview of Waste Sector in Georgia, April 2017

[10] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, GHG Emissions Inventory and BAU Scenario for Waste Sector, March 2017

[11] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Mitigation Measures for Waste Sector, April 2017

[12] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Overview of Forestry Sector in Georgia, April 2017

[13] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, GHG Emissions Inventory and BAU Scenario for Agriculture Sector, March 2017

[14] USAID, Enhancing Capacity For Low Emission Development Strategies (EC-LEDS) Clean Energy Program Georgia, Mitigation Measures for Forestry Sector, April 2017

Table 1: Emission Tracking in the Non-Energy Sector

Sector/ Area	Description
Industrial Processes	
Cement production (Mineral Products)	CO_2 emissions from cement production
Ammonia production (Chemical)	CO_2 emissions from fertilizer production
Nitric acid production (Chemical)	Nitrous oxide from fertilizer production
Iron and steel production (Metal Production)	CO_2 emissions from three (3) production facilities
Ferroalloys production (Metal Production)	CO_2 emissions from silicon-manganese and ferro-manganese production
Agriculture	
Enteric Fermentation	Methane release directly from livestock
Direct Emissions from the soil	Methane and nitrous oxide from manure sitting on the soil
Indirect emissions from the soil	Nitrous oxide from application of fertilizer
Waste	
Solid Waste Disposal	Includes methane emissions from solid waste disposed to the landfills
Domestic wastewater treatment and discharge	Includes methane and NO2 emissions from municipal wastewater treatment plants
Industrial wastewater treatment and discharge	Includes methane emissions from industrial wastewater treatment plants
LULUCF	
Forest Lands	All GHG emissions (CO_2, CH_4, N_2O) arising from forests
Croplands	CO_2 emissions arising from annual croplands (including fallow lands) and perennial croplands
Grasslands	CO_2 emissions arising from hay-lands and pastures

The resulting BAU projection of GHG emission for each non-energy sector are shown in Figure 3, and the aggregate non-energy GHG emissions is shown in Figure 4.

Note that tables with the BAU emission levels are presented in Section 5 when discussing mitigation opportunities for that sector so that the BAU/resulting avoided emissions are presented together. Also, the actual input Excel spreadsheets are presented in Appendix B and the UNFCCC emission and removal tables for the BAU and mitigation scenario can be found in Appendix C.

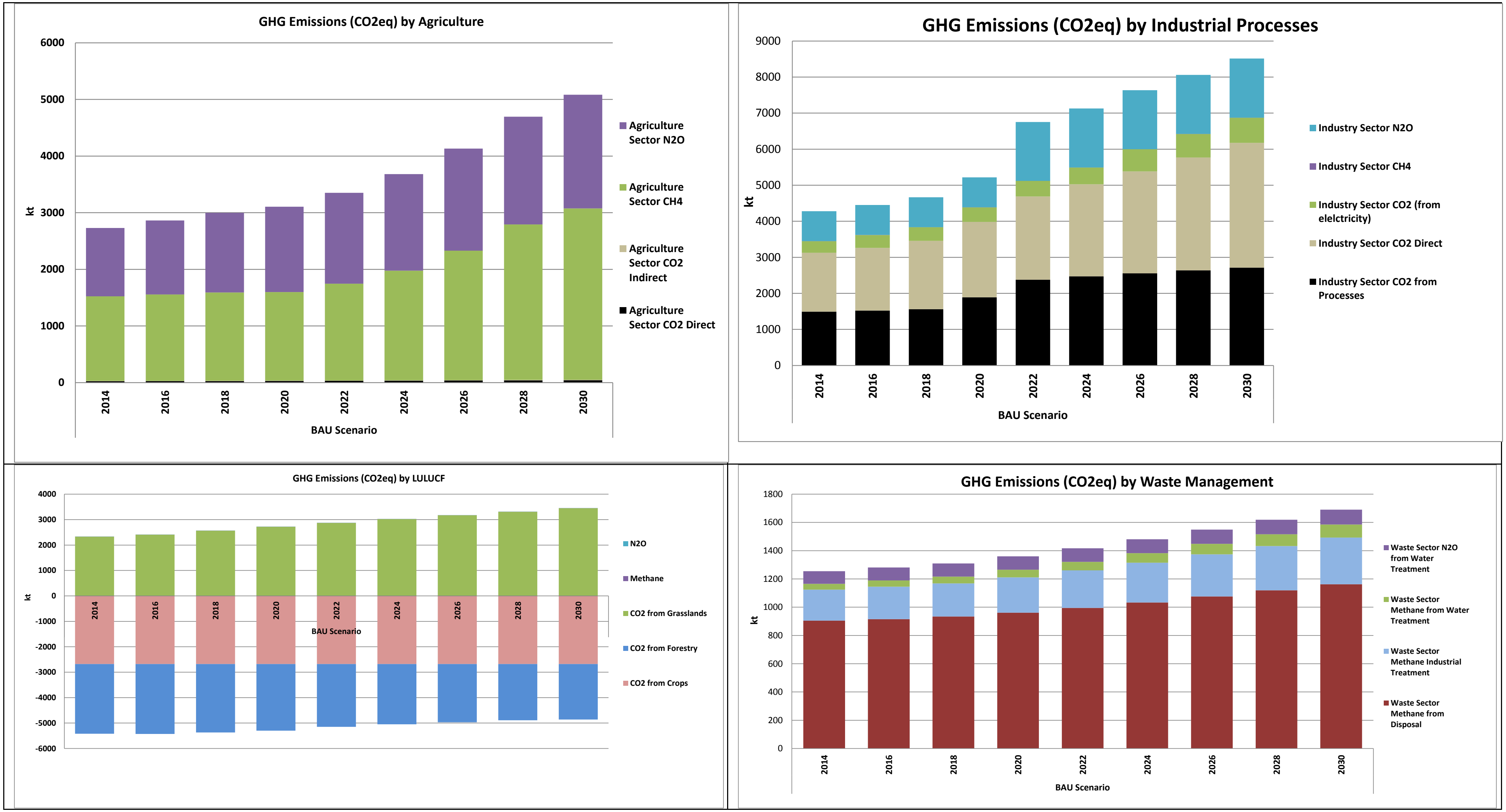


Figure 3: Non-energy BAU GHG Emissions by Sub-sector

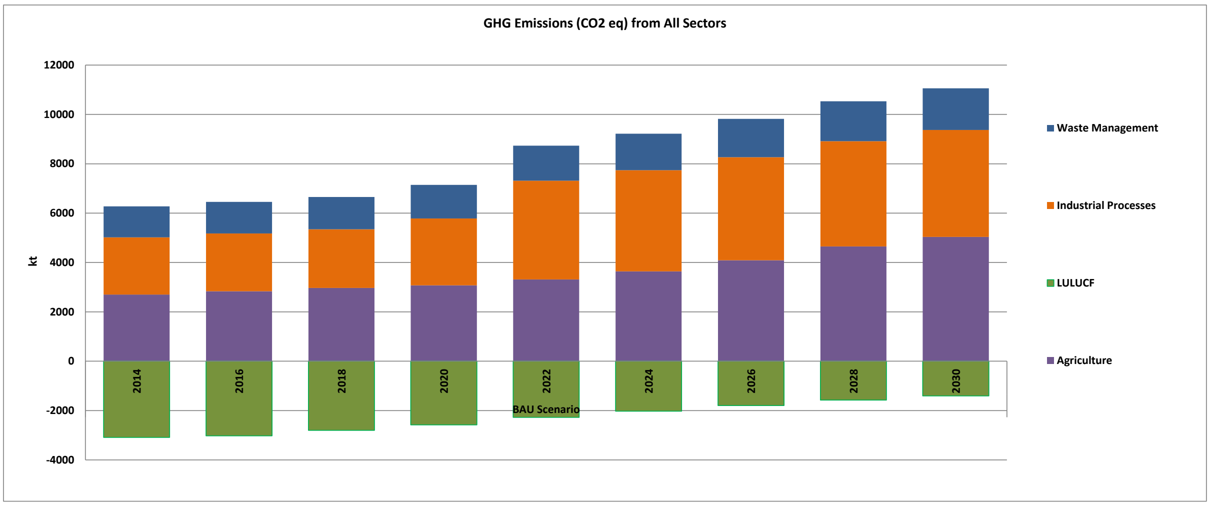


Figure 4: Non-energy BAU Aggregate GHG Emissions and Trend Snapshot (CO_2 eq)

The non-energy sector currently accounts for approximately 25% of the total GHG emissions, while having the potential to greatly reduce emissions, in particular from the LULUCF sector. Table 2 presents the non-energy emissions for the BAU scenario for 2014 and 2030 with the percentage change between those two years. As seen the table, Georgia stands to increase GHG emissions from non-energy sources by more than 200% to 9,654kt (CO_2 eq) per annum by 2030. In the absence of policies to curb the growth, emissions from the agriculture and industrial process sectors continue to increase, and the level of GHG uptake, in the LULUCF sector decreases.

Table 2: BAU Non-Energy Emissions Profile by Source (CO_2 eq)

Non-Energy Emission Sources		2014	2030	Growth
2. Industrial processes		**2,317**	**4,338**	**87%**
	A. Mineral products	838	1,655	97%
	B. Chemical industry	1,153	2,233	94%
	C. Metal production	326	451	38%
	D. Other production			
4. Agriculture		**2,702**	**5,034**	**86%**
	A. Enteric fermentation	1,345	1,694	26%
	B. Manure management	293	1,489	408%
	C. Direct Emissions from the soil	638	1,139	79%
	D. Indirect emissions from the soil	426	712	67%
5. LULUCF		**-3,087**	**-1,408**	**-54%**
	A. Forest Lands	-2,737	-2,178	-20%
	B. Croplands	-2,680	-2,680	0%
	C. Grasslands	2,330	3,450	48%
6. Waste		**1,255**	**1,690**	**35%**
	A. Solid waste disposal on land	905	1,163	28%
	B. Biological treatment of solid waste			
	C. Waste-water Treatment and Discharge	349	527	51%
Total non-energy emissions		**3,186**	**9,654**	**203%**

4.2 Energy Sector BAU

Table 3 presents the primary energy sector metrics and emissions results arising from MARKAL-Georgia for the BAU scenario showing the change between 2014 and 2030.

Table 3: BAU Scenario Parameters

Indicator	Units	2014	2030	Growth
Gross Domestic Product (GDP)	2014M€	12,436	28,566	130%
Primary Energy Supply	PJ	192	409	113%
All Imports	PJ	135	267	98%
Natural gas Imports	PJ	76	152	99%
Net Electricity exports	GWh	-248	13,529	NA
Fuel Expenditure	2014M€	1225	2,773	126%
Power Plant Capacity	MW	3,431	8,780	156%
Hydro Power Plant Capacity	MW	2,751	7,684	179%
Thermal (gas and coal) Power Plant Capacity	MW	680	1,075	58%
Other renewable Power Plant Capacity	MW	0.00	0.02	NA
Electricity generation	GWh	10,135	31,380	210%
Power Plant New Capacity (2014-2030)	MW	NA	5,349	NA
Power Plant Investment Cost (2014-2030)	2014M€	NA	8,049	NA
Total Final Energy	PJ	160	302	89%
Transport Final Energy	PJ	56	114	106%
Buildings Sector Final Energy	PJ	68	118	73%
Industry Final Energy	PJ	30	61	106%
Total CO2 Emissions	Kt	7,907	15,994	102%
Transport sector CO2 Emissions	Kt	3,458	6,709	94%
Buildings sector CO2 Emissions	Kt	1,673	3,671	119%
Industry sector CO2 Emissions	Kt	1,630	3,461	112%
Power sector CO2 Emissions	Kt	1,121	2,111	88%
Total Methane Emissions	Kt	70	140	101%
Total N2O Emissions	Kt	0.19	0.33	69%
Total GHG emissions	Kt CO2 eq	9,421	19,025	102%

4.3 All Sectors

The aggregate BAU arising when both energy and non-energy sectors are considered collectively is summarized in Table 4 and shown in Figure 5. Without intervention to mitigate emissions overall emissions can be expected to grow 127% by 2030. Note that the -54% change for LULUCF is arising because the level of removals occurring from the sector is decreasing. Looking at the BAU without the LULUCF the increase over the planning horizon is 92%.

Table 4: Aggregate BAU Emissions and Removals Profile by Sector (CO2 eq)

BAU = Baseline										
	GHG emissions and Removals (Gg CO2e) with LULUCF									Change
Greenhouse gas source and sink categories	2014	2016	2018	2020	2022	2024	2026	2028	2030	in 2030
1. Energy	9,428	10,345	11,369	12,529	13,793	14,946	16,481	17,771	19,036	102%
2. Industrial processes	2,317	2,345	2,381	2,715	4,002	4,097	4,181	4,264	4,338	87%
4. Agriculture	2,702	2,833	2,967	3,071	3,314	3,643	4,089	4,651	5,034	86%
5. LULUCF	-3,087	-3,023	-2,804	-2,578	-2,276	-2,024	-1,798	-1,578	-1,408	-54%
6. Waste	1,255	1,281	1,310	1,360	1,417	1,481	1,549	1,619	1,690	35%
Total national emissions and removals	**12,614**	**13,779**	**15,223**	**17,095**	**20,250**	**22,142**	**24,502**	**26,726**	**28,690**	**127%**

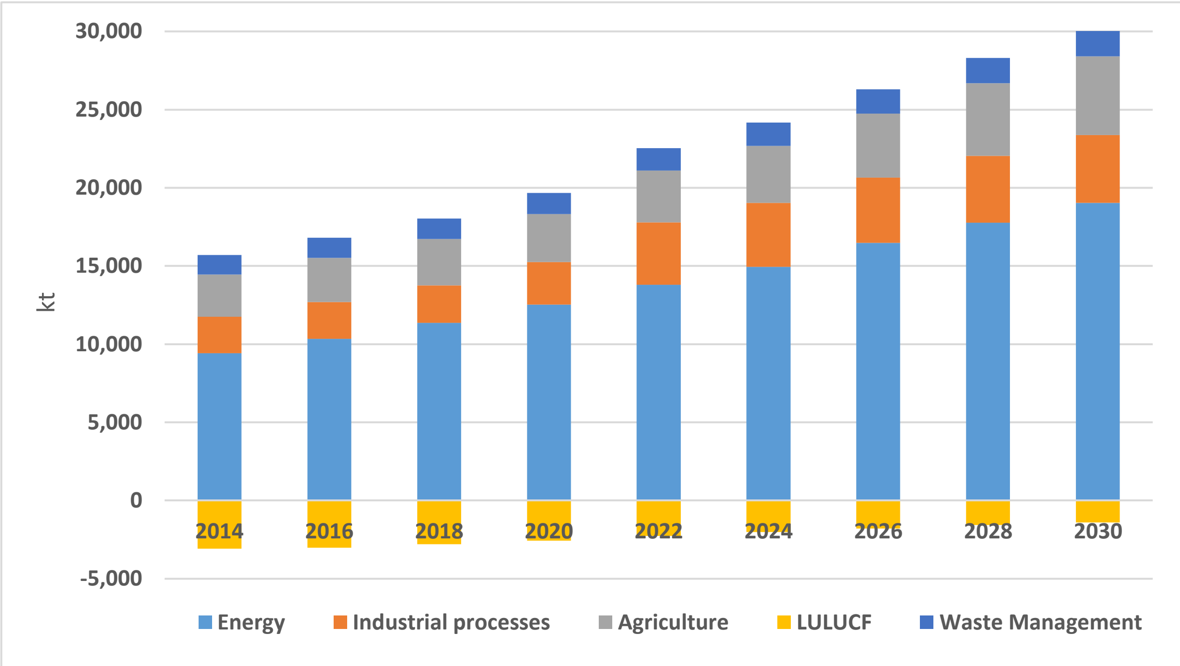


Figure 5: BAU Aggregate GHG Emissions and Removals for All Sectors

5 Non-Energy Mitigation Measures

Winrock has engaged a number of sectoral experts to identify opportunities in the non-energy sectors to reduce GHG emissions. As noted earlier, the sectors and their BAU projections and mitigation measures are described in a series of reports detailing each measure. These measures have been incorporated into the MARKAL-Georgia model. It should be noted that developing cost estimates for many of the measures is challenging and for some measures no cost estimates were able to be provided. As a results the mitigation scenario examined here is prescriptive in nature --- that is each measure identified by the expert is assumed to occur at a particular (or ongoing) point in time and achieve the (maximum) level of reduction that has been determined as feasible and policy-wise acceptable. [Note that this was also the case in the earlier look at some of the energy sector mitigation measures.]

