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

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LEDS BUSINESS-AS-USUAL (BAU) SCENARIO REPORT

September 2014

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CLEAN ENERGY PROGRAM

LEDS BUSINESS-AS-USUAL (BAU) SCENARIO REPORT

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ACRONYMS

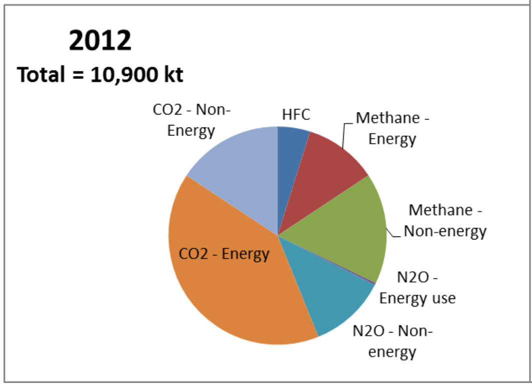
BAU	Business-as-Usual
CH4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
EC-LEDS	Enhanced Capacity – Low Emissions Development Strategy
GDP	Gross Domestic Product
Gg	Gigagram
GWh	Gigawatt Hours
GWP	Global Warming Potential
GHG	Greenhouse Gas
HPEP	Hydro Power and Energy Planning
Kt	Thousand Tons
Ktoe	Thousand Tons Oil Equivalent
LDV	Light Duty Vehicle
MARKAL	MARKet ALlocation
MW	Megawatts
N_2O	Nitrous Oxide
NMVOC	Non-methane volatile organic compounds
PJ	Petajoules
PJa	Petajoules per annum
REDP	Regional Energy Demand Planning
RES	Reference Energy System
RESMD	Regional Energy Security and Market Development
UNFCCC	United Nations Framework Convention on Climate Change
USAID	US Agency for International Development

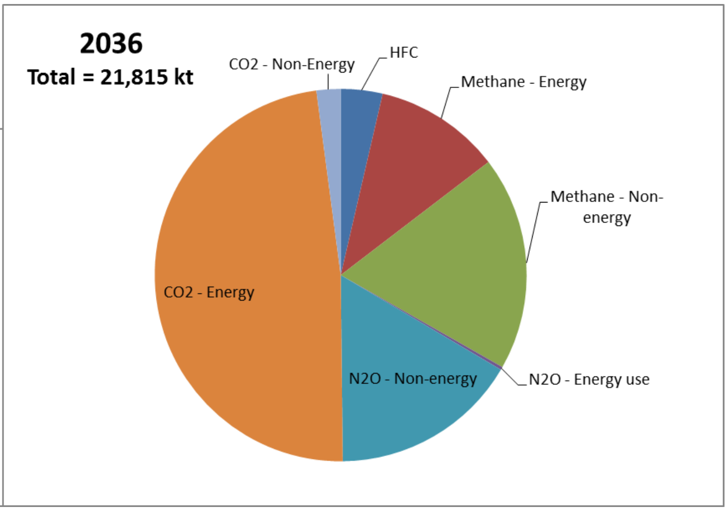
EXECUTIVE SUMMARY

As part of Component 3 of USAID's Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) Clean Energy Program for Georgia, EC-LEDS is coordinating with World Experience for Georgia (WEG) and the Ministry of Energy's Analytical Department to make improvements to the MARKAL-Georgia model and establish a creditable Reference or Business-as-Usual (BAU) scenario to facilitate analysis of national scenarios in support of the work of the EC-LEDS Steering Committee, Expert Working Group, and Sub-working groups.

The modeling platform MARKAL (MARKet ALlocation) is an integrated energy system model, developed under the auspices of the International Energy Agency's Energy Technology Systems Analysis Program (www.iea-etsap.org). The MARKAL-Georgia has been used to examine the role of energy efficiency and renewable energy in meeting future energy requirements through 2030 to support sustained economic growth while considering anticipated Energy Community commitments and European Union accession directives. The model has been recently updated and applied as part of the USAID Hydro Power and Energy Planning (HPEP) project. Capacity is being built within the Ministry of Energy's Analytical Department with an eye towards their long-term stewardship and ongoing use of the model to advise policy and planning. The EC-LEDS project also made improvements to the model. The model improvements include incorporation of new technologies (commercial buildings retrofits, efficient public lighting, CNG compressing), incorporating data from the HPEP and EC-LEDS household surveys, and incorporating full Greenhouse Gas (GHG) emissions accounting into the model.

The BAU scenario represents the expected evolution of GHG emissions from Georgia (from both the energy system and non-energy sources[1]) under current policies and practices, and includes both energy and non-energy emissions. Total GHG emissions increase by 100% with the biggest increase from CO_2 Energy sources, CO_2 Non-Energy, N_2O Non-Energy and methane Non-Energy. Many of the Non-Energy sector emissions are based on proxy data, which will be replaced once BAU projections are ready.





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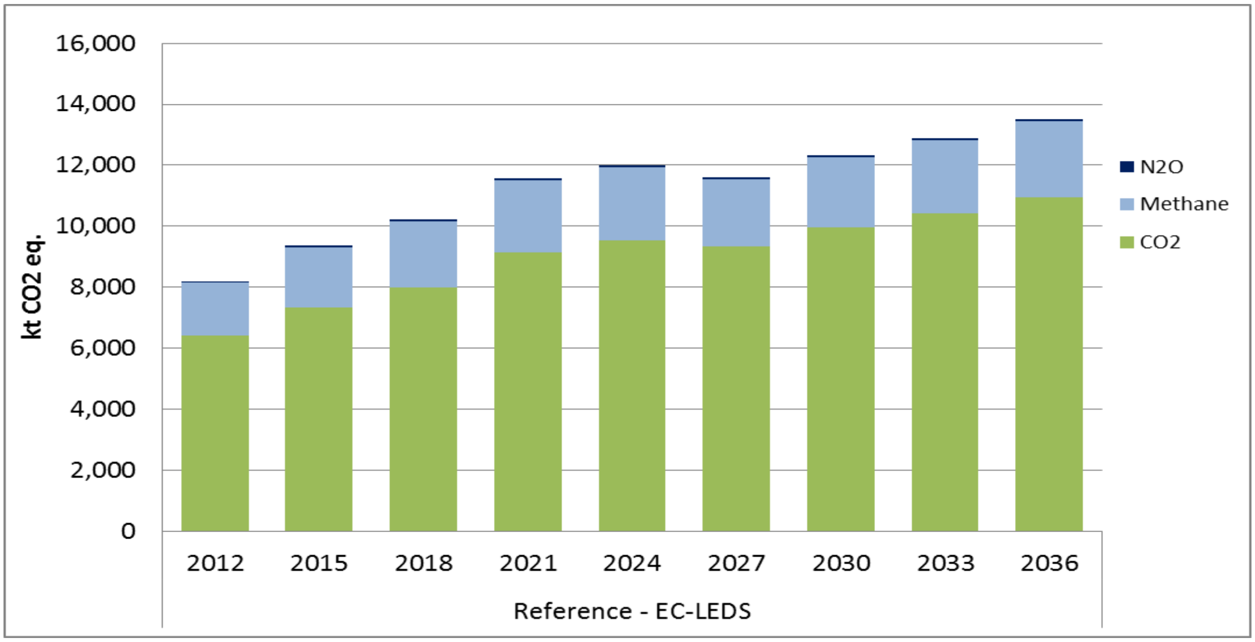
[11] Non-energy emissions in Georgia include CH4 and N_2O from Deforestation and Land degradation, Industrial processes, Agricultural production, Waste, and HFCs (refrigerants for air conditioning appliances).

The BAU energy supply and consumption projection represents the economic optimal future energy system for Georgia under current policies and practices. It serves as the reference scenario for quantifying the costs, benefits, technology changes, fuel switching and other impacts of potential LEDS strategies. The total energy system includes fuel supply and electricity generation, buildings (households and commercial), industry and transportation. The MARKAL-Georgia energy system also contains an agricultural energy sector, but the energy use is small.

In the reference scenario, total final energy use increases by 85% between 2012 and 2036 with most of the growth occurring for transportation, industry and residential sectors. The greatest growth is in natural gas use, which grows from 20% of the total to 36% by 2036. Electricity, gasoline and coal also show significant growth, and biofuels grow from negligent to 3% of the total in 2036.

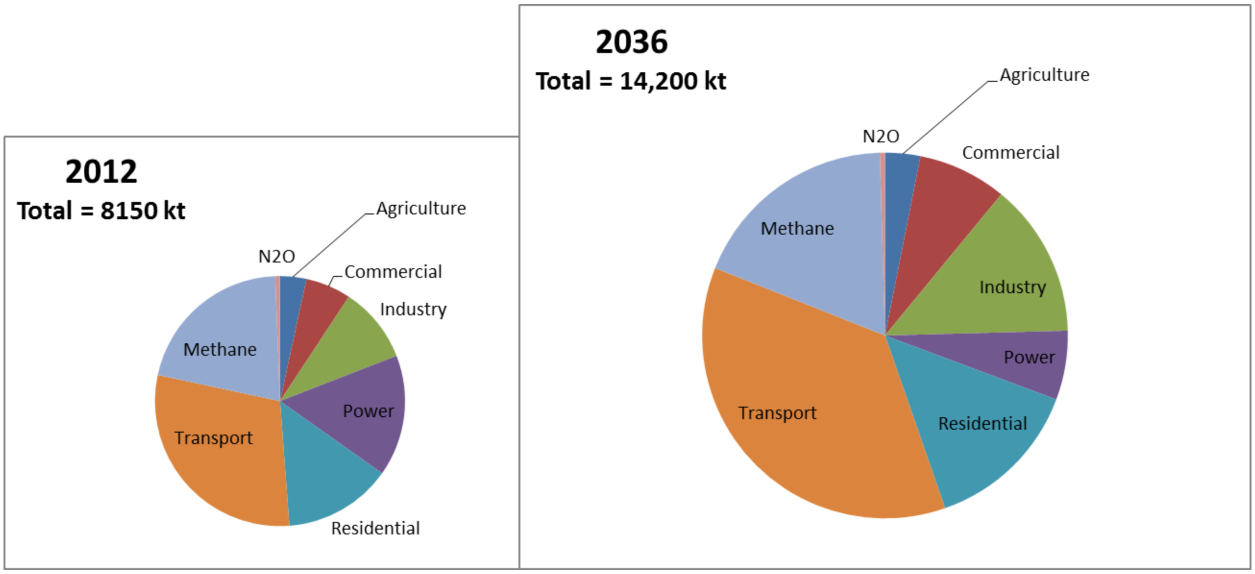
The energy related GHG emissions are directly tied to the consumption of fossil fuels. Because of the dominance of hydropower, gas consumption for power generation decreases from 44% of total gas use in 2012 to only 4% of gas use in 2036. However, gas use increases significantly for Residential and Transportation sectors between 2012 and 2036.

CO_2 emissions from the total energy system increase by 75% between 2012 and 2035 with the transportation, industry and commercial sectors increasing between 115% and 130% each. Power sector emissions decrease as natural gas use decreases. Methane emissions from the total energy system increase by 73% between 2012 and 2036 with natural gas pipelines being the predominant source, while the other emission sources remain flat. N_2O emissions from the energy system, which are due to products of incomplete combustion of fuels, grow at a rate similar to final energy use. The CO_2 equivalent emissions from the total energy system (representing CO2, Methane and N_2O adjusted for global warming potential) are 80% related to fuel combustion and 20% from coal mines and natural gas pipelines, with a very small contribution from N_2O.



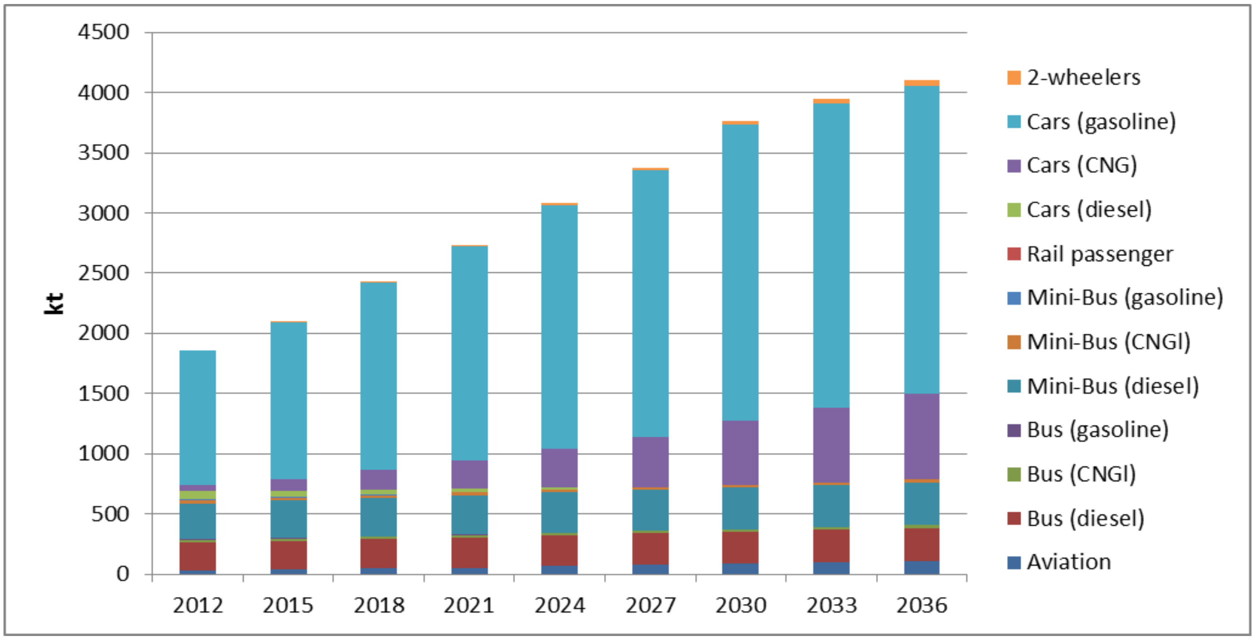
GHG Emissions from the energy sector 2012-2036

Between 2012 and 2036, transport, commercial buildings and industry GHG emissions increase as a share of total GHG emissions, while the power sector decreases. Sectors with the greatest potential for reductions include transport, natural gas leaks (methane), industry fuel use and building fuel use.



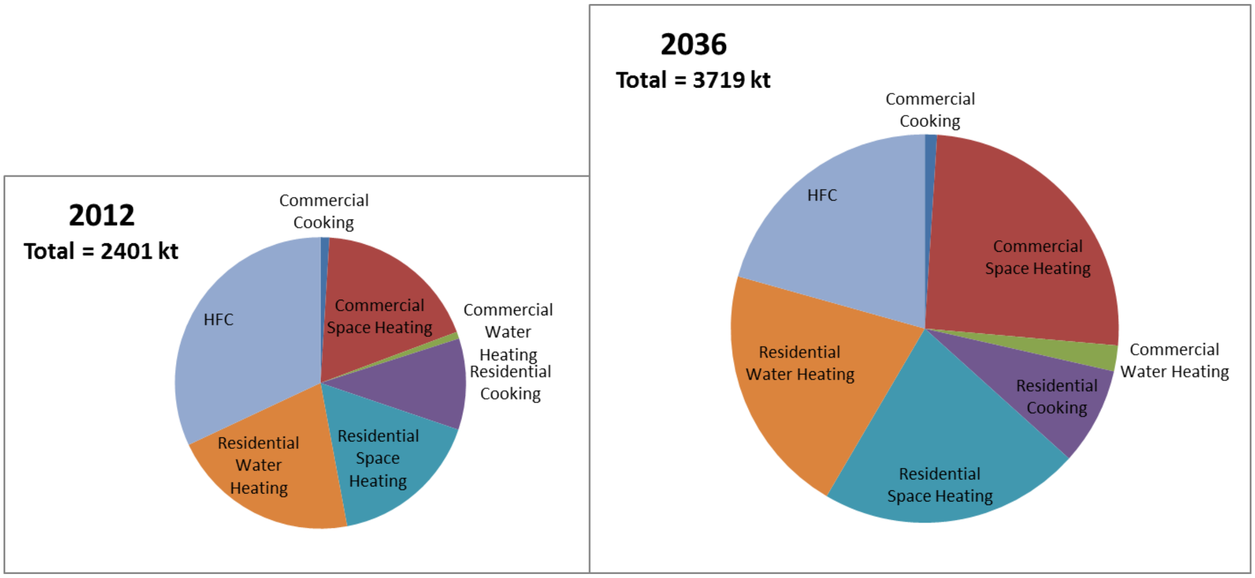
Total GHG Emissions 2012-2036 – Energy and Non-energy Emissions (CO2 equivalent)

In the transport sector, passenger transport emissions grow by 120% and light-duty vehicles account for 80% of all passenger transport GHG emissions as fuel switching from gasoline to CNG does not result in emission reductions, although there is a cost savings.



Passenger transport emissions 2012-2036

Total GHG emissions from the buildings sector increase by 55% with the biggest increases from Commercial space heating, and residential space heating followed by residential water heating. Although hydro-fluorocarbons (HFCs)[2] emissions do not increase much, they remain a significant share of the total GHG emissions in the sector (32% in 2012 and 22% in 2036).