For each non-energy sector a table describes the measures and indicates the main impact seen by 2030. A model results table shows the BAU and mitigation emission levels, along with the percent change from the BAU in 2030 for each measure as well as the total for the sector for each period. An accompanying graph depicts the BAU and mitigation scenario emission levels and reductions by each measure. In Appendix C, the model input Excel workbooks with mitigation potential associated with each measure (along with costs where available) is provided for each sector. Note that the value in those workbook tables are presented in their original input unit (kt, not CO2eq), however the tables and graphs presented in this section are in CO2eq.

5.1 Mitigation Potential in the Industrial Processes

The mitigation opportunities and main 2030 impacts in the Industrial sector are listed in Table 5, and Table 6 provides the emissions levels for BAU and each of the mitigation measures. Overall the GHG emissions growth is slowed from 50% in the BAU scenario to 38% assuming full attainment of the identified mitigation measures. Figure 6 shows the BAU and mitigation scenarios emission profiles and reductions from the BAU, and Figure 7 the reduction contribution from each Industry measure.

The timing of the mitigation measures for the Industry sector are a bit uncertain, where it has been assumed here that most all the measures kick-in in 2022. The reductions in emission mainly occur due to the assumption that the Kaspi cement plants move from a wet to process and the nitric acid industry achieving a 95% reduction in N2O.

Table 5: Mitigation Measure Descriptions & 2030 Impacts - Industry

Mitigation Measure Area	Description	Impact by 2030
Cement production (Mineral Products)	Primarily the shift of Kaspi cement plant from wet to dry process, along with additional process improvements for the other plants (substitution of clinker by lime and/or fly ash/steel slag)	65% reduction of CO_2 emissions
Ammonia production (Chemical)	Primarily the move to solvent scrubbing	85% reduction of CO_2 emissions
Nitric acid production (Chemical)	Primarily optimization of the oxidation step	98% reduction of N2O emissions
Iron and steel production (Metal Production)	No mitigation options identified	
Ferroalloys production (Metal Production)	No mitigation options identified	

Table 6: BAU and Mitigation Scenario Emission Levels - Industry

		GHG emissions and Removals (Gg CO2e)								
Greenhouse gas source and sink categories	2014	2016	2018	2020	2022	2024	2026	2028	2030	2030 % Reduction
BAU Scenario										
2. Industrial processes	**2,317**	**2,345**	**2,381**	**2,715**	**4,002**	**4,097**	**4,181**	**4,264**	**4,338**	
A. Mineral products	838	873	898	1,211	1,371	1,444	1,515	1,585	1,655	
B. Chemical industry	1,153	1,127	1,127	1,127	2,233	2,233	2,233	2,233	2,233	
C. Metal production	326	345	357	377	398	420	433	446	451	
D. Other production	0	0	0	0	0	0	0	0	0	
Mitigation Scenario										
2. Industrial processes	**2,317**	**2,345**	**2,381**	**2,715**	**1,102**	**1,155**	**1,199**	**1,243**	**1,278**	70.5%
A. Mineral products	838	873	898	1,211	578	610	641	671	701	57.6%
B. Chemical industry	1,153	1,127	1,127	1,127	125	125	125	125	125	94.4%
C. Metal production	326	345	357	377	398	420	433	446	451	0.0%
D. Other production	0	0	0	0	0	0	0	0	0	
Reduction					2,900	2,941	2,982	3,021	3,061	
% Reduction					72.5%	71.8%	71.3%	70.9%	70.5%	

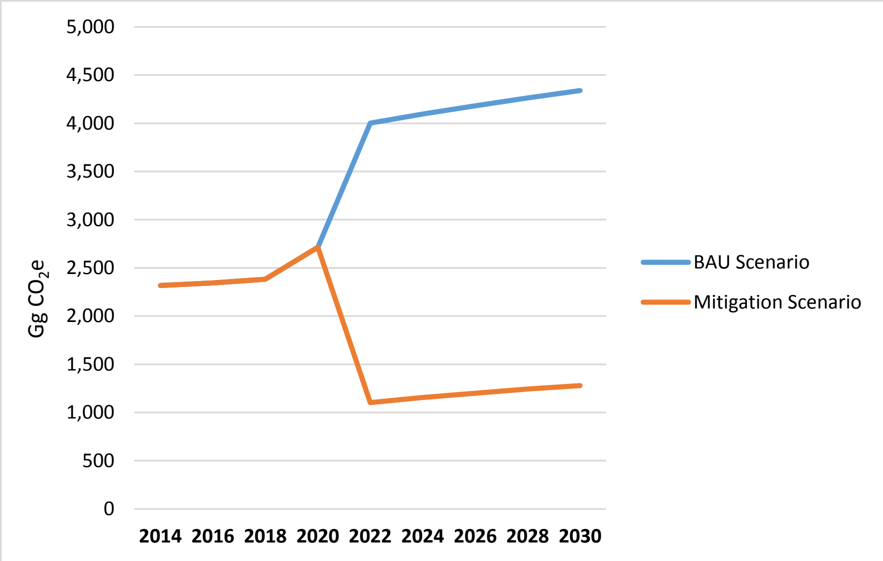


Figure 6: BAU and Mitigation Trajectory (CO2eq) – Industry

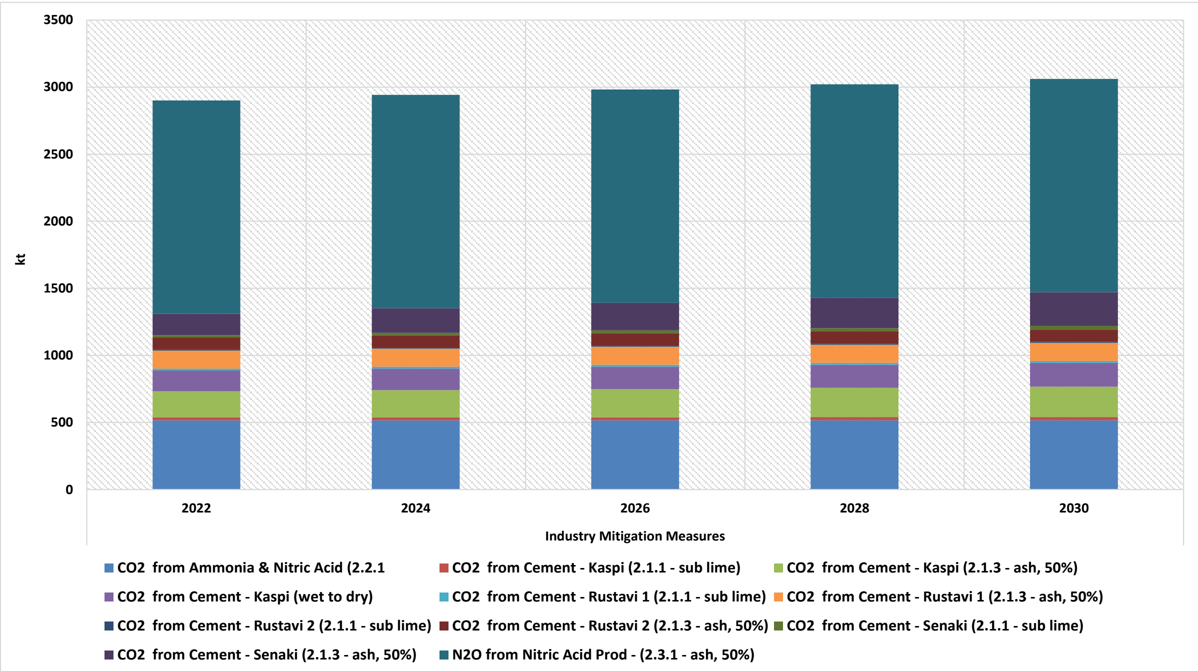


Figure 7: Contribution from Individual Mitigation Measures (CO2eq) – Industry

5.2 Mitigation Potential in the Agriculture Sector

The mitigation opportunities and main 2030 impacts in the Agriculture sector are listed in Table 7, and Table 8 provides the emissions levels for BAU and each of the mitigation measures. Overall the GHG emissions growth is slowed from 46% in the BAU scenario to 35% assuming full attainment of the identified mitigation measures. Figure 8 shows the BAU and mitigation scenarios emission profiles, and Figure 9 the reduction contribution from each Agriculture measure. The key mitigation measure is proper handling of livestock manure by means of lagoons to curb methane emissions.

Table 7: Mitigation Measure Descriptions & 2030 Impacts - Agriculture

Mitigation Measure Area	Description	Impact by 2030
Manure Management	Use of lagoon to handle cattle and swine manure	By 2030 a 54% reduction in CH4 emissions can be achieved
Enteric	Maximize superior feed quality, leading to	By 2030 a 4% reduction in CH4

Fermentation	lower emissions from enteric fermentation in absolute terms.	emissions can be achieved
Direct Emissions from the soil	No mitigation options identified	Emissions remain as in BAU
Indirect emissions from the soil	No mitigation options identified	Emissions remain as in BAU

Table 8: BAU and Mitigation Scenario Emission Levels - Agriculture

		GHG emissions and Removals (Gg CO2e)									
Greenhouse gas source and sink categories		2014	2016	2018	2020	2022	2024	2026	2028	2030	2030 % Reduction
BAU Scenario											
4. Agriculture		**2,702**	**2,833**	**2,967**	**3,071**	**3,314**	**3,643**	**4,089**	**4,651**	**5,034**	
	A. Enteric fermentation	1,345	1,371	1,398	1,398	1,405	1,444	1,526	1,642	1,694	
	B. Manure management	293	300	309	316	454	646	913	1,261	1,489	
	Direct Emissions from the soil	638	700	762	824	886	948	1,010	1,072	1,139	
	Indirect emissions from the soil	426	462	498	533	569	605	640	676	712	
Mitigation Scenario											
4. Agriculture		**2,702**	**2,833**	**2,967**	**3,071**	**3,207**	**3,399**	**3,647**	**3,946**	**4,153**	17.5%
	A. Enteric fermentation	1,345	1,371	1,398	1,398	1,396	1,428	1,499	1,595	1,626	4.0%
	B. Manure management	293	300	309	316	356	418	498	604	675	54.6%
	Direct Emissions from the soil	638	700	762	824	886	948	1,010	1,072	1,139	0.0%
	Indirect emissions from the soil	426	462	498	533	569	605	640	676	712	0.0%
	Reduction					107	244	442	705	881	
	% Reduction					3.2%	6.7%	10.8%	15.1%	17.5%	

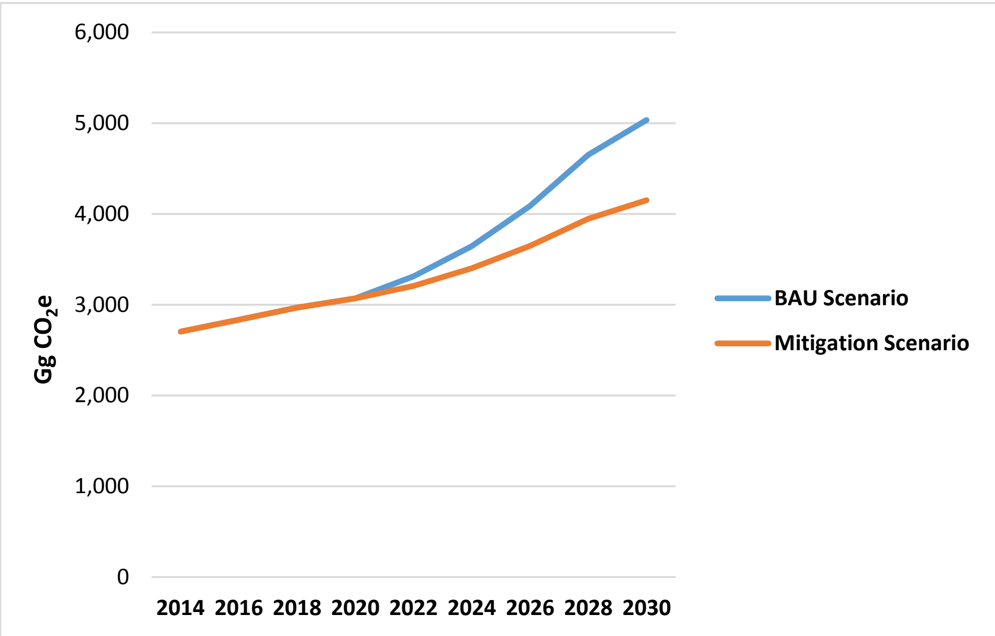


Figure 8: BAU and Mitigation Trajectory (CO2eq) – Agriculture

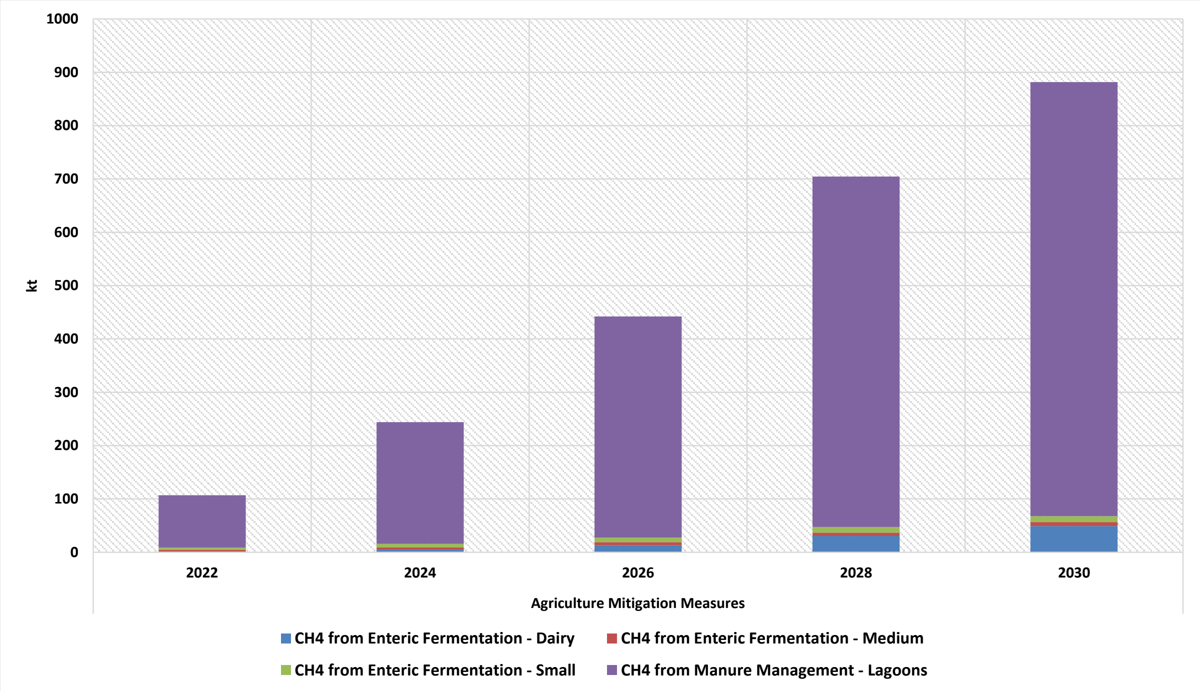


Figure 9: Contribution from Individual Mitigation Measures (CO_2eq) – Agriculture

5.3 Mitigation Potential in the Waste Sector

The mitigation opportunities and main 2030 impacts in the Waste Management sector are listed in Table 9, and Table 10 provides the emissions levels for BAU and each of the mitigation measures and the reductions from the BAU for each Waste Management measure. Overall the GHG emissions growth is slowed from 26% in the BAU scenario to a reduction of 41% below the BAU assuming full attainment of the identified mitigation measures. Figure 10 shows the BAU and mitigation scenarios emission profiles, and Figure 11 the reduction contribution to from each Waste Management measure. Note that there is also a small increase in N_2O emissions from the bio-treatment of waste.

The key measure is obviously capping of landfills to capture the methane that would otherwise be released directly to the atmosphere.

Table 9: Considered Mitigation Measures & Emission Levels - Waste Sector

Mitigation Measure	Description	Impact by 2030
Measure W1. Setup of paper, plastic, glass and metal separation system in municipalities	A gradual introduction and proper functioning of municipal waste separate collection system, which implies a reduction of waste at landfills, as well as facilitation of their reuse and recovery, including recycling.	Methane reduction in Solid waste disposal category of 5.10 Gg CH_4 (107.19 Gg CO_2 eq) by 2030
Measure W2. Construction of solid municipal waste processing plant in Tbilisi	Complete reprocessing of solid waste generated throughout Tbilisi from 2018 onward.	Methane reduction in Solid waste disposal category of 14.57 Gg CH_4 (306.03 Gg CO_2 eq)
Measure W3. Setup of biogas flaring/utilization system on Tbilisi (Norio) landfill	It is assumed that starting from 2018 80% of methane emissions from Tbilisi landfill will be captured and flared.	Methane reduction in Solid waste disposal category of – 3.00 Gg CH_4 (63.09Gg CO_2 eq) (together with measure W2)
Measure W4. Biogas collection and flaring/utilization system setup in new Adjara	It is assumed that 80% of methane emissions from new Adjara landfills will be captured and flared.	Methane reduction in Solid waste disposal category of 3.38 Gg CH_4 (71.09 Gg CO_2 eq)

landfills		
Measure W5. Biogas flaring/utilization system setup in Rustavi landfill	It is assumed that starting from 2019, 80% of methane emissions from Rustavi landfill will be captured and flared.	Methane reduction in Solid waste disposal category of 1.11 Gg CH4 (23.35 Gg CO2 eq)
Measure W6. Biogas collection and flaring/utilization system setup in Kutaisi, Telavi and Borjomi landfills	It is assumed that starting from 2019 80% of methane emissions from Kutaisi, Telavi and Borjomi landfill will be captured and flared. The landfills will be closed in 2025.	Methane reduction in Solid waste disposal category of 1.65 Gg CH4 (34.63 Gg CO2 eq)
Measure W7. Biogas flaring/utilization system setup in new regional landfills of Georgia	It is assumed that 80% of methane emissions from new regional landfills throughout Georgia, which will be commissioned in 2025, will be captured and flared.	Methane reduction in Solid waste disposal category of 7.01 Gg CH4 (147.13Gg CO2 eq)
Measure W8. Reduction of biodegradable waste allocation - biodegradable waste composting	The measure assumes that the extraction (separation) of organic fraction (food and garden bulk) for the purpose of further composting will be performed in 20% of new regional landfills reaching up to 80% of organic waste allocated there.	Methane reduction in Solid waste disposal category of 0.85 Gg CH4, (17.86 Gg CO2 eq) by 2030 N2O Increment in the category of biological treatment of solid waste by 0.013 Gg N2O (4.04 Gg CO2 eq)
Measure W9. Incineration and co-incineration	Measure includes creation of legal base for incineration and co-incineration practices in Georgia.	Emission reductions not assessed and thus not considered in mitigation scenario results.
Measure W10. Methane collection and application in Adlia water treatment plant	To assess the effect of the measure it was assumed that 80% of methane generated at Adlia wastewater treatment plant will be captured and flared.	Methane reduction at domestic wastewater treatment and disposal category of 1.12 Gg CH4 (23.4 Gg CO2 eq). In case part of methane is used for electricity generation, additional 0.176 Gg CO2 will be reduced from energy sector, but this is not considered in mitigation scenario.

Table 10: BAU and Mitigation Scenario Emission Levels - Waste

Greenhouse gas source and sink categories	2014	2016	2018	2020	2022	2024	2026	2028	2030	2030 % Reduction
	GHG emissions and Removals (Gg CO2e)									
BAU Scenario										
6. Waste	**1,255**	**1,281**	**1,310**	**1,360**	**1,417**	**1,481**	**1,549**	**1,619**	**1,690**	
A. Solid waste disposal	905	915	934	962	995	1,034	1,076	1,120	1,163	
B. Biological treatment of	0	0	0	0	0	0	0	0	0	
C1. Domestic	308	321	327	344	362	380	398	416	434	
C2. Industrial	41	44	49	54	60	67	75	83	93	
Mitigation Scenario										
6. Waste	**1,255**	**1,281**	**1,119**	**1,057**	**1,019**	**1,015**	**1,031**	**1,025**	**896**	47.0%
A. Solid waste disposal	905	915	743	659	597	568	558	546	389	66.6%
B. Biological treatment of	0	0	0	0	0	0	0	3	4	n/a
C1. Domestic	308	321	327	344	362	380	398	392	411	5.4%
C2. Industrial	41	44	49	54	60	67	75	83	93	0.0%
Reduction					398	466	518	594	794	
% Reduction					28.1%	31.5%	33.5%	36.7%	47.0%	

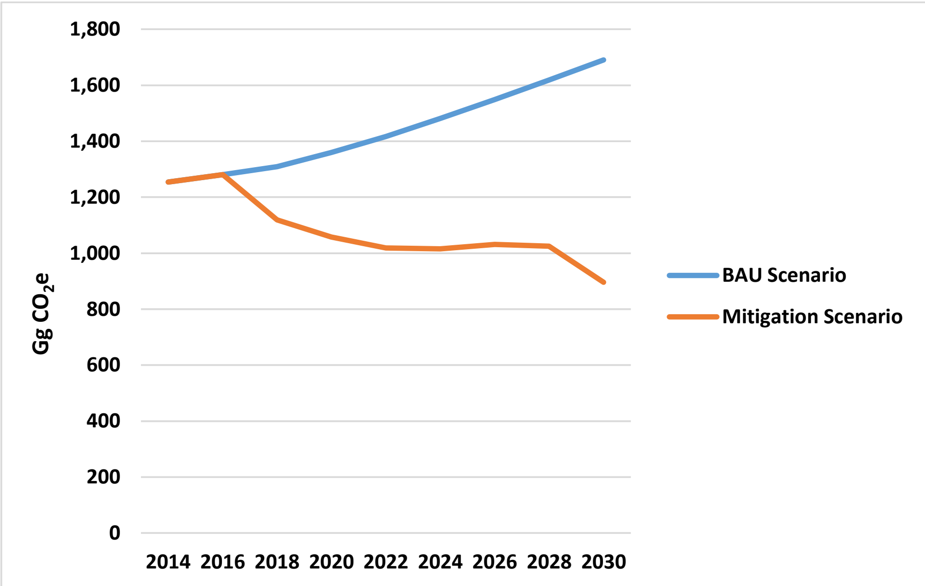


Figure 10: BAU and Mitigation Trajectory (CO2eq) – Waste Management

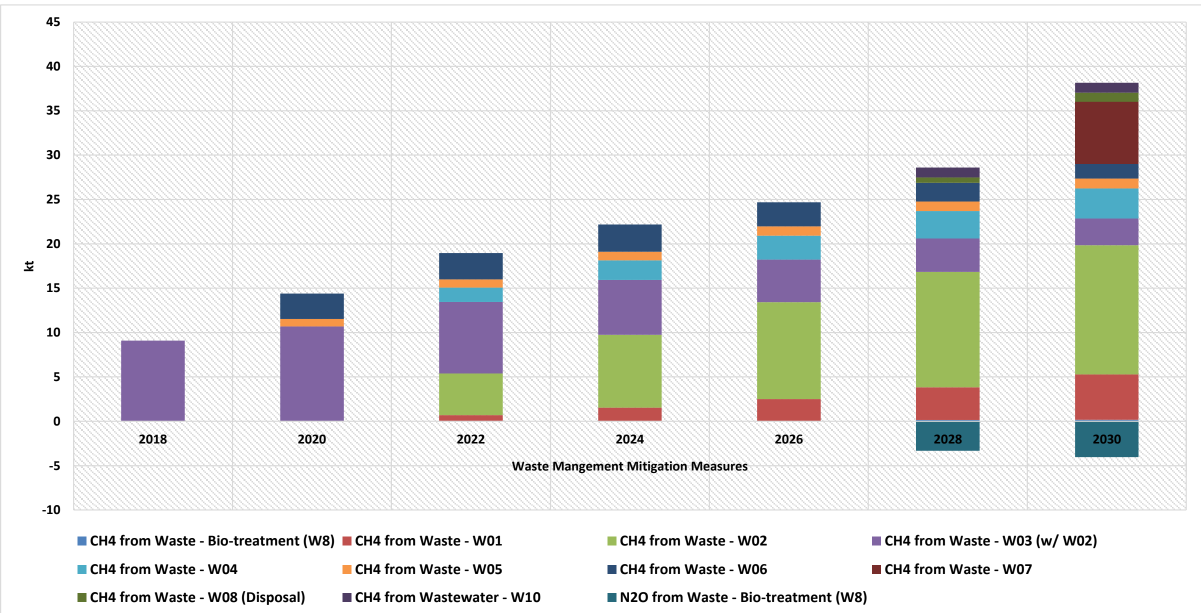


Figure 11: Contribution from Individual Mitigation Measures (CO2eq) – Waste Management

5.4 Mitigation Potential in the LULUCF Sector

The mitigation opportunities and main 2030 impacts in the LULUCF sector are listed in **Error! Reference source not found.**, and The key measures center around the National Forest Agency's policy and programs planned to preserve and the improve quality of the country's forests through implementing new forest codes and sustainable management practices.

Table 11 provides the emissions levels for BAU and each of the mitigation measures. Overall the GHG emissions growth is slowed from 119% increase in the BAU scenario (due to less sequestration) to an 8% reduction in 2030 assuming full attainment of the identified mitigation measures. Figure 12 shows the BAU and mitigation scenarios emission profiles, and Figure 13 the reduction contribution to from each LULUCF measure.

The key measures center around the National Forest Agency's policy and programs planned to preserve and the improve quality of the country's forests through implementing new forest codes and sustainable management practices.

Table 11: BAU and Mitigation Scenario Emission Levels - LULUCF

Greenhouse gas source and sink categories		GHG emissions and Removals (Gg CO2e) 2014	2016	2018	2020	2022	2024	2026	2028	2030	2030 % Reduction
BAU Scenario											
5. LULUCF		-3,087	-3,023	-2,804	-2,578	-2,276	-2,024	-1,798	-1,578	-1,408	
	A. Forest Lands	-2,737	-2,748	-2,688	-2,618	-2,468	-2,368	-2,288	-2,208	-2,178	
	B. Croplands	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	
	C. Grasslands	2,330	2,405	2,564	2,720	2,872	3,024	3,170	3,310	3,450	
Mitigation Scenario											
5. LULUCF		-3,087	-3,024	-3,001	-3,355	-3,397	-3,403	-3,372	-3,343	-3,359	-138.5%
	A. Forest Lands	-2,737	-2,749	-2,885	-3,391	-3,579	-3,727	-3,829	-3,924	-4,068	-86.7%
	B. Croplands	-2,680	-2,680	-2,680	-2,682	-2,685	-2,689	-2,694	-2,701	-2,707	-1.0%
	C. Grasslands	2,330	2,405	2,564	2,718	2,867	3,014	3,151	3,283	3,416	1.0%
	Reduction			196	777	1,120	1,378	1,573	1,764	1,950	
	% Reduction			-7.0%	-30.1%	-49.2%	-68.1%	-87.5%	-111.8%	-138.5%	

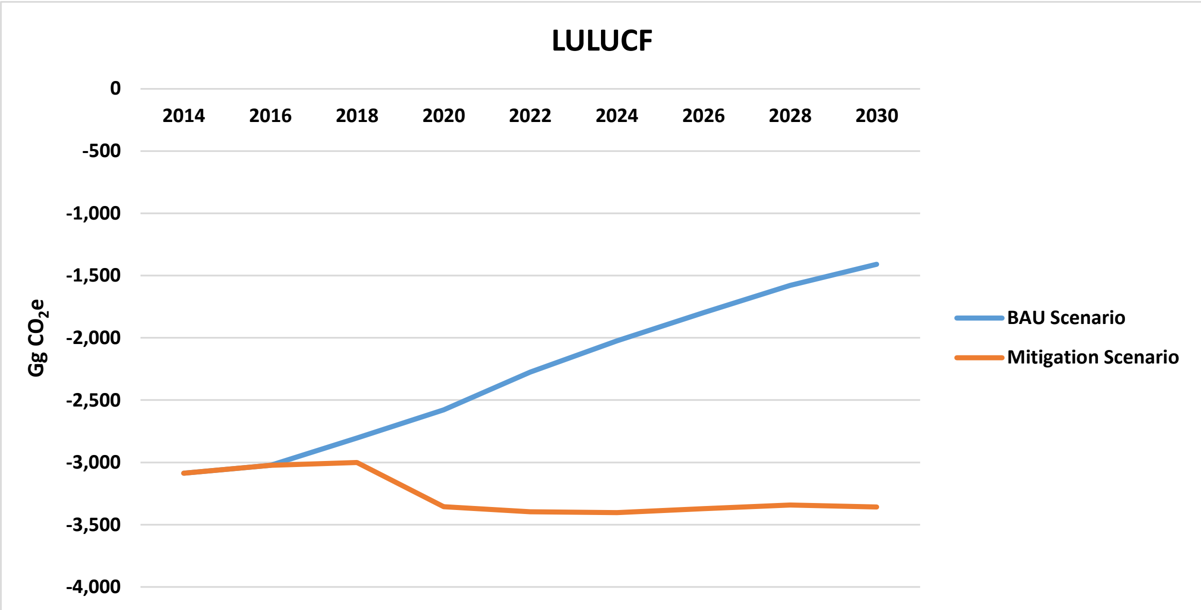


Figure 12: BAU and Mitigation Trajectory (CO2eq) - LULUCF

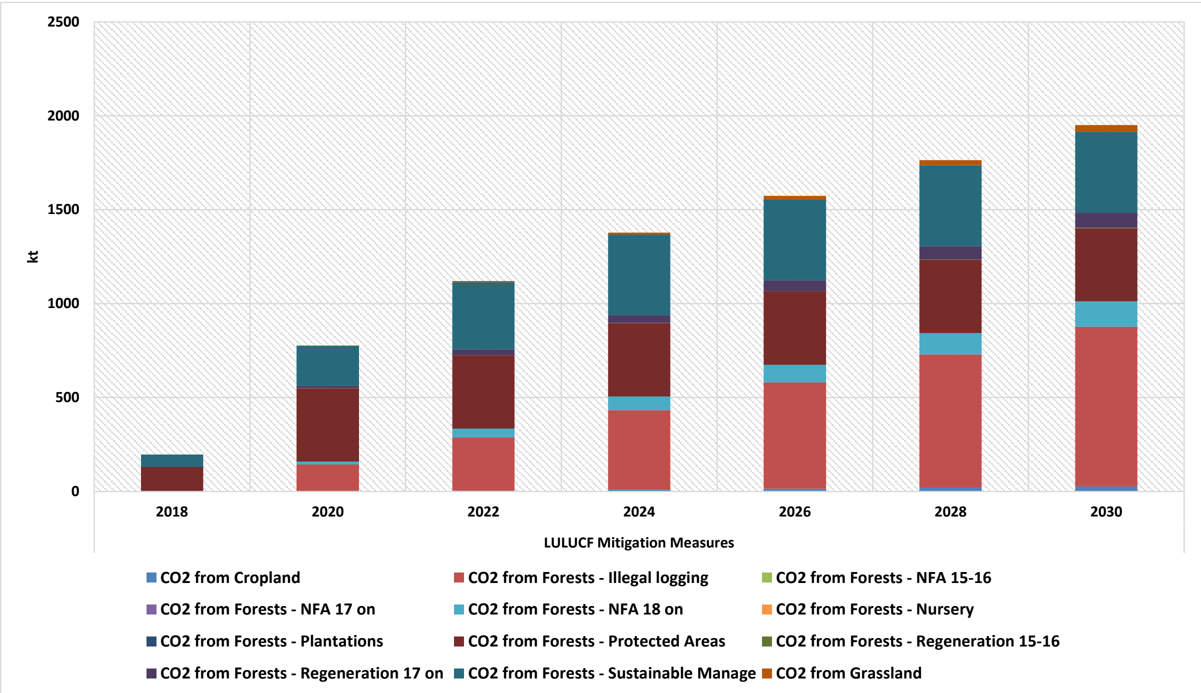


Figure 13: Contribution to Reductions from Individual Mitigation Measures (CO2eq) – LULUCF

5.5 Overall Mitigation Potential in the Non-Energy Sectors

Unlike the energy sector, where actions untaken in one part of the system may have an effect on another, each non-energy subsector acts independently, although there can sometimes be interactions within a sector. Therefore, the reductions obtained from the individuals measures within each sector can be summed to provide a mitigation profile for all non-energy sectors as shown in Figure 14. As described in the sections above, the key measures are those related to:

- Better manure management practices for livestock;
- Shifting from wet to dry processing in the cement industry (for the Kaspi plant);
- Actions to curb N2O releases from nitric acid production;
- Implementation of sustainable management practices for forests, and
- Process facilities to handle solid waste.