Buildings Sector GHG Emissions 2012-2036

Industry sector CO_2 emissions come primarily from cement production (65%), with all other subsectors accounting for less than 10% each.

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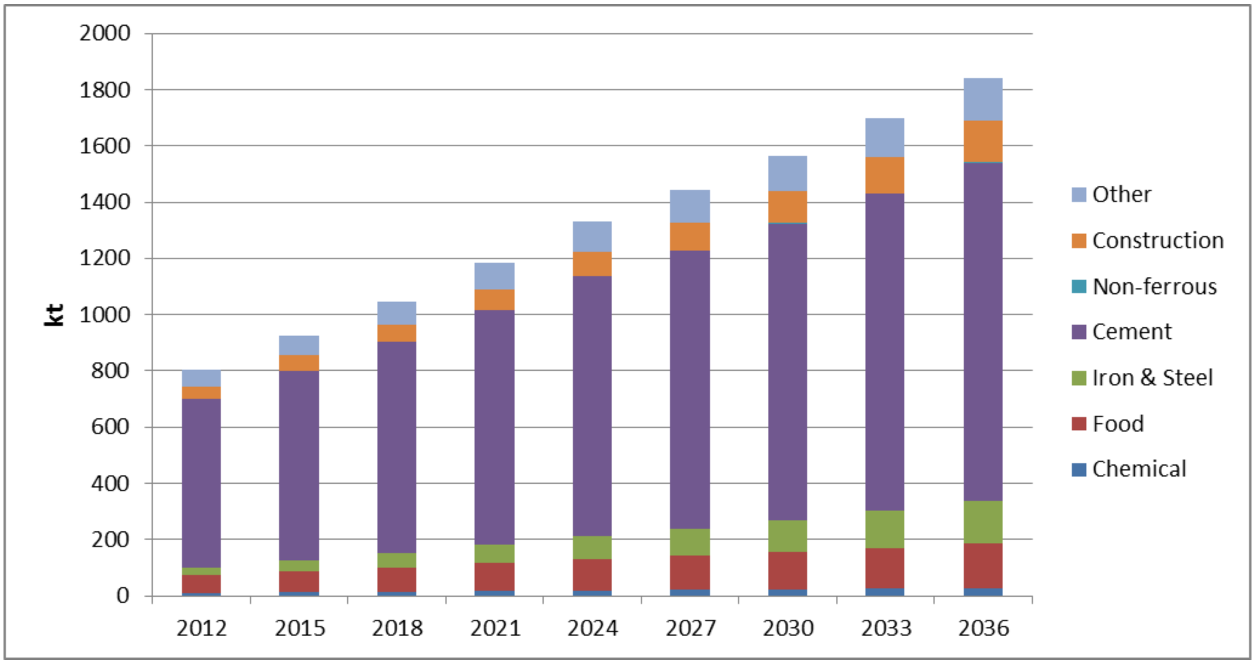
[2] Hydrofluorocarbons, or "super greenhouse gases," are gases used for refrigeration and air conditioning, and known as super greenhouse gases because the combined effect of their soaring use and high global warming potential could undercut the benefits expected from the reduction of other greenhouse gases such as carbon dioxide. Used as refrigerants, they were introduced by the chemical industry to replace ozone destroying CFCs (chlorofluorocarbons) which have (almost) been phased out by the Montreal Protocol. However, HFCs production is rising by 15% per year. HFCs are 3,830 times more potent than CO2 with a lifetime of 14 years.



Industrial CO_2 Emissions by Sector 2012-2036

INTRODUCTION

As part of Component 3 of USAID's Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) Clean Energy Program for Georgia, EC-LEDS is coordinating with World Experience for Georgia (WEG) and the Ministry of Energy's Analytical Department to make improvements to the MARKAL-Georgia model and establish a creditable Reference or Business-as-Usual (BAU) scenario to facilitate analysis of national scenarios in support of the work of the EC-LEDS Steering Committee and Working Groups.

This report presents the current BAU scenario, which will be the reference against which the costs and benefits of various LEDS policies can be assessed, and describes these two model enhancement activities. Each of these are briefly described in this section, with the BAU presented in detail and supported by Annexes presenting the model preparation.

Improvements and New Technology Characterizations

In preparing the MARKAL-Georgia model for LEDS analyses, it was agreed that DWG would make the following model improvements and enhancements based on its experience and new data available:

1. Update base year transport technology characterizations relative to new technology options;
2. Add commercial buildings retrofit technologies;
3. Add efficient technologies for public lighting;
4. Add Compressed Natural Gas (CNG) compressing technologies for filling stations, and
5. Review hurdle[3] rates for demand technologies.

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[3] A hurdle rate is a technology-specific discount rate that reflects either 1) the cost of money to the purchaser of that technology or 2) the "apparent" cost to the purchaser due to various barriers,

The details of these model improvements are described in Annex A.

GHG Emissions Accounting for EC-LEDS

The addition of full GHG emissions accounting was made to the Georgia MARKAL model in two stages:

1. Non-energy GHG emissions accounting was added to the model according to the approach described in Annex B, and
2. Energy sector methane and N_2O emissions sources were added to the model according to the approach described in Annex C.
3. The data, assumptions and model inputs supporting these additions are described in Annex D.

MARKAL-GEORGIA OVERVIEW

With support from several US Agency for International Development (USAID) regional projects, comprehensive national energy planning models were developed for most of the countries in Southeast Europe and Eurasia. The planning models were designed to support policy making and analysis of future energy investment options. The modeling platform used is the MARKAL (MARKet ALlocation) integrated energy system model, developed under the auspices of the International Energy Agency's Energy Technology Systems Analysis Program (www.iea-etsap.org). The resulting MARKAL-Georgia has been used to examine the role of energy efficiency and renewable energy in meeting future energy requirements through 2030 to support sustained economic growth while considering anticipated Energy Community commitments and European Union accession directives. The model has been recently updated and applied as part of the USAID Hydro Power and Energy Planning (HPEP) project. Capacity is being built within the Ministry of Energy's Analytical Department with an eye towards their long-term stewardship and ongoing use of the model to advise policy and planning.

Key features of MARKAL models are:

- Encompasses an *entire energy system* from resource extraction through to end-use demands as represented by a Reference Energy System (RES) network (see Figure 1);
- 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.

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such as lack of information on the true life-cycle cost, higher priority to first cost rather than life-cycle cost, unwillingness to try new technologies, etc.

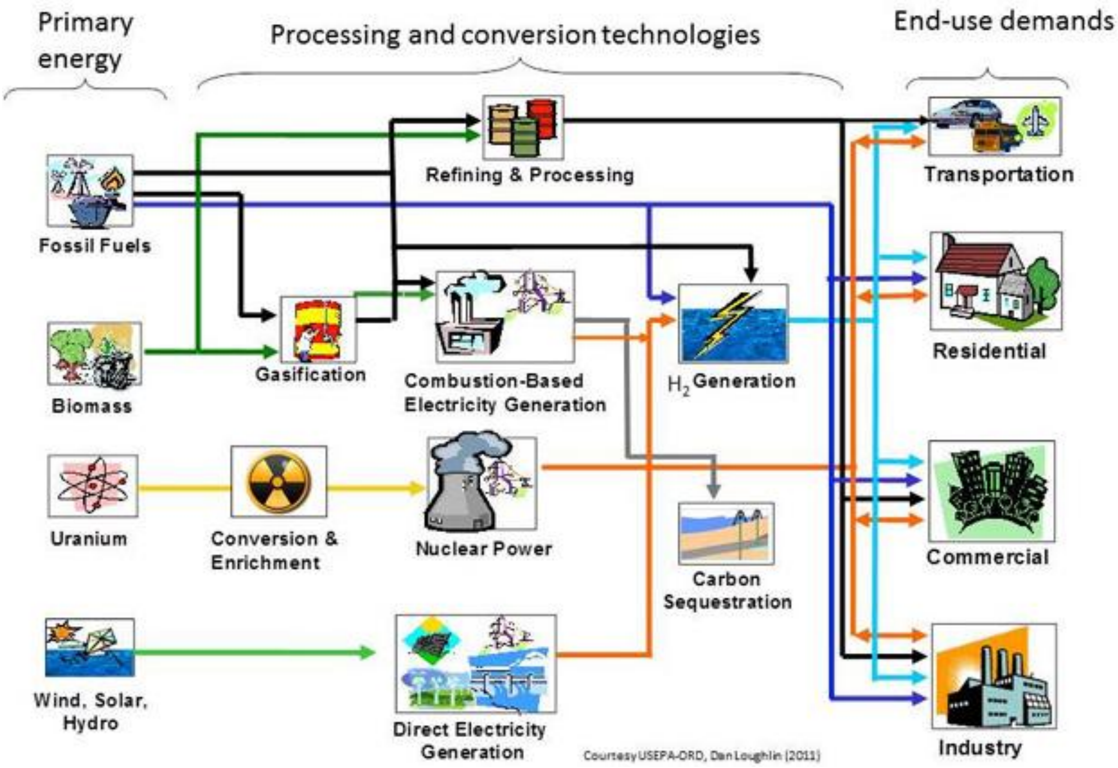

Figure 1: Simplified Reference Energy System

For LEDS the RES has been expanded to track non-CO2 GHGs from the energy system as well as track GHG emissions from non-energy sources, and a suite of additional emission reduction options are planned to be added to enable the MARKAL-Georgia model to take a comprehensive look at GHG mitigation potential for Georgia, and help with prioritizing programs and actions to reduce those emissions.