This initial analysis assumes that the full potential is achieved for all mitigation measures in the non-energy sectors, and as a result emissions from non-energy sources can be reduced by 69% by 2030 compared to the BAU. If we don't consider LULUCF, then the other non-energy sectors can achieve a 33% reduction.

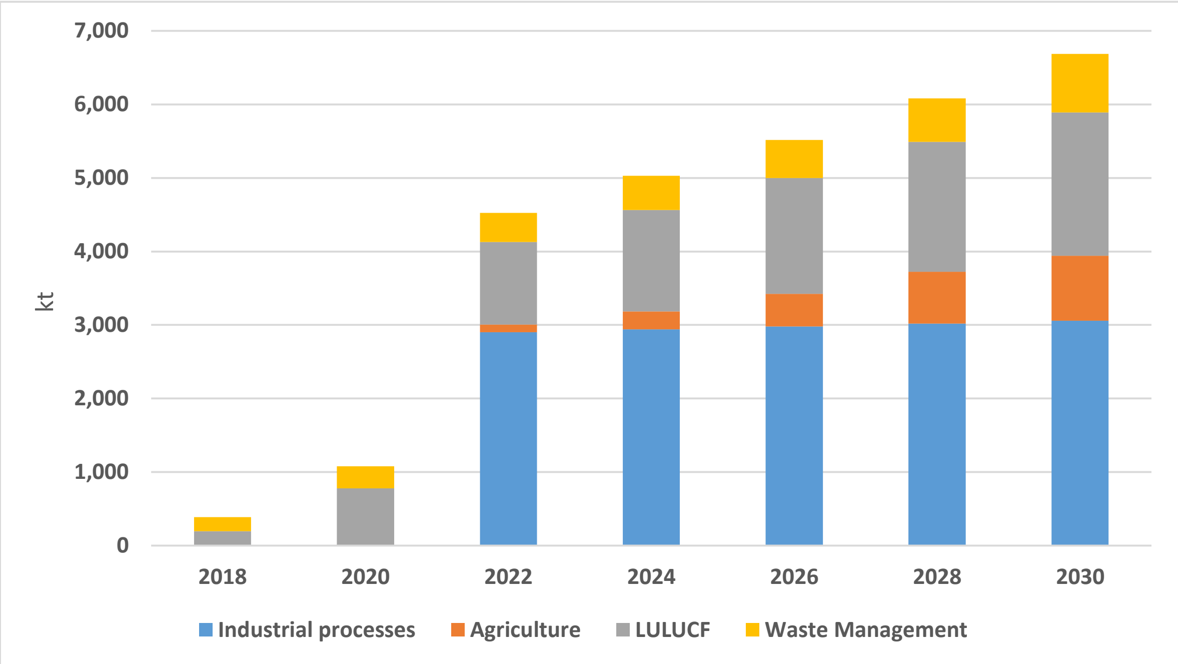


Figure 14: Reduction of GHG Emissions (CO2eq) from the Non-Energy Sector

Note that for the most part the non-energy and energy measures to not interact, with the exception of the LULUCF measure to prevent illegal felling of trees in national forests. As discussed in Section 7 looking at the combined energy and non-energy mitigation picture owing to the restriction on the availability of wood for heating, hot water, and cooking to meet these demands more natural gas, LPB and electricity is needed, resulting in more GHG emissions from the Buildings sector.

6 Energy Sector Mitigation Measures Results

This section summarizes the results of the previous detailed analysis of mitigation measures for the energy sector. The main outcome arising from the mitigation measures in each energy demand sector are identified in Table 12. Detailed results for each measure can be found in the Mitigation Measures analysis report[2], and summary tables for the combined runs are reproduced in Appendix A of this report to provide some insight into them, as they underpin the comprehensive GHG analysis undertaken.

6.1 Energy Sector Combined Mitigation Measures

Many of the individual LEDS measures have some overlapping or counteracting impacts that are not necessarily additive, and so the MARKAL-Georgia model was used to ensure that the combined impacts of the measures is properly integrated. This section summarizes the combination scenarios for each sector and the full set of integrated measures for Georgia, where the All LEDS Energy Measures scenario is also unpins the contribution from the energy sector measures reported on for the comprehensive GHG analysis discussed in Section 7.

Table 12: Summary of Results for Sectoral and All LEDS Energy Measures

Measure	Impact in 2030
All supply and power sector measures	• Reduce natural gas imports by 12.7% and lowers GHG emissions by 13.3% (2.54 Mt). • Reduces fuel costs by 104 MEUR and power plant investment increases by 408 MEUR. • Reduces energy system costs by 72 MEUR.
All Buildings (Commercial and Residential) Sector Measures	• Reduces natural gas imports by 9.4%, electricity generation by 8.4% and GHG emissions by 5.6% (1074 kt). • Reduces fuel expenditures by 153 MEUR and power plant investment by 937 MEUR. • Reduces energy system costs by 671 MEUR.
All Industry Sector Measures	• Reduces natural gas imports by 0.9% and electricity generation by1.4%. • Reduces fuel expenditures by 45 MEUR and power plant investment by 165 MEUR. • Reduces CO2 emissions by 4% and GHG emissions by 3.7% (710 kt). • Reduces energy system costs by 224 MEUR.
All Transport Sector Measures and Mode Shifts	• Reduces transport final energy use by 17.7% and total fuel expenditures by 409 MEUR. • Decreases natural gas imports by 4.1%, and total imports by 8.6%. • Increases electricity generation by 2.1% and power plant investment by 236 MEUR. • Decreases GHG emissions by 8.3% (1570 kt). • Decreases energy system costs by 4.62 BEUR, but not all infrastructure costs are included.
All LEDS Measures	• Reduces total final energy use by 15.7% and total fuel expenditures by 705 MEUR. • Decreases natural gas imports by 26%, and total imports by 22%. • Decreases electricity generation by 11% and power plant investment by 450 MEUR. • Decreases GHG emissions by 29.4% (5596 kt). • Decreases energy system costs by 5.6 BEUR, but not all infrastructure costs are included.
Most Feasible LEDS Measures	• Reduces total final energy use by 7.8% and total fuel expenditures by 435 MEUR in 2030. • Decreases natural gas imports by 14.6% and total imports by 13.4%. • Decreases electricity generation by 5.1% and power plant investment by 2.27 BEUR. • Decreases GHG emissions by 21.2% (4036 kt). • Decreases energy system costs by 3.2 BEUR, but not all infrastructure costs are included.

The trajectory of emission for the BAU scenario and the All Energy Measures scenario is shown in Table 13 and Figure 16. Figure 16 shows the breakdown on GHG emission reductions from the energy sector, indicating that by 2030 the potential exists to reduce GHG emissions from the energy sector by 27.6% compared to the BAU.

Table 13: BAU and All Energy Mitigation Scenario GHG Emission Levels

Greenhouse gas source and sink categories	GHG emissions and Removals (Gg CO2e)								
	2014	2016	2018	2020	2022	2024	2026	2028	2030
BAU									
1. Energy	**9,428**	**10,345**	**11,369**	**12,529**	**13,793**	**14,946**	**16,481**	**17,771**	**19,036**
A. Fuel combustion (sectoral approach)	8,117	8,893	9,776	10,774	11,868	12,846	14,189	15,227	16,285
1. Energy Industries	1,128	1,235	1,305	1,372	1,442	1,511	1,963	2,041	2,122
2. Manufacturing industries and	1,638	1,749	1,906	2,100	2,321	2,568	2,841	3,144	3,478
3. Transport	3,493	3,768	4,221	4,685	5,213	5,576	5,949	6,378	6,789
4a. Commercial/Institutional	465	548	581	631	682	740	774	810	861
4b. Residential	1,367	1,567	1,735	1,957	2,177	2,417	2,625	2,814	2,991
4c. Agriculture/Forestry/Fishin	25	26	28	30	32	34	37	40	43
B. Fugitive emissions from fuels	1,311	1,452	1,593	1,754	1,925	2,099	2,292	2,544	2,751
1. Solid fuels	84	104	114	126	140	154	274	292	313
2. Oil and natural gas	1,227	1,347	1,479	1,628	1,786	1,945	2,018	2,252	2,438
Mitigation Scenario									
1. Energy	**9,427**	**10,060**	**10,575**	**10,669**	**11,401**	**12,023**	**12,737**	**13,149**	**13,778**
A. Fuel combustion (sectoral approach)	8,116	8,617	9,173	9,391	10,173	10,862	11,641	12,145	12,873
1. Energy Industries	1,128	1,236	1,268	1,055	1,043	1,049	1,205	1,135	1,140
2. Manufacturing industries and	1,638	1,749	1,905	1,760	1,929	2,148	2,393	2,562	2,867
3. Transport	3,493	3,527	3,674	3,995	4,371	4,579	4,782	5,023	5,270
4a. Commercial/Institutional	465	540	565	604	644	688	710	732	764
4b. Residential	1,367	1,538	1,734	1,946	2,154	2,364	2,513	2,654	2,789
4c. Agriculture/Forestry/Fishin	25	26	28	30	32	34	37	40	43
B. Fugitive emissions from fuels	1,311	1,444	1,401	1,279	1,228	1,160	1,096	1,004	905
1. Solid fuels	84	104	114	94	107	121	240	248	268
2. Oil and natural gas	1,227	1,339	1,287	1,185	1,121	1,039	856	756	637
Reduction		284	795	1,859	2,392	2,923	3,744	4,622	5,258
% Reduction		2.7%	7.0%	14.8%	17.3%	19.6%	22.7%	26.0%	27.6%

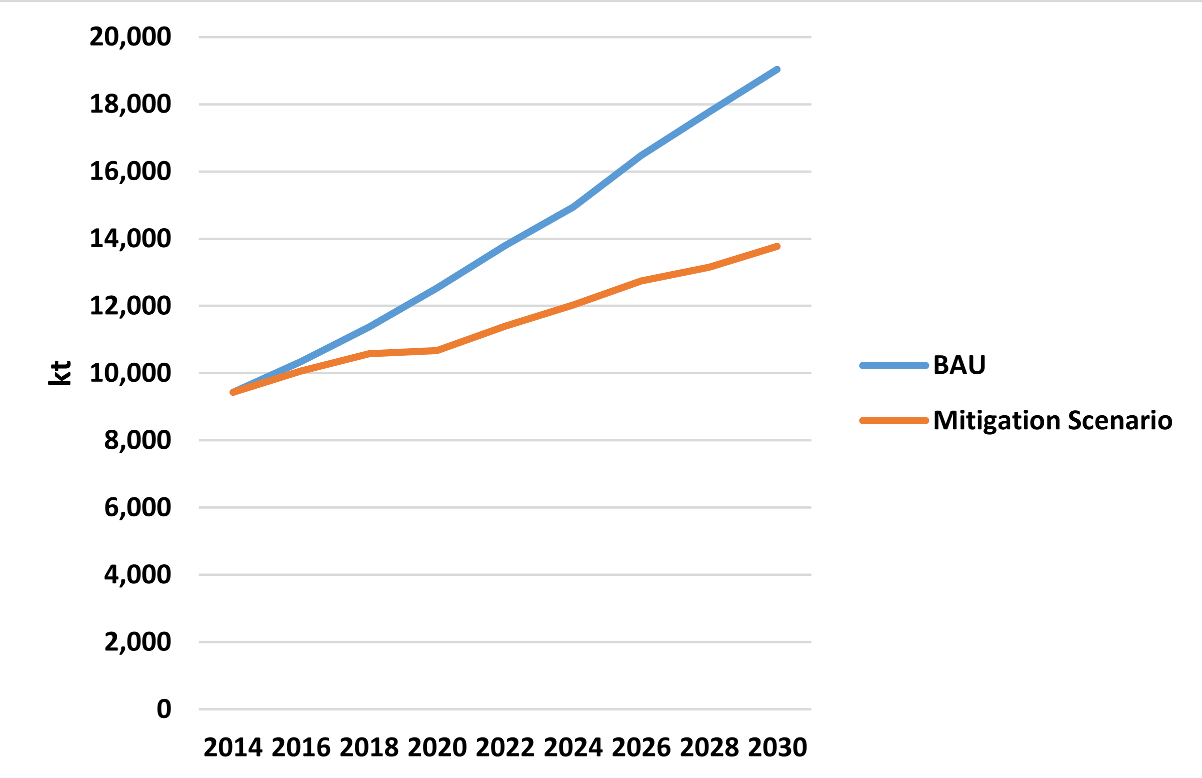


Figure 15: BAU and All Mitigation Scenario GHG Emissions Trajectories (CO2eq) - Energy

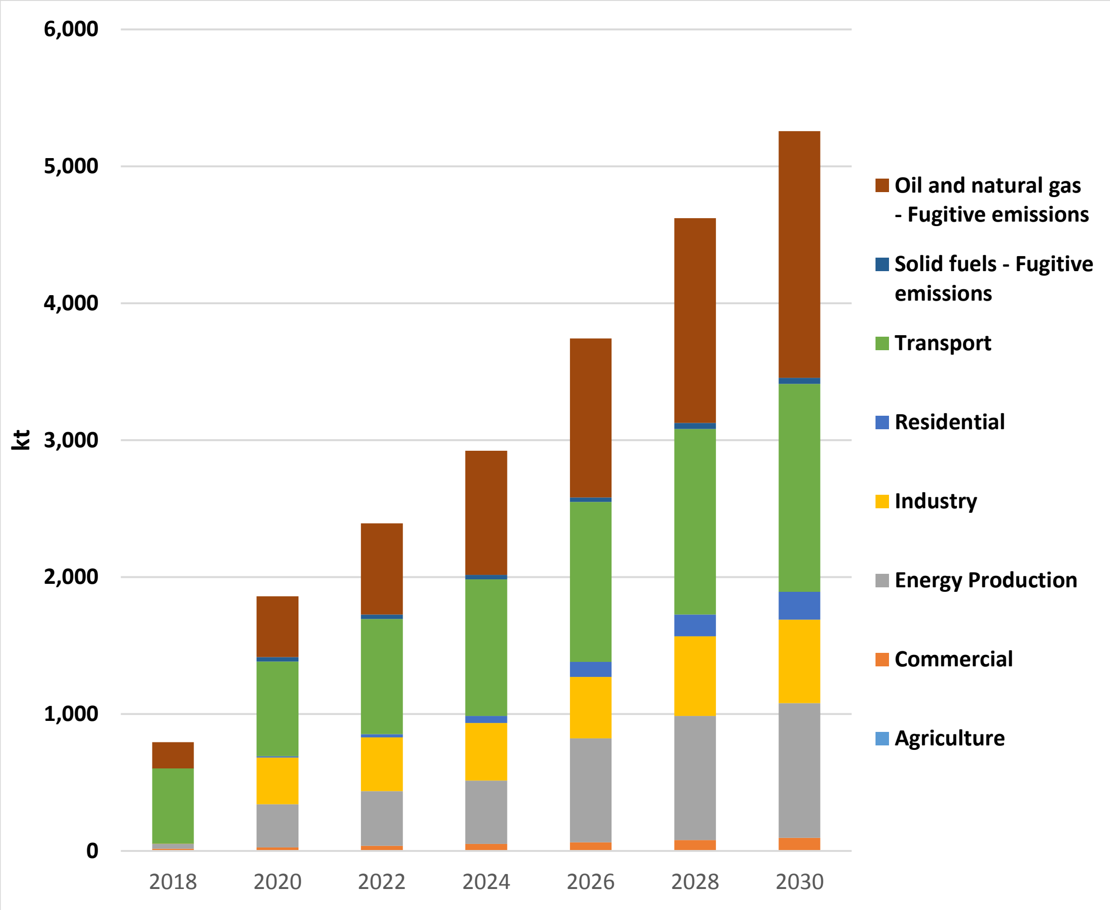


Figure 16: GHG Reductions for the All Mitigation Measures by Sector (CO2eq)

Figure 17 shows the reductions in CO_2, methane and GHG emissions for the set of all combined energy sector measures. The power sector contributes 45% of all GHG emission reductions in the All LEDS policies run due to the significant methane reduction measure in the gas distribution network. The Feasible LEDS policies case, which includes this measure, still achieves a 21% reduction.

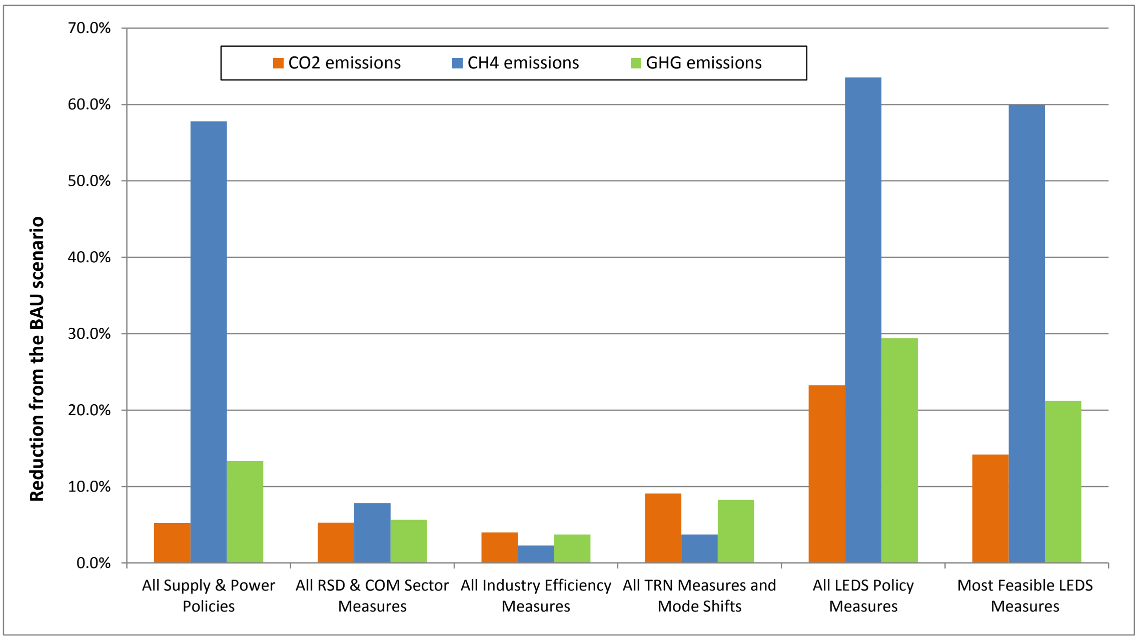


Figure 17: Impact of Sectoral and Combined LEDS Measures – Emissions

The Most Feasible energy mitigation measures were also run along with the non-energy measures, but the impact on the system was the same as was seen when just the energy measures were examined, owing to the independence of the choices between the two parts of the system.

7 Assessment of Combined Energy and Non-Energy Sector Action

The challenge for Georgia as it looks to plan their LEDS pathway is to find the right balance of most effective measures to curb GHG emissions while supporting robust economic growth. This section of the report looks at the comprehensive GHG landscape in the country to identify which sectors and measures will help Georgia to achieve its LEDS goals. In Appendix C the UNFCCC Emissions and Reduction tables for the BAU and mitigation scenario can be found providing a snapshot of the GHG profiles under each situation.

From information provided by the energy sector LEDS WGs and the non-energy sector experts a comprehensive mitigation scenario was established, where the level of mitigation achieved by each measure is determined outside the model, a. Thus, the model provides more of a simulation than an optimization (with some consideration having been given in the interdependencies of specific energy sector measures) to develop the resulting combined energy system and non-energy sector emissions profile. Table 14 provides an overall summary of how the Combined scenario affects the emission profile, and Figure 18 shows the GHG emission trajectories for the BAU and Combined mitigation measures run. Figure 20 shows the emission reduction contributions from each sector for the Combined scenario.

Looking across all energy and non-energy sectors, the full mitigation potential of the combined measures will slow overall emission growth from 127% above 2014 levels to just 33%, reducing GHG emissions in 2030 by some 42% compared with the BAU. It should be noted that since the energy and non-energy sectors have no overlap (with the exception of the demand for firewood, discussed below) in terms of their mitigation actions the scenario is essential the cumulative result of applying all measures.

Table 14: Combined Energy & Non-Energy Mitigation Measure Reductions

All Non-Energy & Energy Measures Change from BAU										
	GHG emissions and Removals (Gg CO2e) with LULUCF									Change
Greenhouse gas source and sink categories	2014	2016	2018	2020	2022	2024	2026	2028	2030	in 2030
1. Energy	0	-284	-795	-1,859	-2,392	-2,923	-3,744	-4,622	-5,258	-28%
2. Industrial processes	0	0	0	0	-2,900	-2,941	-2,982	-3,021	-3,061	-71%
4. Agriculture	0	0	0	0	-107	-244	-442	-705	-881	-18%
5. LULUCF	0	0	-196	-777	-1,120	-1,378	-1,573	-1,764	-1,950	-138%
6. Waste	0	0	-191	-302	-398	-466	-518	-594	-794	-47%
Total national emissions and removals	0	-284	-1,182	-2,938	-6,918	-7,952	-9,259	-10,707	-11,944	-42%
		-2%	-8%	-17%	-34%	-36%	-38%	-40%	-42%	

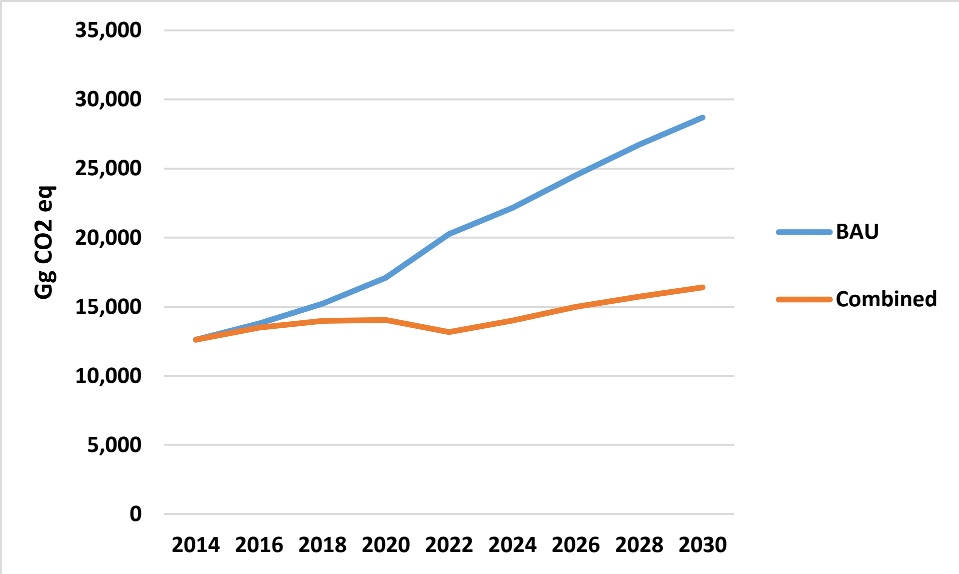


Figure 18: BAU and Combined Mitigation Measures GHG Emissions (CO2eq)

The LULUCF measure restricting illegal forest cuttings assumes that the felling of trees for fuel wood will be halved by 2030 compared to 2014. This results in increases removals from LULUCF sector as noted earlier. But at the same time the measure has an effect on energy emissions, because when amount of available fuel wood reduces, the individuals will need to use some other fuel for heating, hot water and cooking. Table 15 shows the net effect of the LULUCF measure on illegal forest logging. So the overall impact of the measure in 2030 is 506 Gg of CO2e.

Table 15: Effect of LULUCF Illegal Logging Measure

Effect on Emissions (Gg CO2e)	2020	2022	2024	2026	2028	2030
Increase of removals in LULUCF sector	-141	-283	-424	-566	-707	-849
Increase of Emissions in energy sector	43	102	152	225	280	343
Overall net removals from the measure	**-98**	**-181**	**-272**	**-341**	**-427**	**-506**

The most affected energy sector is residential, where natural gas consumption is increased (by 1.7PJ in 2030) and to LPG (increase of 5PJ in 2030). This is all very logical because by 2030 fuel wood is mostly consumed in areas where gas is not available. This switch causes the increase in CO_2 emissions, and decrease in methane and NO2 emissions from incomplete combustion, because fuel wood has quite high emission factors for methane and N2O from incomplete combustion. Overall GHG emissions in buildings sector are increased by 330 Gg in 2030 (CO_2 emissions increase by 408 Gg, methane decrease by 62 and N2O decrease by 18 Gg CO2e). Figure 19 shows the GHG emissions from Buildings sector in BAU scenario (blue), in case when only energy sector measures are implemented (red), and in case when LULUCF measure is also implemented (gray). It shows that LEDS energy measures reduce emissions in buildings sector by 630Gg by 2030, but LULUCF measure on illegal cuttings causes increase of these emissions by 330Gg, so overall emissions in buildings sector are reduced by only 300Gg with combined energy and LULUCF measures.

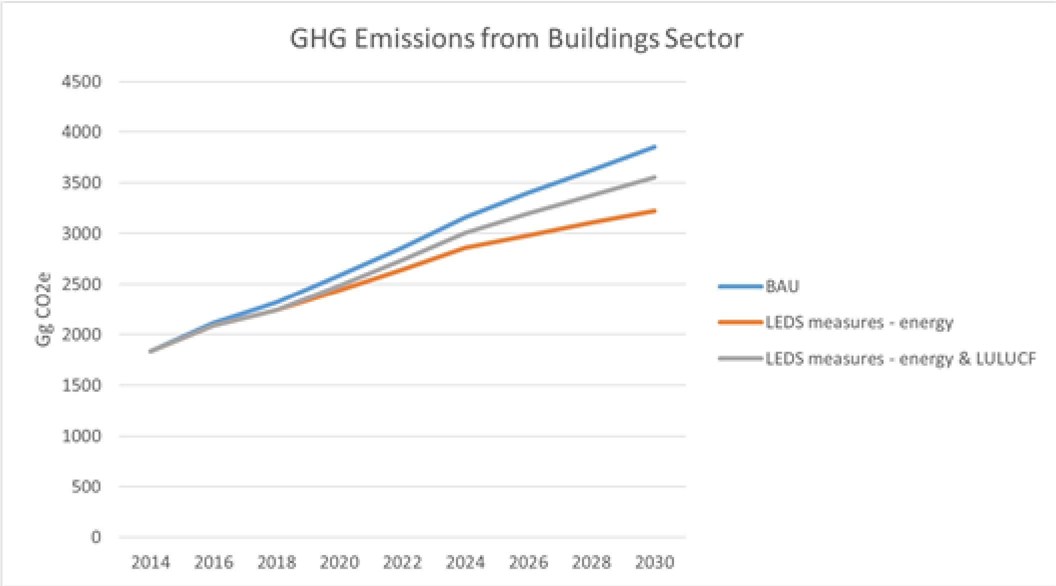


Figure 19: Effect on Building Sector GHG Emissions from Prevention of Illegal Logging

Other than buildings sector there is an effect on fugitive emissions from gas distribution (in energy supply sector) because of increased natural gas consumption and overall effect on energy emissions is increase by 343 Gg as depicted in Table above.

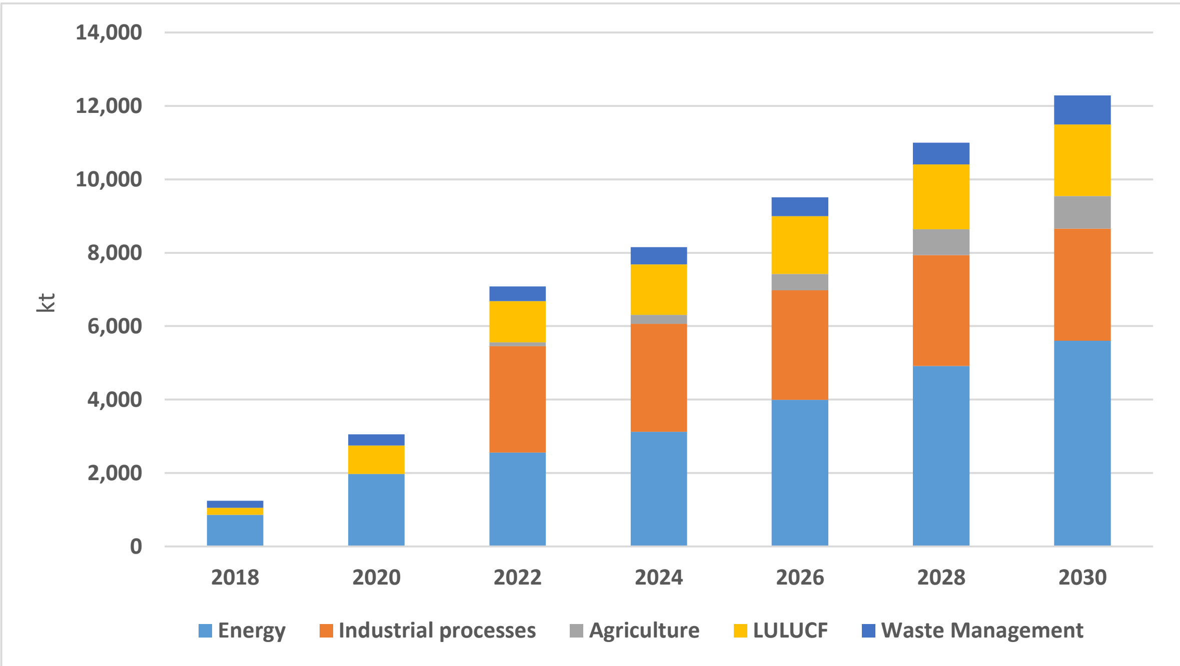


Figure 20: GHG Emission Reductions from the Combined Scenario (CO2eq)

Two other comprehensive runs were also examined, the Feasible (or most likely) energy mitigation measures and an (partial) Optimal scenario. In the Feasible run, the full set of non-energy mitigation measures were added to the Feasible set of energy measures. This Combined Feasible run showed the same scaled difference (in terms of higher cost, emissions, etc.) as was seen when examining only the All Energy mitigation measures scenario. Thus, it is not included in this report.