MARKAL-GEORGIA LEDS BUSINESS AS USUAL SCENARIO

The BAU scenario represents the expected evolution of GHG emissions from Georgia (from both the energy system and non-energy sources) under current policies and practices. This section of the report examines these two main components of the GHG emissions inventory: Energy-related emissions and Non-energy emissions and removals.

Energy-Related Emissions

Energy Consumption BAU

The BAU energy supply and consumption projection represents the economic optimal future energy system for Georgia under current policies and practices. It serves as the reference scenario for quantifying the costs, benefits, technology changes, fuel switching and other impacts of potential LEDS strategies.

For the purposes of this Georgia LEDS work, the total energy system will be presented according to the following energy sectors:

- Fuel supply and electricity generation;
- Buildings (households and commercial);
- Industry, and
- Transportation.

The MARKAL-Georgia energy system also contains an agricultural energy sector, but the energy use is small, and a separate breakdown in not provided.

Fuel Supply and Electricity Generation

The upstream portion of the energy system is comprised of primary energy supply (e.g., coal mining, natural gas wells), imports, electricity generation, and the natural gas network in Georgia. As shown in Figure 2, under the BAU assumptions total primary energy use increases 74% from 2012 to 2036 with most of the growth occurring for natural gas (1170 ktoe), renewables (865 ktoe) and coal (368 ktoe).

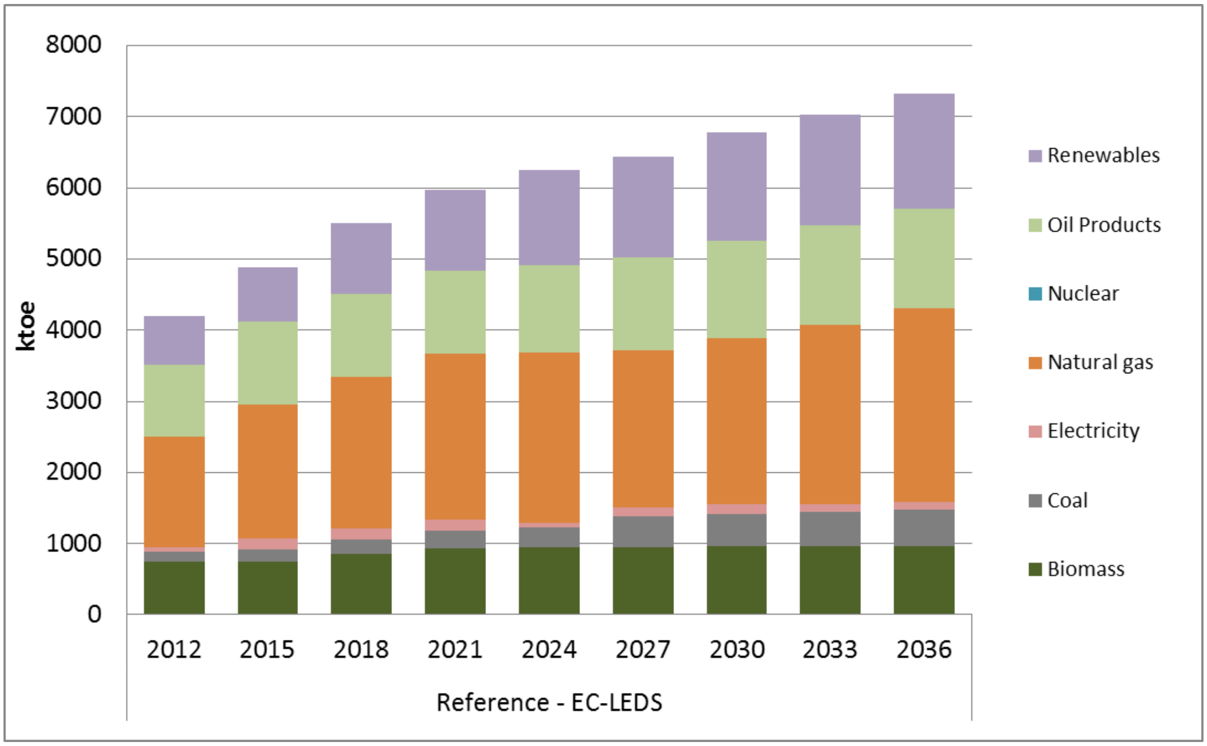

Figure 2: Primary Energy Production and Imports

Figure 3 shows a simplified RES diagram for the upstream and electricity supply sector of the Georgian energy system, where for each of the electricity generation types there may be several instances identifying individual power plants.

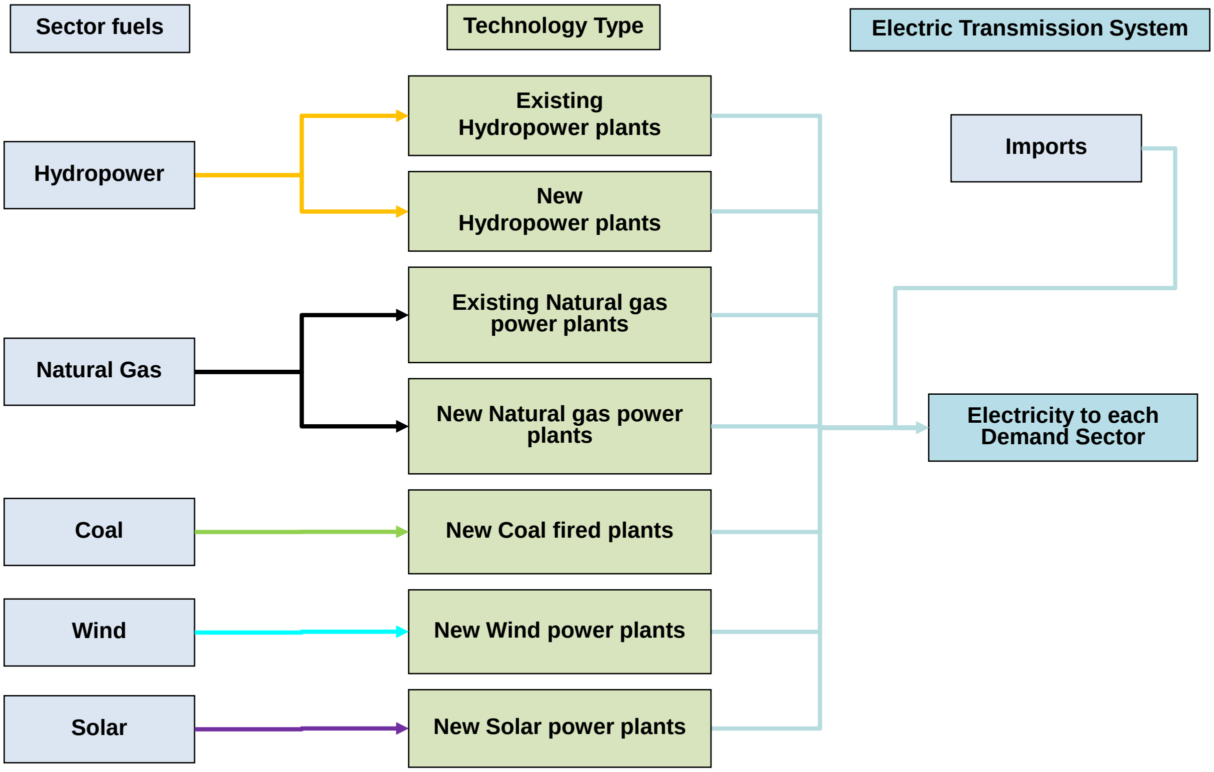

Figure 3: Upstream Energy Supply

As shown in Figure 4, total electricity generation increases 90% from 2012 to 2036 with most of the growth occurring from hydropower (9,500 GWh), coal (590 GWh) and renewables (482 GWh). Natural gas for power generation decreases by 1,866 GWh, and imports average 1,365 GWh.