In the Optimal scenario, the energy and non-energy mitigation measures were allowed to compete against each other under an emissions cap similar to the emissions profile from the Combined run. One caveat to the term Optimal is that not all the mitigation measures have cost information that would allow them to compete, so some measures remained fixed, and so this run represents only a partial optimization, but that was the most possible from the available data. However, this run showed little difference from the prescriptive scenario so is not presented here either.

8 Conclusions

The analyses presented in this report were performed using the MARKAL-Georgia model and the best available local data, augmented by international data for future technology characterizations. As described in the Energy sector Mitigation report, the energy sector LEDS measures were identified by sector-based Working Groups (WG) and represent practical and implementable options for Georgia. Likewise, the non-energy sector emissions baseline and mitigation measures were developed by sector experts as the most practical and implementable options for Georgia.

The report presents the GHG emissions baseline and mitigation options for each non-energy sector:

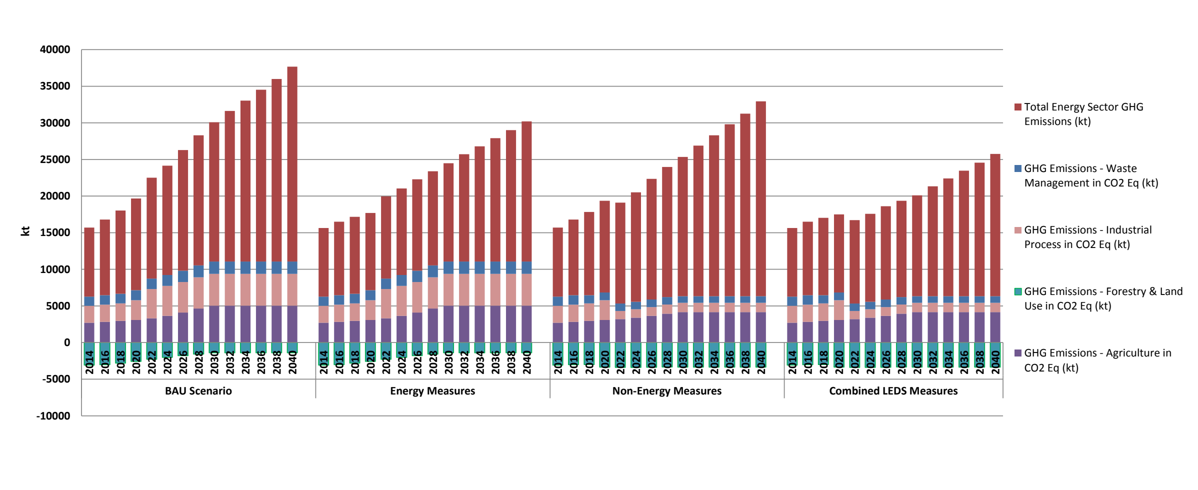
- Agriculture,
- Land Use, Land-Use Change and Forestry (LULUCF)
- Industrial processes, and
- Waste Management;

and examines them individually in some details and collectively with the energy sector. Thus, complete the coverage of GHG emissions was provided, a BAU projection developed for the all sectors, and some fifty eight non-energy mitigation measures were identified and added to the options discussed in the Energy Mitigation Measures report.

This report looks at the emission profile and level of avoided GHG emissions arising from for four (4) main scenarios:

- BAU with full GHG accounting;
- All energy sector mitigation measures;
- All non-energy sector mitigation measures
- Combined energy and non-energy mitigation measures (prescriptive).

Figure 21 presents the full GHG emissions profile for Georgia for the 4 scenario listed above, and clearly shows the importance of looking at the entire emission profile and mitigation options to get a complete picture for LEDS. The figure shows that nearly equal levels of mitigation will come from the energy and non-energy sectors by 2030. The difference in cumulative emission levels and reductions from all measures is clearly seen, pointing out that approximately 25% of emissions arise from the non-energy sector (40% excluding LULUCF sequestration).



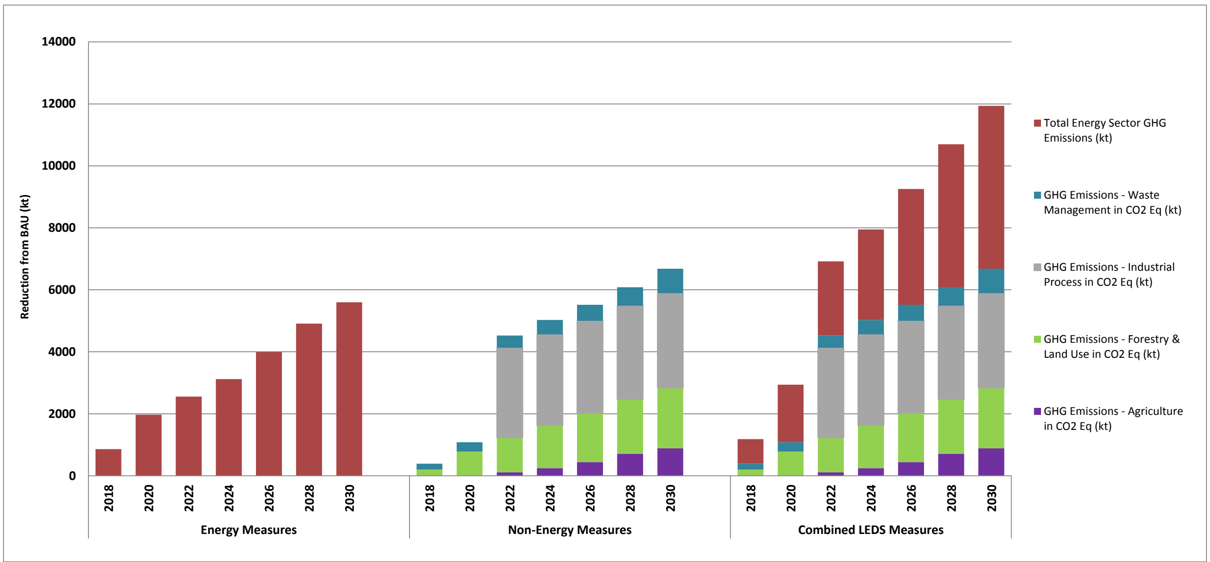


Figure 21: BAU GHG Emission Levels and Mitigation Reductions (CO2 eq)

The impact all measures acting in concert to reduce the BAU emission trajectory is shown in Figure 22, showing that overall emission are cut 42% by 2030.

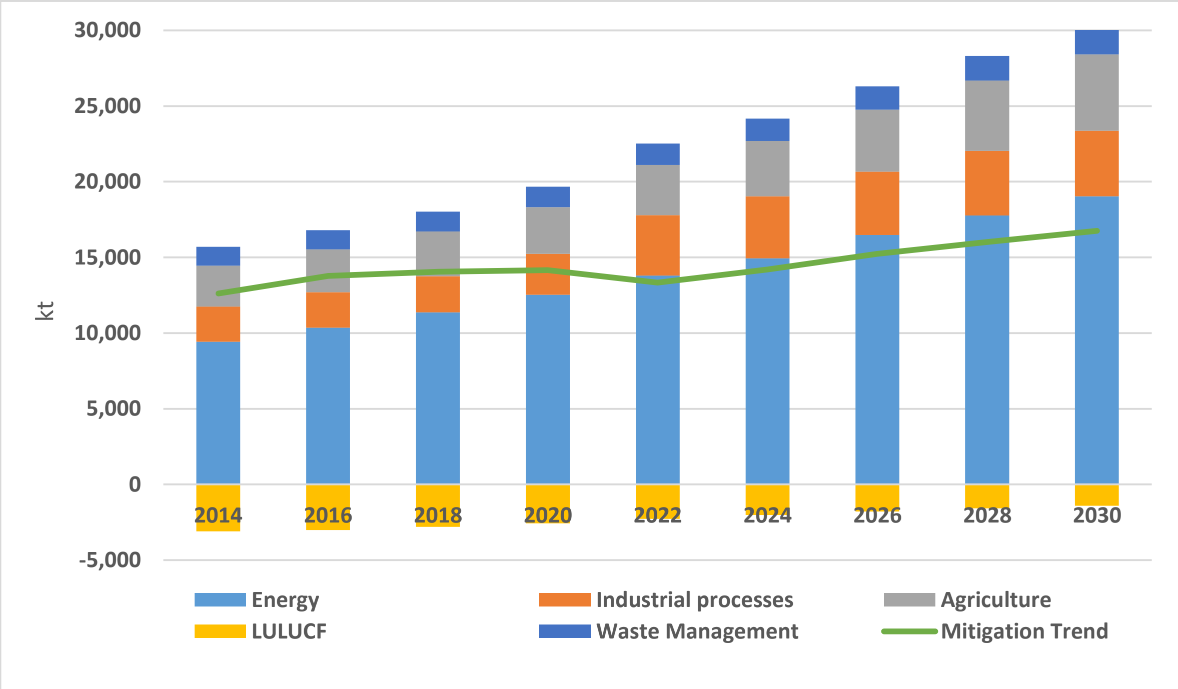


Figure 22: BAU GHG Emission Profile and Mitigation Trajectory (CO2 eq)

The most important measure for the GOG to consider as it plans its LEDS and the pathway that will achieve the NDC goals are listed in Table 16.

Table 16: Key Mitigation Measure in Each Sector

Sector	Key Measure
Agriculture	Lagoons for handling livestock manure
Energy	• Supply - stemming leaks in the gas pipeline network, improved efficiency of thermal plants • Buildings – promoting efficiency (e.g., lighting, appliances, building shells) • Industry – implement sub-sector-specific energy efficiency measures • Transport - improve fleet efficiency, increase use of alternative fuels (CNG and electricity), shift truck freight traffic to rail, promote mode-shifts (to public transit and non-energy modes (e.g., walking/biking)
Industrial Processes	• Shifting from wet to dry processing in the cement industry (for the Kaspi plant) • Actions to curb N2O releases from nitric acid production
LULUCF	Implementation of sustainable management practices for forests
Waste Management	Process facilities to handle solid waste in landfills

The Combined scenario demonstrates a viable framework for full GHG accounting and the examination of mitigation actions across all sectors of the economy producing GHG emissions. It is a first big step to unpin analytically LEDS planning, where the next step would be a full set of reliable cost estimates for the various measures to enable examination of how the two sector might "compete" to meet NDC targets at least-cost.

Appendix A: Detailed Results of Combined Sector Energy Mitigation Measures

Indicator	Units	Reference	All Supply & Power Policies			All RSD & COM Sector Measures			All Industry Efficiency Measures			All TRN Measures and Mode Shifts		
			Absolute value	Difference	Difference (%)	Absolute value	Difference	Difference (%)	Absolute value	Difference	Difference (%)	Absolute value	Difference	Difference (%)
Total Discounted Energy System Cost (2014-2030)	2014M€	58,659	58,587	-72	-0.1%	57,988	-671	-1.1%	58,415	-244	-0.4%	54,035	-4,624	-7.9%
Primary Energy Supply -2030	PJ	409	389	-21	-5.0%	388	-22	-5.3%	401	-8	-2.1%	389	-20	-4.9%
All Imports -2030	PJ	267	248	-19	-7.2%	252	-15	-5.8%	263	-4	-1.7%	245	-22	-8.2%
Natural gas Imports	PJ	152	133	-19	-12.7%	138	-14	-9.4%	150	-1	-0.9%	146	-6	-4.1%
Net Electricty Exports	Gwh	-13,529	-12,370	1,160	-8.6%	-13,696	-167	1.2%	-13,524	5	0.0%	-13,526	3	0.0%
Electricity Generation	Gwh	31,380	30,218	-1,162	-3.7%	28,758	-2,622	-8.4%	30,926	-454	-1.4%	32,032	652	2.1%
Fuel Expenditure - 2030	2014M€	2,773	2,669	-104	-3.8%	2,620	-153	-5.5%	2,727	-45	-1.6%	2,363	-409	-14.8%
Power Plant Capacity -2030	GW	9	9	0	0.0%	8	-1	-5.7%	9	0	-1.0%	9	0	1.4%
Hydro Power Plant Capacity -2030	GW	8	8	0	-1.0%	7	-1	-6.6%	8	0	-1.2%	8	0	1.7%
Thermal (gas and coal) Power Plant Capacity-2030	GW	1.08	1.01	0	-6.5%	1.08	0	0.0%	1.08	0	0.0%	1.08	0	0.0%
Renewable Power Plant Capacity-2030	GW	0.02	0.17	0	724.6%	0.02	0	0.0%	0.02	0	0.0%	0.02	0	0.0%
Power Plant New Capacity (2014-2030)	GW	5.35	5.92	1	10.7%	4.85	-1	-9.4%	5.26	-0.09	-1.7%	5.48	0	2.4%
Power Plant Investment Cost (2014-2030)	2014M€	8,049	8,457	408	5.1%	7,112	-937	-11.6%	7,884	-165	-2.0%	8,285	236	2.9%
Total Final Energy - 2030	PJ	302	302	0	0.0%	283	-19	-6.4%	294	-8	-2.7%	282	-20	-6.7%
Transport Final Energy - 2030	PJ	114	114	0	0.0%	114	0	0.0%	114	0	0.0%	94	-20	-17.7%
Buildings Sector Final Energy - 2030	PJ	88	88	0	0.0%	75	-12	-14.1%	88	0	0.0%	88	0	0.0%
Industry Final Energy - 2030	PJ	61	61	0	0.0%	61	0	0.0%	53	-8	-13.0%	61	0	0.0%
Total CO_2 Emissions - 2030	Kt	15,994	15,158	-836	-5.2%	15,153	-841	-5.3%	15,354	-640	-4.0%	14,538	-1,456	-9.1%
Transport sector CO2 Emissions - 2030	Kt	6,709	6,709	0	0.0%	6,709	0	0.0%	6,709	0	0.0%	5,205	-1,504	-22.4%
Buildings sector CO2 Emissions - 2030	Kt	2,816	2,816	0	0.0%	2,277	-539	-19.2%	2,817	1	0.0%	2,816	0	0.0%
Industry sector CO2 Emissions - 2030	Kt	3,461	3,461	0	0.0%	3,460	-1	0.0%	2,854	-608	-17.6%	3,461	0	0.0%
Power sector CO2 Emissions - 2030	Kt	2,111	1,275	-836	-39.6%	1,907	-204	-9.7%	2,078	-33	-1.6%	2,158	48	2.3%
Total Methane Emissions -2030	Kt	140	59	-81	-57.8%	129	-11	-7.8%	137	-3	-2.3%	135	-5	-3.7%
Total N2O Emissions -2030	Kt	0.33	0.31	0	-4.5%	0.32	0	-4.3%	0.32	0	-2.9%	0.31	0	-4.6%
Total GHG emissions	Kt CO2 eq	19,025	16,490	-2,535	-13.3%	17,951	-1,074	-5.6%	18,315	-710	-3.7%	17,454	-1,570	-8.3%