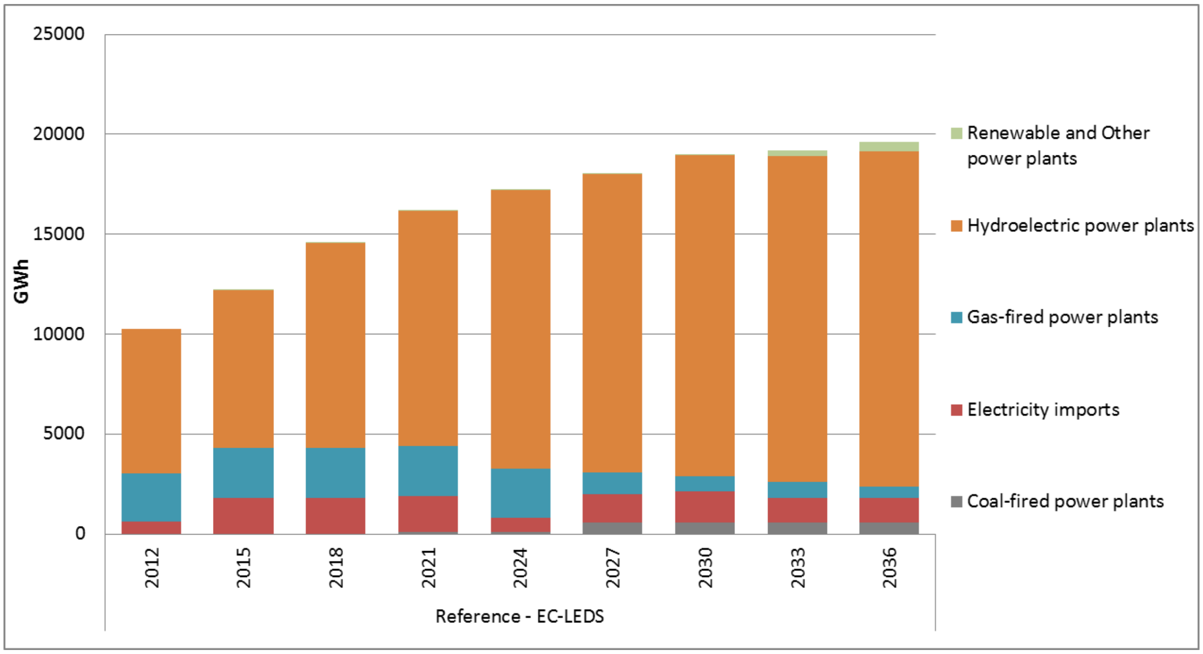

Figure 4: Primary Energy Production and Imports

Figure 5, which provides new power plant capacity installed in each 3-year period, shows that the BAU scenario add hydropower in every period, along with a 220 MW gas-fired plant in 2018, a 120 MW coal plant in 2027, and renewables in 2033 and 2036.

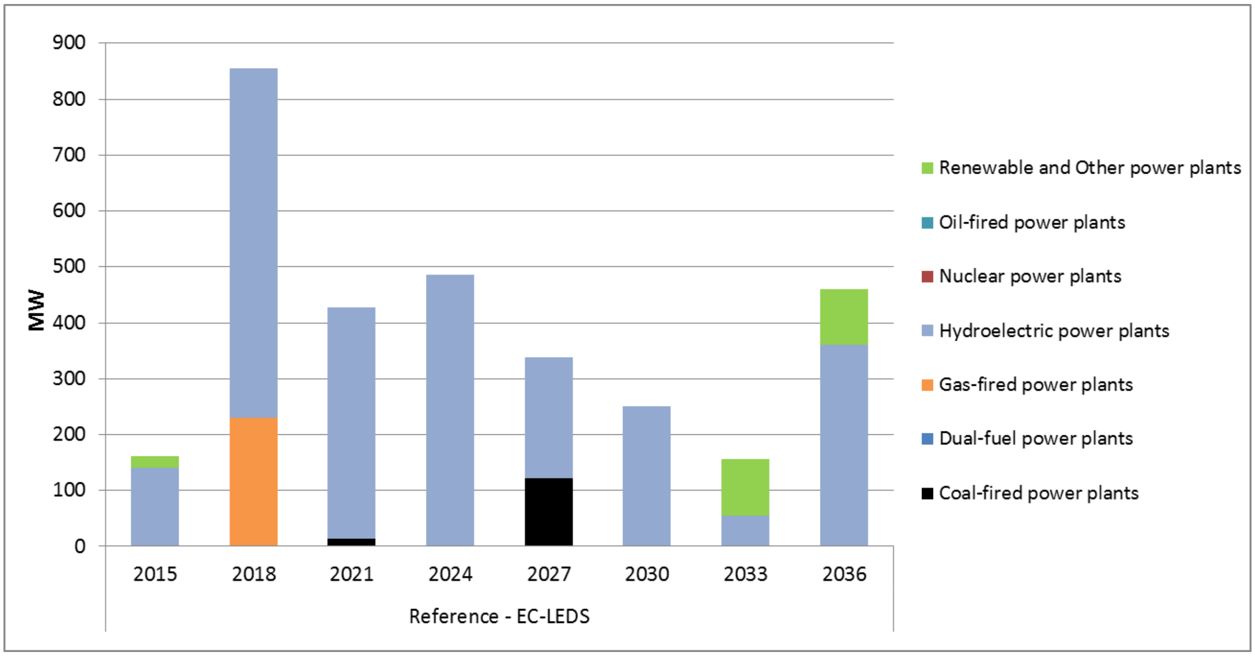

Figure 5: Power Plant Installed Capacity

Figure 6 shows that gas consumption for power generation increases until 2021 and drops dramatically in 2027 after new hydropower plants and the new coal and renewable plants come on line.

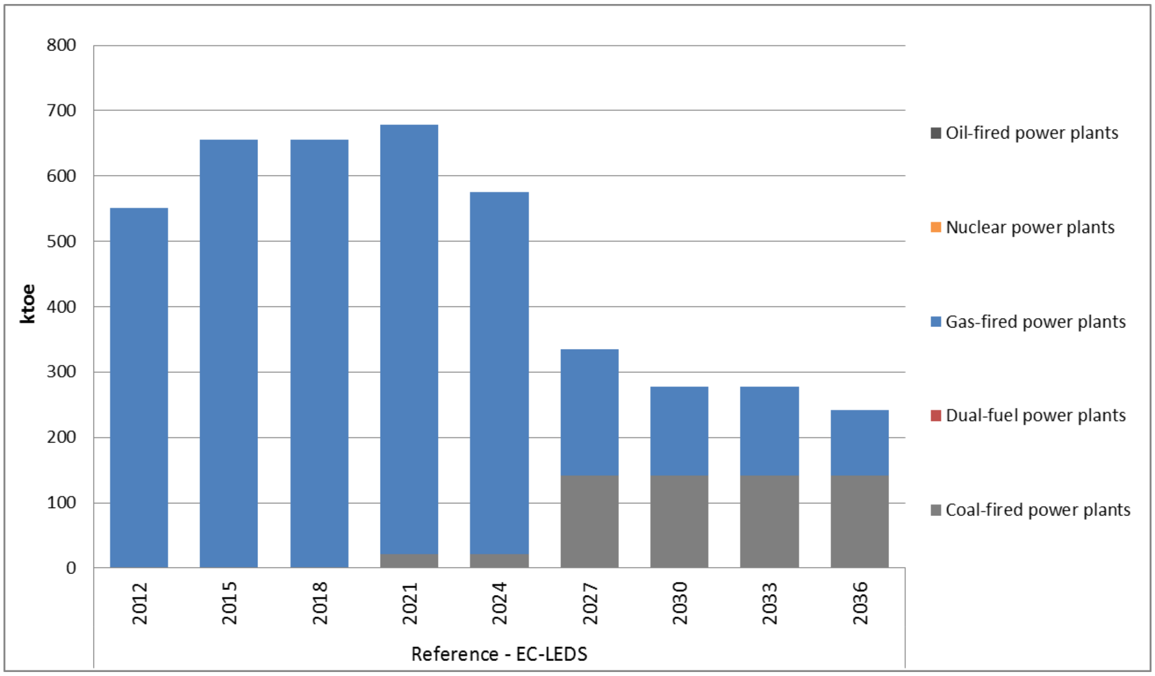

Figure 6: Power Plant Fuel Consumption

Energy Sector GHG Emissions

The energy related GHG emissions are directly tied to the consumption of fossil fuels. Figure 7 shows total natural gas consumption, and a noted above, because of the dominance of hydropower, gas consumption for power generation decreases from 44% of total gas use in 2012 to only 4% of gas use in 2036. Gas use increases most significantly for Residential (440 ktoe) and Transportation (880 ktoe) sectors between 2012 and 2036.

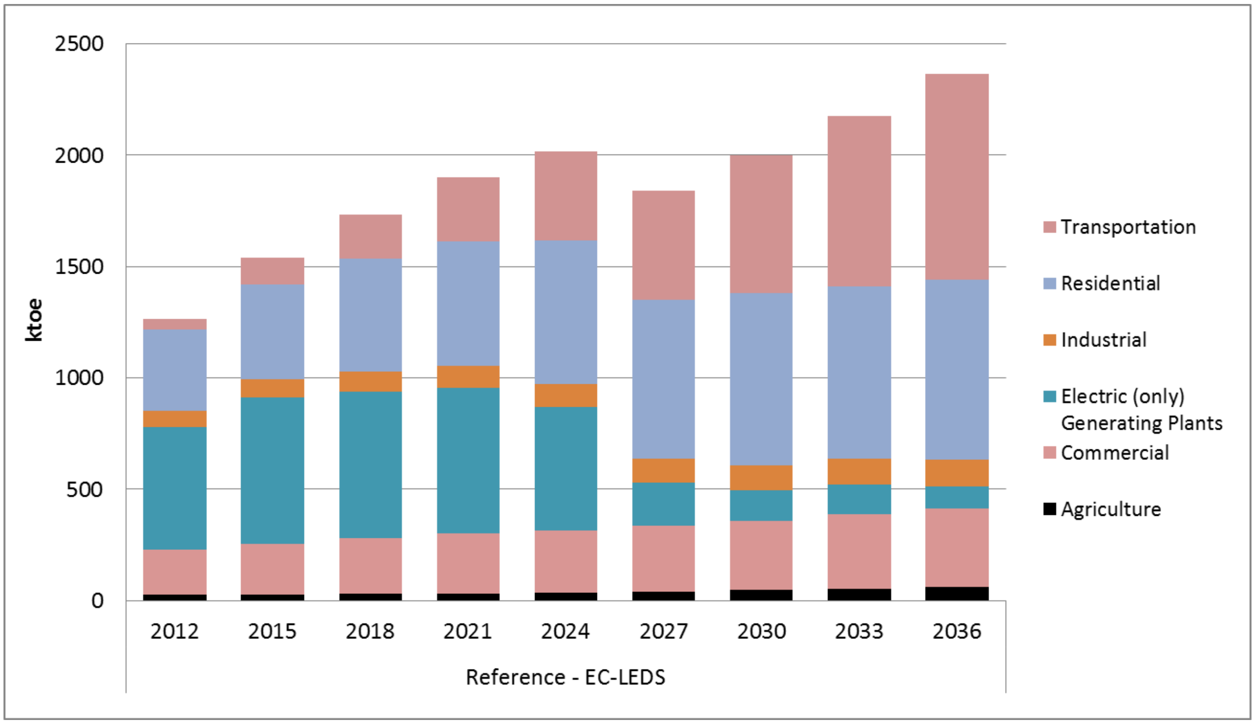

Figure 7: Consumption of Natural Gas by Sector

Total final energy use increases by 85% between 2012 and 2036 with most of the growth occurring for transportation (1,460 ktoe), industry (521 ktoe) and residential sectors (517 ktoe). Figure 8 shows final energy use by fuel type. The greatest growth is in natural gas use, which grows from 20% of the total to 36% by 2036. Electricity, gasoline and coal are the also show significant growth, and biofuels grow from nothing to 3% of the total in 2036.

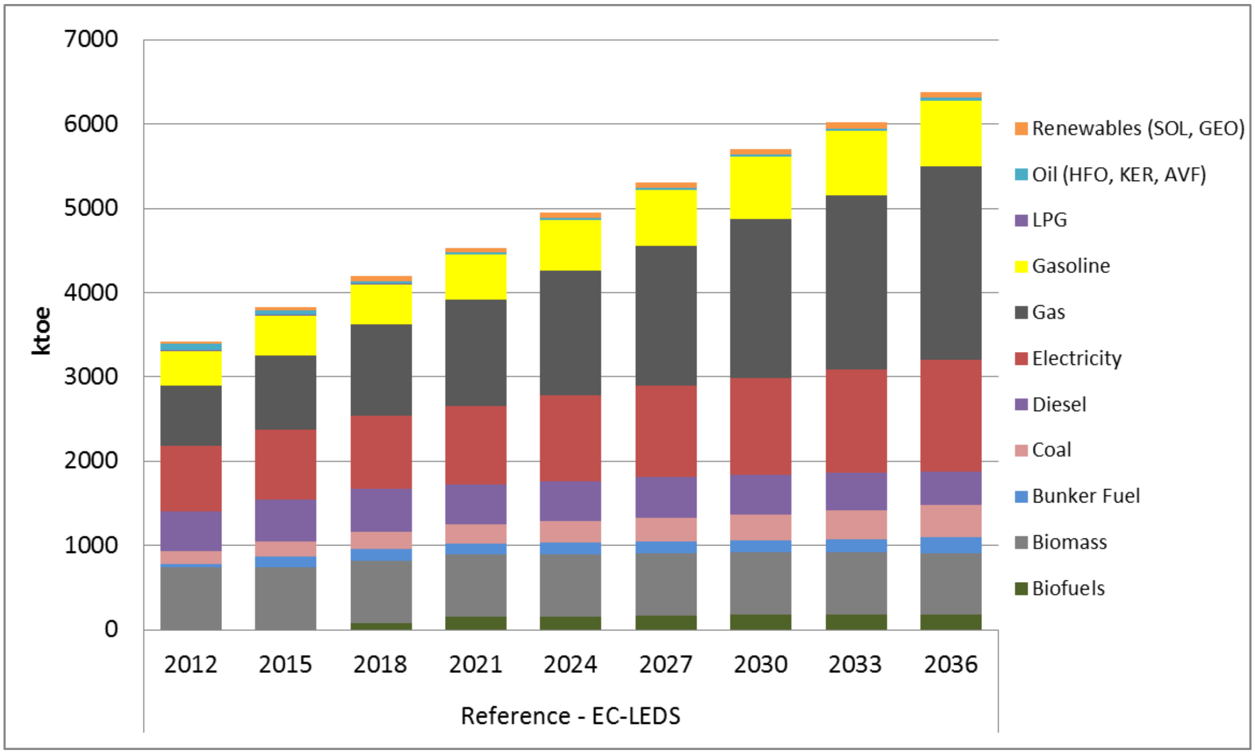

Figure 8: Final Energy Consumption

As shown in Figure 9, CO_2 emissions from the total energy system increase by 75% between 2012 and 2035 with the transportation (increasing 2,800 kt), industry (increasing 1,035 kt) and commercial (increasing 742 kt) sectors increasing between 115% and 130% each. Power sector emissions decrease by 495 kt, as natural gas use decreases.