Indicator	Units	Reference	All LEDS measures			Feasable measures		
			Absolute value	Difference	Difference (%)	Absolute value	Difference	Difference (%)
Total Discounted Energy System Cost (2014-2030)	2014M€	58 659	53 084	-5 575	-9.5%	55 452	-3 207	-5.5%
Primary Energy Supply -2030	Ktoe	409	340	-69	-16.8%	368	-41	-9.9%
All Imports -2030	Ktoe	267	208	-60	-22.3%	232	-36	-13.4%
Natural gas Imports	Ktoe	152	112	-40	-26.0%	130	-22	-14.6%
Net Electricty Exports	Gwh	-13 529	-12 679	850	-6.3%	-12 727	802	-5.9%
Electricity Generation	Gwh	31 380	27 932	-3 448	-11.0%	29 793	-1 587	-5.1%
Fuel Expenditure - 2030	2014M€	2 773	2 067	-705	-25.4%	2 337	-435	-15.7%
Power Plant Capacity -2030	GW	9	8	-0.459	-5.2%	9	-0.223	-2.5%
Hydro Power Plant Capacity -2030	GW	8	7	-0.539	-7.0%	8	-0.153	-2.0%
Thermal (gas and coal) Power Plant Capacity-2030	GW	1.08	1.01	0	-6.5%	1.01	0	-6.5%
Renewable Power Plant Capacity-2030	GW	0.02	0.17	0	724.6%	0.02	0	0.0%
Power Plant New Capacity (2014-2030)	GW	5.35	5.46	0	2.1%	5.70	0	6.5%
Power Plant Investment Cost (2014-2030)	2014M€	8 049	7 600	-449.69	-5.6%	8 121	72.26	0.9%
Total Final Energy - 2030	Ktoe	302	254	-47	-15.7%	278	-23	-7.8%
Transport Final Energy - 2030	Ktoe	114	94	-20	-17.7%	101	-14	-11.9%
Buildings Sector Final Energy - 2030	Ktoe	118	99	-19	-16.2%	114	-4	-3.4%
Industry Final Energy - 2030	Ktoe	61	53	-8	-13.1%	56	-6	-9.4%
Total CO_2 Emissions - 2030	Kt	15 994	12 277	-3 717	-23.2%	13 726	-2 268	-14.2%
Transport sector CO2 Emissions - 2030	Kt	6 709	5 205	-1 504	-22.4%	5 685	-1 024	-15.3%
Buildings sector CO2 Emissions - 2030	Kt	3 671	3 045	-626	-17.0%	3 597	-74	-2.0%
Industry sector CO2 Emissions - 2030	Kt	3 461	2 852	-610	-17.6%	3 024	-437	-12.6%
Power sector CO2 Emissions - 2030	Kt	2 111	1 133	-978	-46.3%	1 377	-733	-34.7%
Total Methane Emissions -2030	Kt	139.97	51	-89	-63.6%	56	-84	-60.0%
Total N2O Emissions -2030	Kt	0.33	0.28	0	-16.1%	0.30	0	-9.4%
Total GHG emissions	Kt CO2 eq	19 035	13 434	-5 601	-29.4%	14 995	-4 040	-21.2%
GHG Emissions CO2eq								
Transport	Kt CO2 eq	6 789	5 270	-1 519	-22.4%	5 757	-1 032	-15.2%
Buildings	Kt CO2 eq	3 852	3 222	-630	-16.4%	3 778	-74	-1.9%
Industry	Kt CO2 eq	3 478	2 866	-612	-17.6%	3 039	-439	-12.6%
Agriculture	Kt CO2 eq	43	43	0	0%	43	0	0.0%
Power	Kt CO2 eq	2 122	1 139	-984	-46.4%	1 384	-738	-34.8%
Fugitives	Kt CO2 eq	2751	895	-1 856	-67.5%	993	-1 757	-63.9%
Total	Kt CO2 eq	19 036	13 434	-5 601	-29.4%	14 995	-4 040	-21.2%

Appendix B: Non-Energy BAU and Mitigation Measures Details

The non-energy BAU and mitigation measures have been prepared from the sector reports and provided by the sectors in the form of Excel workbooks that are then transformed into input templates that can be directly loaded into the MARKAL-Georgia model as separate scenarios. The spreadsheets for each sector are below first BAU then the mitigation measures. Each of the Categories shaded green are the rows loaded into the model (where the GHG CO2eq conversion is done as needed).

B.1: Industrial Processes BAU and Mitigation Measures Specification Worksheets

Sector:	Cement production (Mineral Products)														
Emissions															
SubCategory/Gas	Unit	2014	2016	2018	2020	2022		2024		2026		2028		2030	
SubCategory 1: Kaspi plant															
						dry	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**
CO_2	Gg	455.4	479.16	479.16	479.16	411.84	566.28	427.68	588.06	443.52	609.84	459.36	631.62	475.2	653.4
SubCategory 2: Rustavi 1 plant															
CO_2	Gg	201.96	217.8	239.58	261.36		283.14		283.14		283.14		283.14		283.14
SubCategory 3: Rustavi 2 plant															
CO_2	Gg	180.48	175.68	179.04	182.4	185.28		188.64		190.08		190.08		190.08	
SubCategory 4: Senaki plant															
CO_2	Gg				288	336		384		432		480		528	
Sector Cement Total															
CO_2	Gg	837.84	872.64	897.78	1210.92	933.12	849.42	1000.32	871.2	1065.6	892.98	1129.44	914.76	1193.28	936.54

Sector:	Ammonia production (Chemical)									
Emissions										
SubCategory/Gas	Unit	2014	2016	2018	2020	2022	2024	2026	2028	2030
SubCategory 5: Ammonia production										
CO_2	Gg	330.45	304.5	304.5	304.5	609	609	609	609	609
Sector Ammonia Total										
CO_2	Gg	330.45	304.5	304.5	304.5	609	609	609	609	609

Sector:	Nitric acid production (Chemical 2)									
Emissions										
SubCategory/Gas	Unit	2014	2016	2018	2020	2022	2024	2026	2028	2030
SubCategory 6: Nitric acid production										
CO_2	Gg									
N_2O	Gg	2.653	2.653	2.653	2.653	5.238	5.238	5.238	5.238	5.238
Sector Nitric acid Total										
CO_2 eq	Gg	822.43	822.43	822.43	822.43	1623.78	1623.78	1623.78	1623.78	1623.78

Sector:	Iron and steel production (Metal Production)									
Emissions										
SubCategory/Gas	Unit	2014	2016	2018	2020	2022	2024	2026	2028	2030
SubCategory 7: Iron and steel production										
CO_2	Gg	21.2	24.56	27.92	31.2	34.56	37.92	41.28	44.64	48
Sector Iron and steel Total										
CO_2	Gg	21.2	24.56	27.92	31.2	34.56	37.92	41.28	44.64	48

Sector:	Ferroalloys production (Metal Production 2)									
Emissions										
SubCategory/Gas	Unit	2014	2016	2018	2020	2022	2024	2026	2028	2030
SubCategory 8: Ferroalloys production										
CO_2 - Siliconmanganese production	Gg	298.2	302.4	310.8	327.6	345.8	364	373.8	383.6	385
CO_2 - Ferromanganese production	Gg	6.9	18	18	18	18	18	18	18	18
Sector Ferroalloys Total										
CO_2	Gg	305.1	320.4	328.8	345.6	363.8	382	391.8	401.6	403

Sector:	Cement production (Mineral Products)														
Emissions															
SubCategory/Gas	Total Investment (M$)	cost/savings ($/ton reduced)	Unit	2018	2020	2022		2024		2026		2028		2030	
SubCategory 1: Kaspi plant															
						dry	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**	**dry**	**wet**
CO2 (wet to dry)			Gg			154.44		160.38		166.32		172.26		178.2	
CO2 (2.1.1 - sub lime)			Gg			20.592		21.384		22.176		22.968		23.76	
CO2 (2.1.2 - sub pozz)			Gg												
CO2 (2.1.3 - ash, 50%)			Gg			195.62		203.15		210.67		218.2		225.7	
SubCategory 2: Rustavi 1 plant															
CO2 (2.1.1 - sub lime)			Gg				14.157		14.157		14.157		14.157		14.157
CO2 (2.1.2 - sub pozz)			Gg												
CO2 (2.1.3 - ash, 50%)			Gg				134.49		134.49		134.49		134.49		134.49
SubCategory 3: Rustavi 2 plant															
CO2 (2.1.1 - lime)			Gg			9.264		9.432		9.504		9.504		9.504	
CO2 (2.1.2 - sub pozz)			Gg												
CO2 (2.1.3 - ash, 50%)			Gg			88.008		89.604		90.288		90.288		90.29	
SubCategory 4: Senaki plant															
CO2 (2.1.1 - lime)			Gg			16.8		19.2		21.6		24		26.4	
CO2 (2.1.2 - sub pozz)			Gg												
CO2 (2.1.3 - ash, 50%)			Gg			159.6		182.4		205.2		228		250.8	
Sector Cement Total															
CO2			Gg	0	0	644.33	148.65	685.55	148.65	725.76	148.65	765.22	148.65	804.7	148.65

Sector:	Ammonia production (Chemical)									
Emissions										
SubCategory/Gas	Total investment	cost/savings ($/ton reduced)	Unit	2018	2020	2022	2024	2026	2028	2030
SubCategory 5: Ammonia production										
CO2 (2.2.1 - solvent scrub)	€ 13.80	€ (5.41)	Gg			517	517	517	517	517

Sector:	Nitric acid production (Chemical 2)									
Emissions										
SubCategory/Gas	Total investment	cost/savings ($/ton reduced)	Unit	2018	2020	2022	2024	2026	2028	2030
SubCategory 6: Nitric acid production										
N2O (2.3.1 - Opt Ox)			Gg			5.13	5.13	5.13	5.13	5.13
N2O (2.3.2 - alt Ox)	€ 2.00	€ (1.55)	Gg							2.6
N2O (2.3.3 - Decomp Ox)	€ 0.00	€ -	Gg							4.45
N2O (2.3.4 - Decomp ExReactor)			Gg							3.14
N2O (2.3.5 - Cat perform)			Gg							0.524
N2O (2.3.6 - Tailgas)	€ 2.10	€ 2.10	Gg							5.21
N2O (2.3.7 - Non-Sel Cat)	€ 0.14	€ 0.14	Gg							4.97

B.2: Agriculture BAU and Mitigation Measures Specification Worksheets

Sector:	Agriculture									
Emissions										
SubCategory/Gas	Unit	2014	2016	2018	2020	2022	2024	2026	2028	2030
SubCategory 1: Manure Managemet										
CO2	Gg									
CH4	Gg	7.1	7.4	7.7	8.0	14.5	23.5	36.2	52.7	63.5
CH4	Gg CO2eq	149	155	162	167	304	494	760	1106	1333
N2O	Gg	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
N20	Gg CO2eq	144	145	147	149	150	152	153	155	156
Total for Subcategory	Gg CO2eq	293	300	309	316	454	646	913	1261	1489
SubCategory 2: Enteric Fermentation										
CO2	Gg									
CH4	Gg	64.0	65.3	66.6	66.6	66.9	68.8	72.7	78.2	80.7
CH4	Gg CO2eq	1345	1371	1398	1398	1405	1444	1526	1642	1694
N2O	Gg									
N20	Gg CO2eq									
Total for Subcategory	Gg CO2eq	1345	1371	1398	1398	1405	1444	1526	1642	1694
SubCategory N3: Direct Emissions from the soil										
CO2	Gg									
CH4	Gg									
CH4	Gg CO2eq									
N2O	Gg	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7
N20	Gg CO2eq	638	700	762	824	886	948	1010	1072	1139
Total for Subcategory	Gg CO2eq	638	700	762	824	886	948	1010	1072	1139
SubCategory N4: Indirect emissions from the soil										
CO2	Gg									
CH4	Gg									
CH4	Gg CO2eq									
N2O	Gg	1.37	1.49	1.61	1.72	1.84	1.95	2.06	2.18	2.30
N20	Gg CO2eq	426	462	498	533	569	605	640	676	712
Total for Subcategory	Gg CO2eq	426	462	498	533	569	605	640	676	712
Sector Total										
CO2	Gg									
CH4	Gg	71.1	72.7	74.3	74.5	81.4	92.3	108.9	130.9	144.1
CH4	Gg CO2eq	1494	1526	1560	1565	1709	1938	2286	2748	3027
N2O	Gg	3.90	4.22	4.54	4.86	5.18	5.50	5.82	6.14	6.47
N20	Gg CO2eq	1208	1307	1407	1506	1605	1705	1803	1903	2007
Total for Sector	Gg CO2eq	2702	2833	2967	3071	3314	3643	4089	4651	5034

Sector:	Agriculture									
Emissions										
SubCategory/Gas	Total Investment (EuroM)	Operating cost/savings ($/ton reduced)	Unit	2018	2020	2022	2024	2026	2028	2030
SubCategory 1: Manure Management (Anaerobic digestion & bio gas)										
CO2			Gg							
CH4 Dairy to Lagoons	€ 7.44		Gg	0.00	0.00	2.44	6.87	14.50	24.42	29.77
CH4 Dairy to Lagoons			Gg CO2eq	0.00	0.00	51.29	144.25	304.53	512.90	625.09
CH4 Swine to Lagoons	€ 1.80		Gg	0.00	0.00	2.25	4.00	5.25	6.87	8.98
CH4 Swine to Lagoons			Gg CO2eq	0.00	0.00	47.15	83.93	110.34	144.28	188.61
N2O (cattle)			Gg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N2O (cattle)			Gg CO2eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2O (swine)			Gg	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
N2O (swine)			Gg CO2eq	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total for Subcategory			Gg CO2eq	0	0	98	228	415	657	814
SubCategory 2: Enteric Fermentation										
CO2			Gg							
CH4 (small)	€ -	€ -	Gg	0.00	0.00	0.21	0.31	0.41	0.50	0.54
CH4 (small)			Gg CO2eq	0.00	0.00	4.47	6.56	8.55	10.45	11.36
CH4 (medium)	€ -	€ -	Gg	0.00	0.00	0.14	0.20	0.26	0.32	0.34
CH4 (medium)			Gg CO2eq	0.00	0.00	2.85	4.18	5.45	6.65	7.24
CH4 (dairy)	€ -	€ -	Gg	0.00	0.00	0.06	0.24	0.64	1.44	2.34
CH4 (dairy)			Gg CO2eq	0.00	0.00	1.26	4.96	13.46	30.24	49.14
N2O			Gg							
N2O			Gg CO2eq							
Total for Subcategory			Gg CO2eq	0	0	9	16	27	47	68
Sector Total										
CO2			Gg	0	0	0	0	0	0	0
CH4			Gg	0.0	0.0	2.9	7.6	15.8	26.7	33.0
CH4			Gg CO2eq	0.0	0.0	107.0	243.9	442.3	704.5	881.4
N2O			Gg	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
N2O			Gg CO2eq	0.0	0.0	0.0000	0.0000	0.0000	0.0000	0.0000
Total for Sector			Gg CO2eq	0	0	107	244	442	705	881