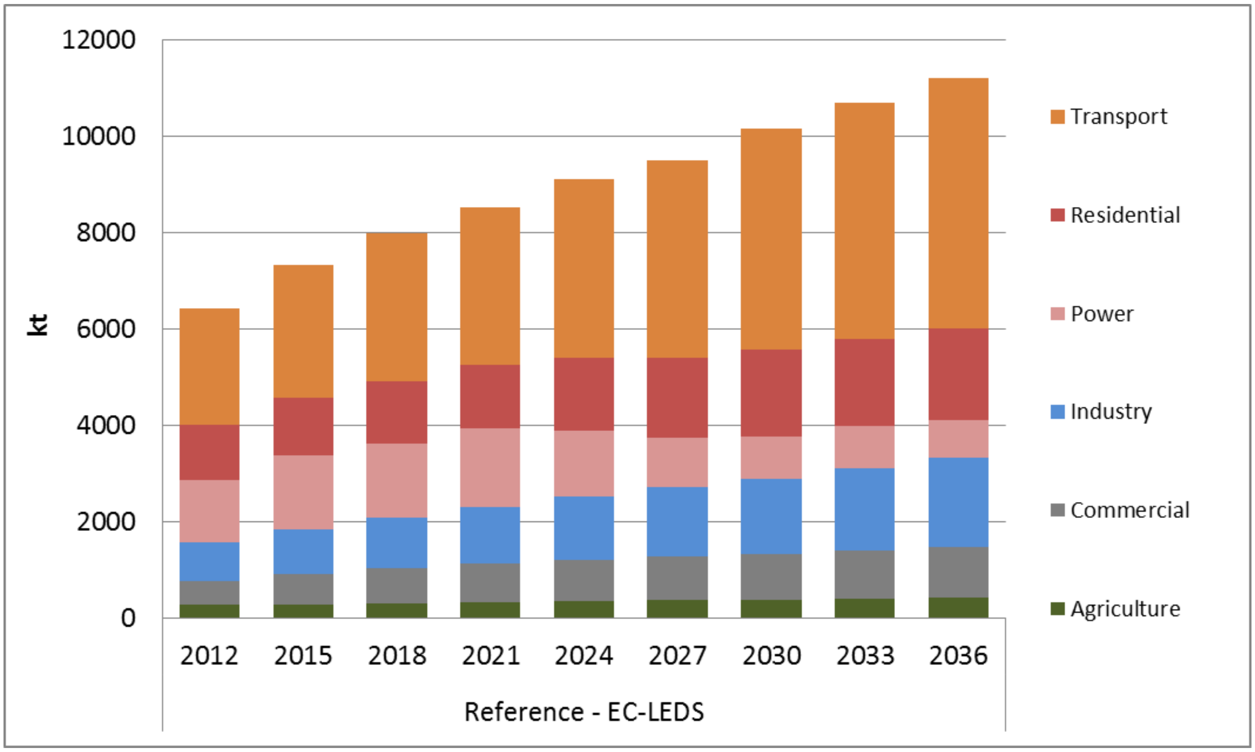

Figure 9: CO_2 Emissions by Sector

Figure 10 shows that methane emissions from the total energy system increase by 73% between 2012 and 2036 with natural gas pipelines being the predominant source (increasing 57 kt), while the other emission sources remain flat.

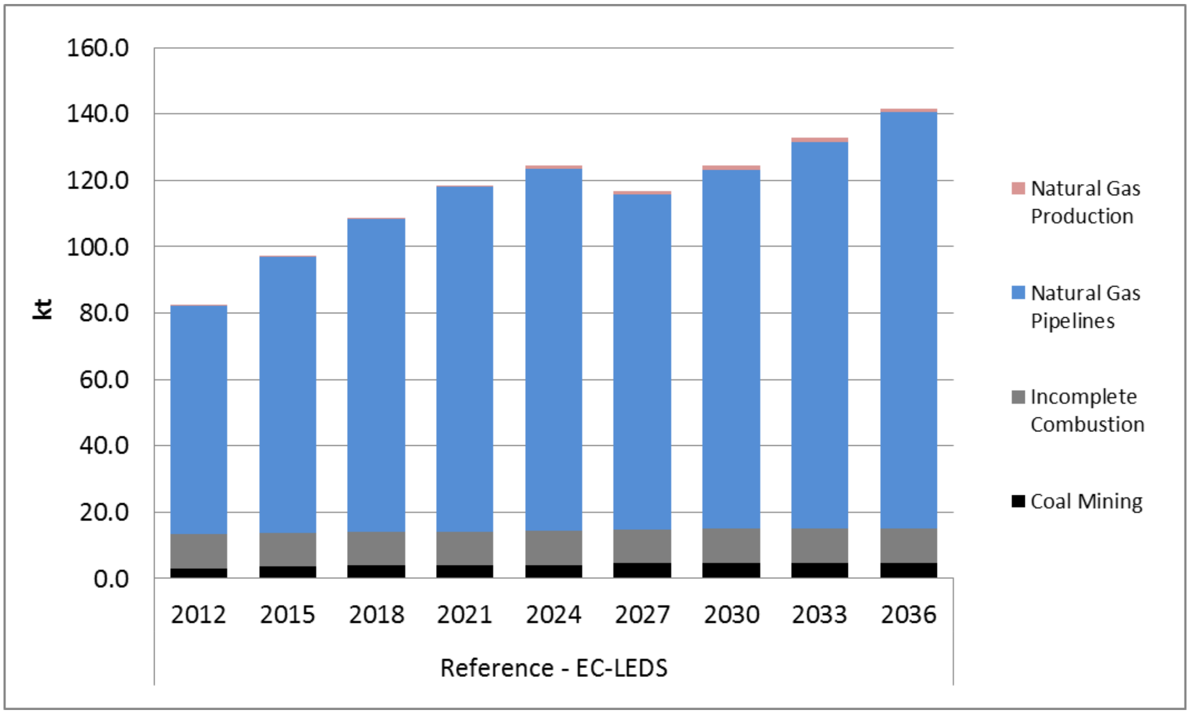

Figure 10: Methane Emissions by Activity

Figure 11 shows N_2O emissions from the energy system, which are due to products of incomplete combustion of fuels, and grow at a rate similar to final energy use.

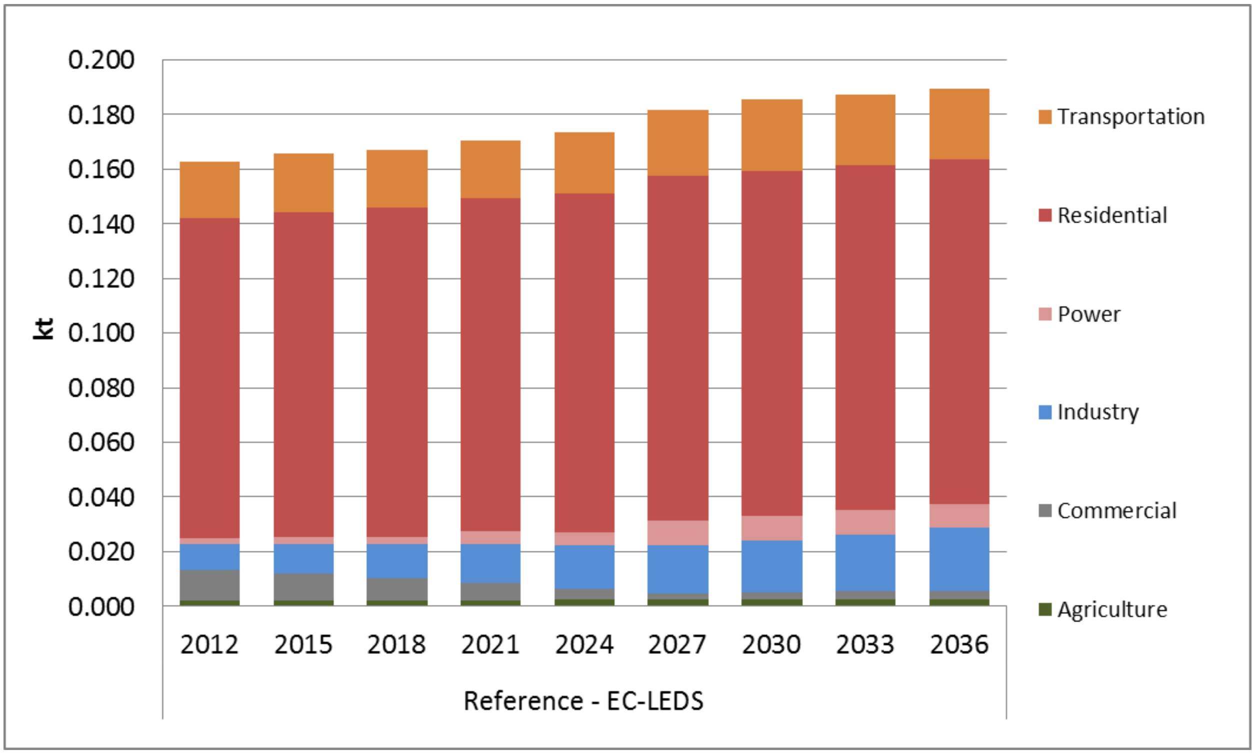

Figure 11: N_2O Emissions by Sector

CO_2 equivalent emissions from the total energy system are shown in Figure 12 and consist of about 80% related to fuel combustion and 20% from coal mines and natural gas pipelines, with a very small contribution from N2O.