B.3: Waste Management BAU and Mitigation Measures Specification Worksheets

Sector:	Waste									
Emissions										
SubCategory/Gas	Unit	2014	2016	2018	2020	2022	2024	2026	2028	2030
SubCategory 1: Solid Waste Disposal										
CO2	Gg									
CH4	Gg	43.1	43.6	44.5	45.8	47.4	49.2	51.3	53.3	55.4
CH4	Gg CO2eq	905.3	915.3	934.5	961.6	995.1	1033.6	1076.5	1119.8	1162.9
N2O	Gg									
N20	Gg CO2eq									
Total for Subcategory	**Gg CO2eq**	**905.3**	**915.3**	**934.5**	**961.6**	**995.1**	**1033.6**	**1076.5**	**1119.8**	**1162.9**
SubCategory 2: Domestic wastewater treatment and discharge										
CO2	Gg									
CH4	Gg	10.43	10.97	11.13	11.88	12.64	13.41	14.17	14.93	15.70172
CH4	Gg CO2eq	219.01	230.28	233.76	249.49	265.48	281.71	297.61	313.48	329.74
N2O	Gg	0.29	0.29	0.30	0.31	0.31	0.32	0.32	0.33	0.34
N2O	Gg CO2eq	89.07	90.92	92.74	94.61	96.51	98.45	100.43	102.45	104.51
Total for Subcategory	**Gg CO2eq**	**308.07**	**321.20**	**326.50**	**344.10**	**361.99**	**380.16**	**398.04**	**415.93**	**434.24**
SubCategory 3: Industrial wastewater treatment and discharge										
CO2	Gg									
CH4	Gg	1.97	2.11	2.31	2.57	2.87	3.2	3.56	3.97	4.43
CH4	Gg CO2eq	41.37	44.31	48.51	53.97	60.27	67.2	74.76	83.37	93.03
N2O	Gg									
N2O	Gg CO2eq									
Total for Subcategory	**Gg CO2eq**	**41.37**	**44.31**	**48.51**	**53.97**	**60.27**	**67.2**	**74.76**	**83.37**	**93.03**
Sector Total										
CO2	Gg	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH4	Gg	55.51	56.66	57.94	60.24	62.90	65.83	68.99	72.22	75.51
CH4	Gg CO2eq	1165.68	1189.93	1216.76	1265.08	1320.85	1382.50	1448.85	1516.63	1585.63
N2O	Gg	0.29	0.29	0.30	0.31	0.31	0.32	0.32	0.33	0.34
N2O	Gg CO2eq	89.07	90.92	92.74	94.61	96.51	98.45	100.43	102.45	104.51
Total for Sector	**Gg CO2eq**	**1254.74**	**1280.84**	**1309.51**	**1359.69**	**1417.36**	**1480.95**	**1549.28**	**1619.08**	**1690.14**

Sector:	Waste									
Emissions										
SubCategory/Gas	Unit	Upfront Investment Costs (EuroM)	Annual cost (EuroM/kton emissions reduced)	2018	2020	2022	2024	2026	2028	2030
SubCategory 1: Solid Waste Disposal										
CO2	Gg									
CH4	Gg			-9.1	-14.4	-19.0	-22.2	-24.7	-27.3	-36.9
CH4	Gg CO2eq			-191.0	-302.4	-398.3	-465.8	-518.3	-574.0	-774.0
	Measure W1			0.0	0.0	-0.7	-1.5	-2.5	-3.7	-5.1
	Measure W2	€ 72.73		0.0	0.0	-4.7	-8.2	-10.9	-13.0	-14.6
	Measure W3 (with W2)	€ 1.67		-9.1	-10.7	-8.1	-6.2	-4.8	-3.8	-3.0
	Measure W3 (without W2)	€ 1.67		-9.1	-10.7	-11.8	-12.8	-13.5	-14.2	-14.7
	Measure W4	€ 0.60		0.0	0.0	-1.6	-2.2	-2.7	-3.1	-3.4
	Measure W5	€ 0.30		0.0	-0.8	-0.9	-1.0	-1.0	-1.1	-1.1
	Measure W6	€ 0.90		0.0	-2.9	-3.0	-3.1	-2.7	-2.1	-1.6
	Measure W7	€ 1.50		0.0	0.0	0.0	0.0	0.0	0.0	-7.0
	Measure W8		€ 0.80	0.0	0.0	0.0	0.0	0.0	-0.6	-1.0
N2O	Gg									
N2O	Gg CO2eq									
Total for Subcategory	**Gg CO2eq**			**-191.0**	**-302.4**	**-398.3**	**-465.8**	**-518.3**	**-574.0**	**-774.0**
SubCategory 2: Domestic wastewater treatment and discharge										
CO2	Gg									
CH4	Gg			0.00	0.00	0.00	0.00	0.00	-1.12	-1.12
CH4	Gg CO2eq			0.00	0.00	0.00	0.00	0.00	-23.44	-23.44
	Measure W10	€ 0.84		0.00	0.00	0.00	0.00	0.00	-1.12	-1.12
N2O	Gg									
N2O	Gg CO2eq			0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total for Subcategory	**Gg CO2eq**			**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**-23.44**	**-23.44**
SubCategory 4: Biological treatment of solid waste										
CO2	Gg									
CH4	Gg			0.00	0.00	0.00	0.00	0.00	0.14	0.17
CH4	Gg CO2eq			0.00	0.00	0.00	0.00	0.00	3.00	3.65
	Measure W8			0.00	0.00	0.00	0.00	0.00	0.14	0.17
N2O	Gg			0.00	0.00	0.00	0.00	0.00	0.01	0.01
N2O	Gg CO2eq			0.00	0.00	0.00	0.00	0.00	3.32	4.04
	Measure W8			0.00	0.00	0.00	0.00	0.00	0.01	0.01
Total for Subcategory	**Gg CO2eq**			**0**	**0**	**0**	**0**	**0**	**6.318013**	**7.687825**
Sector Total										
CO2	Gg			0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH4	Gg			-9.1	-14.4	-19.0	-22.2	-24.7	-28.3	-37.8
CH4	Gg CO2eq			-191.0	-302.4	-398.3	-465.8	-518.3	-594.5	-793.8
N2O	Gg			0.00	0.00	0.00	0.00	0.00	0.01	0.01
N2O	Gg CO2eq			0.00	0.00	0.00	0.00	0.00	3.32	4.04
Total for Sector	**Gg CO2eq**			**-191.01**	**-302.38**	**-398.31**	**-465.85**	**-518.27**	**-591.14**	**-789.78**

B.4: LULUCF BAU and Mitigation Measures Specification Worksheets

Sector:	LULUCF			
Emissions				
SubCategory/Gas	Unit	2014	2016	20
SubCategory 1: Forest Lands (5A)				
CO2	Gg	-2740.00	-2750.00	-2690.
CH4	Gg	0.11	0.06	0.
CH4	Gg CO2eq	2.25	1.30	1.
N2O	Gg	0.00131	0.0008	0.00
N2O	Gg CO2eq	0.41	0.248	0.2
Total for Subcategory	Gg CO2eq	-2737.34	-2748.45	-2688.
SubCategory 2: Croplands (5B)				
CO2	Gg	-2680.00	-2680.00	-2680.
CH4	Gg	0	0	
CH4	Gg CO2eq	0	0	
N2O	Gg	0	0	
N2O	Gg CO2eq	0	0	
Total for Subcategory	Gg CO2eq	-2680.00	-2680.00	-2680.
SubCategory 3: Grasslands (5C)				
CO2	Gg	2330.00	2405.00	2564.
CH4	Gg	0	0	
CH4	Gg CO2eq	0	0	
N2O	Gg	0	0	
N2O	Gg CO2eq	0	0	
Total for Subcategory	Gg CO2eq	2330.00	2405.00	2564.
Sector Total				
CO2	Gg	-3090.00	-3025.00	-2806.
CH4	Gg	0.11	0.06	0.
CH4	Gg CO2eq	2.25	1.30	1.
N2O	Gg	0.00131	0.0008	0.00
N2O	Gg CO2eq	0.41	0.25	0.
Total for Sector	Gg CO2eq	-3090(-430,60)	-3023.45	-2804.

Appendix C: UNFCCC Emission and Removal Tables

Table 17: BAU Emission Level from All Sources

	GHG emissions and Removals (Gg CO2e)									
Greenhouse gas source and sink categories	**2014**	**2016**	**2018**	**2020**	**2022**	**2024**	**2026**	**2028**	**2030**	**Growth**
1. Energy	**9,428**	**10,345**	**11,369**	**12,529**	**13,793**	**14,946**	**16,481**	**17,771**	**19,036**	**102%**
A. Fuel combustion (sectoral approach)	8,117	8,893	9,776	10,774	11,868	12,846	14,189	15,227	16,285	101%
1. Energy Industries	1,128	1,235	1,305	1,372	1,442	1,511	1,963	2,041	2,122	88%
2. Manufacturing industries and construction	1,638	1,749	1,906	2,100	2,321	2,568	2,841	3,144	3,478	112%
3. Transport	3,493	3,768	4,221	4,685	5,213	5,576	5,949	6,378	6,789	94%
4a. Commercial/Institutional	465	548	581	631	682	740	774	810	861	85%
4b. Residential	1,367	1,567	1,735	1,957	2,177	2,417	2,625	2,814	2,991	119%
4c. Agriculture/Forestry/Fishing	25	26	28	30	32	34	37	40	43	69%
B. Fugitive emissions from fuels	1,311	1,452	1,593	1,754	1,925	2,099	2,292	2,544	2,751	110%
1. Solid fuels	84	104	114	126	140	154	274	292	313	274%
2. Oil and natural gas	1,227	1,347	1,479	1,628	1,786	1,945	2,018	2,252	2,438	99%
2. Industrial processes	**2,317**	**2,345**	**2,381**	**2,715**	**4,002**	**4,097**	**4,181**	**4,264**	**4,338**	**87%**
A. Mineral products	838	873	898	1,211	1,371	1,444	1,515	1,585	1,655	97%
B. Chemical industry	1,153	1,127	1,127	1,127	2,233	2,233	2,233	2,233	2,233	94%
C. Metal production	326	345	357	377	398	420	433	446	451	38%
D. Other production	0	0	0	0	0	0	0	0	0	
4. Agriculture	**2,702**	**2,833**	**2,967**	**3,071**	**3,314**	**3,643**	**4,089**	**4,651**	**5,034**	**86%**
A. Enteric fermentation	1,345	1,371	1,398	1,398	1,405	1,444	1,526	1,642	1,694	26%
B. Manure management	293	300	309	316	454	646	913	1,261	1,489	408%
C. Direct Emissions from the soil	638	700	762	824	886	948	1,010	1,072	1,139	79%
D. Indirect emissions from the soil	426	462	498	533	569	605	640	676	712	67%
5. LULUCF	**-3,087**	**-3,023**	**-2,804**	**-2,578**	**-2,276**	**-2,024**	**-1,798**	**-1,578**	**-1,408**	**-54%**
A. Forest Lands	-2,737	-2,748	-2,688	-2,618	-2,468	-2,368	-2,288	-2,208	-2,178	-20%
B. Croplands	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	-2,680	0%
C. Grasslands	2,330	2,405	2,564	2,720	2,872	3,024	3,170	3,310	3,450	48%
6. Waste	**1,255**	**1,281**	**1,310**	**1,360**	**1,417**	**1,481**	**1,549**	**1,619**	**1,690**	**35%**
A. Solid waste disposal on land	905	915	934	962	995	1,034	1,076	1,120	1,163	28%
B. Biological treatment of solid waste	0	0	0	0	0	0	0	0	0	
C. Waste-water Treatment and Discharge	349	366	375	398	422	447	473	499	527	51%
1. Domestic wastewater treatment and discharge	308	321	327	344	362	380	398	416	434	41%
2. Industrial wastewater treatment and discharge	41	44	49	54	60	67	75	83	93	125%
Total non-energy emissions	**3,186**	**3,435**	**3,854**	**4,567**	**6,457**	**7,196**	**8,021**	**8,955**	**9,654**	**203%**
Total national emissions and removals	**12,614**	**13,779**	**15,223**	**17,095**	**20,250**	**22,142**	**24,502**	**26,726**	**28,690**	**127%**

Table 18: Post-Mitigation Emission Level from All Sources

	GHG emissions and Removals (Gg CO2e)									
Greenhouse gas source and sink categories	2014	2016	2018	2020	2022	2024	2026	2028	2030	Growth
1. Energy	**9,427**	**10,060**	**10,575**	**10,669**	**11,401**	**12,023**	**12,737**	**13,149**	**13,778**	**46%**
A. Fuel combustion (sectoral approach)	8,116	8,617	9,173	9,391	10,173	10,862	11,641	12,145	12,873	59%
1. Energy Industries	1,128	1,236	1,268	1,055	1,043	1,049	1,205	1,135	1,140	1%
2. Manufacturing industries and construction	1,638	1,749	1,905	1,760	1,929	2,148	2,393	2,562	2,867	75%
3. Transport	3,493	3,527	3,674	3,995	4,371	4,579	4,782	5,023	5,270	51%
4a. Commercial/Institutional	465	540	565	604	644	688	710	732	764	64%
4b. Residential	1,367	1,538	1,734	1,946	2,154	2,364	2,513	2,654	2,789	104%
4c. Agriculture/Forestry/Fishing	25	26	28	30	32	34	37	40	43	69%
B. Fugitive emissions from fuels	1,311	1,444	1,401	1,279	1,228	1,160	1,096	1,004	905	-31%
1. Solid fuels	84	104	114	94	107	121	240	248	268	221%
2. Oil and natural gas	1,227	1,339	1,287	1,185	1,121	1,039	856	756	637	-48%
2. Industrial processes	**2,317**	**2,345**	**2,381**	**2,715**	**1,102**	**1,155**	**1,199**	**1,243**	**1,278**	**-45%**
A. Mineral products	838	873	898	1,211	578	610	641	671	701	-16%
B. Chemical industry	1,153	1,127	1,127	1,127	125	125	125	125	125	-89%
C. Metal production	326	345	357	377	398	420	433	446	451	38%
D. Other production	0	0	0	0	0	0	0	0	0	
4. Agriculture	**2,702**	**2,833**	**2,967**	**3,071**	**3,207**	**3,399**	**3,647**	**3,946**	**4,153**	**54%**
A. Enteric fermentation	1,345	1,371	1,398	1,398	1,396	1,428	1,499	1,595	1,626	21%
B. Manure management	293	300	309	316	356	418	498	604	675	130%
C. Direct Emissions from the soil	638	700	762	824	886	948	1,010	1,072	1,139	79%
D. Indirect emissions from the soil	426	462	498	533	569	605	640	676	712	67%
5. LULUCF	**-3,087**	**-3,024**	**-3,001**	**-3,355**	**-3,397**	**-3,403**	**-3,372**	**-3,343**	**-3,359**	**9%**
A. Forest Lands	-2,737	-2,749	-2,885	-3,391	-3,579	-3,727	-3,829	-3,924	-4,068	49%
B. Croplands	-2,680	-2,680	-2,680	-2,682	-2,685	-2,689	-2,694	-2,701	-2,707	1%
C. Grasslands	2,330	2,405	2,564	2,718	2,867	3,014	3,151	3,283	3,416	47%
6. Waste	**1,255**	**1,281**	**1,119**	**1,057**	**1,019**	**1,015**	**1,031**	**1,025**	**896**	**-29%**
A. Solid waste disposal on land	905	915	743	659	597	568	558	546	389	-57%
B. Biological treatment of solid waste	0	0	0	0	0	0	0	3	4	
C. Waste-water Treatment and Discharge	349	366	375	398	422	447	473	476	504	44%
1. Domestic wastewater treatment and discharge	308	321	327	344	362	380	398	392	411	33%
2. Industrial wastewater treatment and discharge	41	44	49	54	60	67	75	83	93	125%
Total non-energy emissions	**3,186**	**3,435**	**3,466**	**3,488**	**1,931**	**2,167**	**2,505**	**2,871**	**2,968**	**-7%**
Total national emissions and removals	**12,614**	**13,495**	**14,041**	**14,157**	**13,332**	**14,189**	**15,242**	**16,020**	**16,746**	**33%**
Difference from BAU	0	-284	-1,182	-2,938	-6,918	-7,952	-9,259	-10,707	-11,944	
% reduction	0%	-2%	-8%	-17%	-34%	-36%	-38%	-40%	-42%	