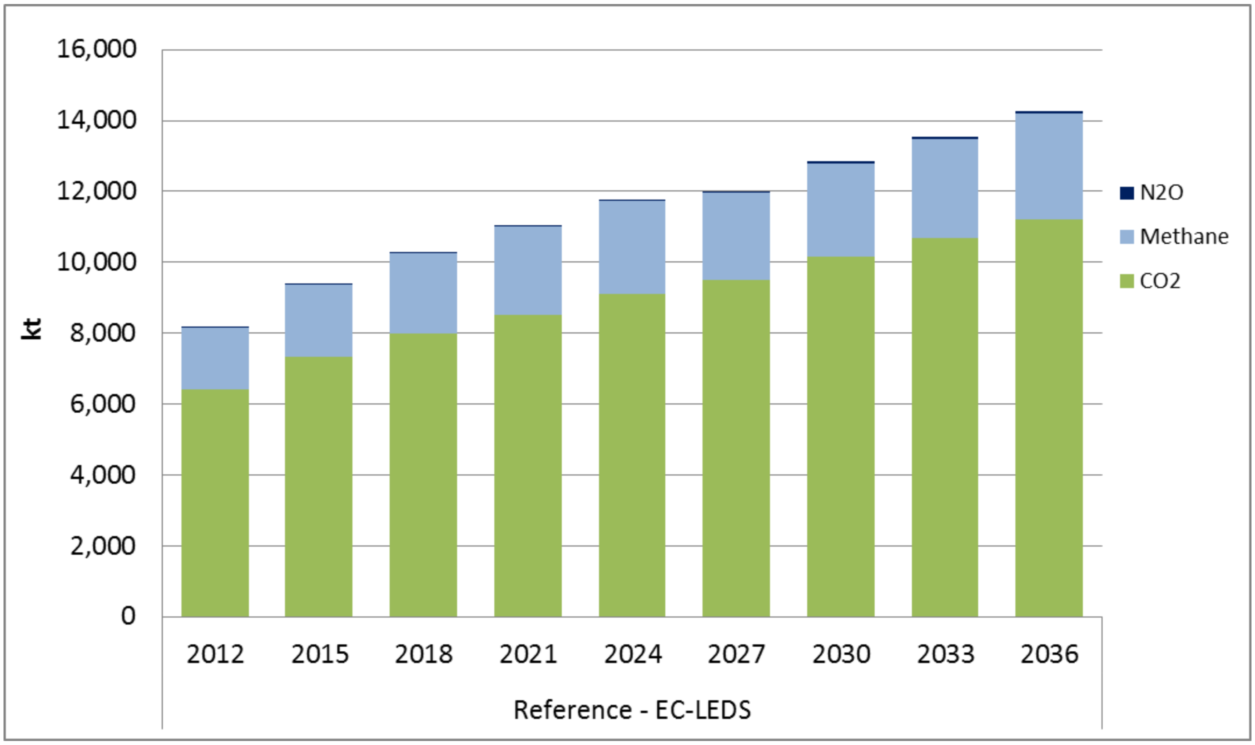

Figure 12: CO_2 equivalent emissions by Type

Direct Emissions from Buildings

In MARKAL-Georgia, the buildings sector consists of both commercial (government and services) and residential (households) buildings. A simplified RES diagram of the commercial sector is presented in Figure 13, and shows the fuels, technology types and end-use services included in the model. In addition to energy efficient devices for all the technologies identified, the model also includes measures to reduce overall building energy demand.

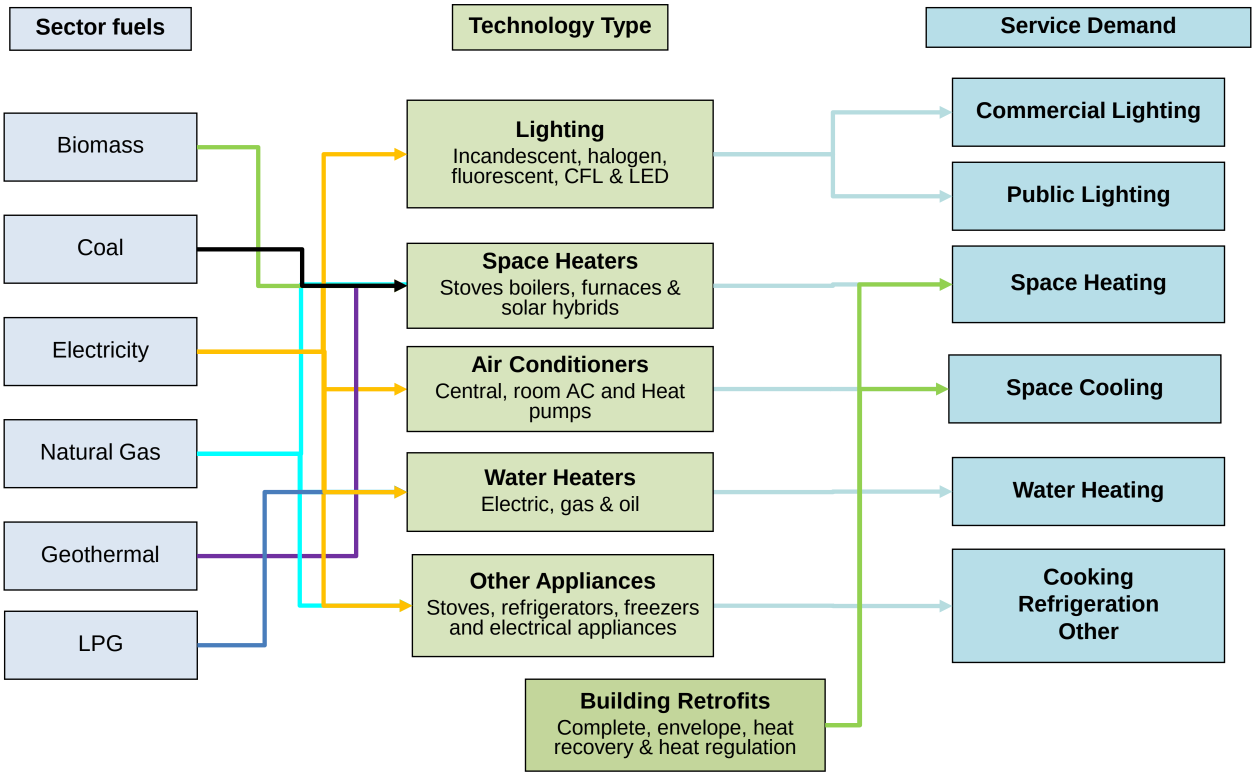

Figure 13: Commercial Buildings RES

As shown in Figure 14, commercial sector energy use increases most significantly for natural gas (149 ktoe) and renewables (50 ktoe), with biomass use declining.

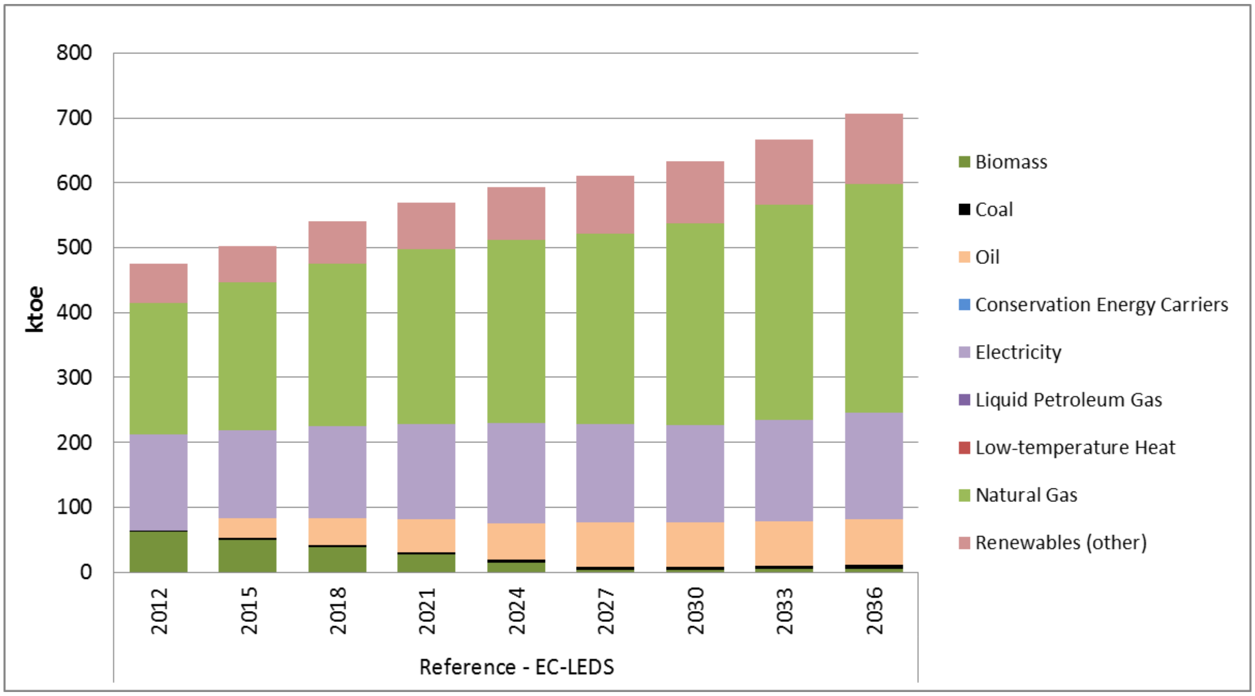

Figure 14: Commercial Energy Use by Fuel Type

Figure 15, which shows energy use by end-use service, is dominated by space heating (increasing 127 ktoe) and water heating (increasing 77 ktoe). Space heating stays constant at a 56% share while water heating increases from 17 to 22% and public lighting decreases from 15% to 4%.

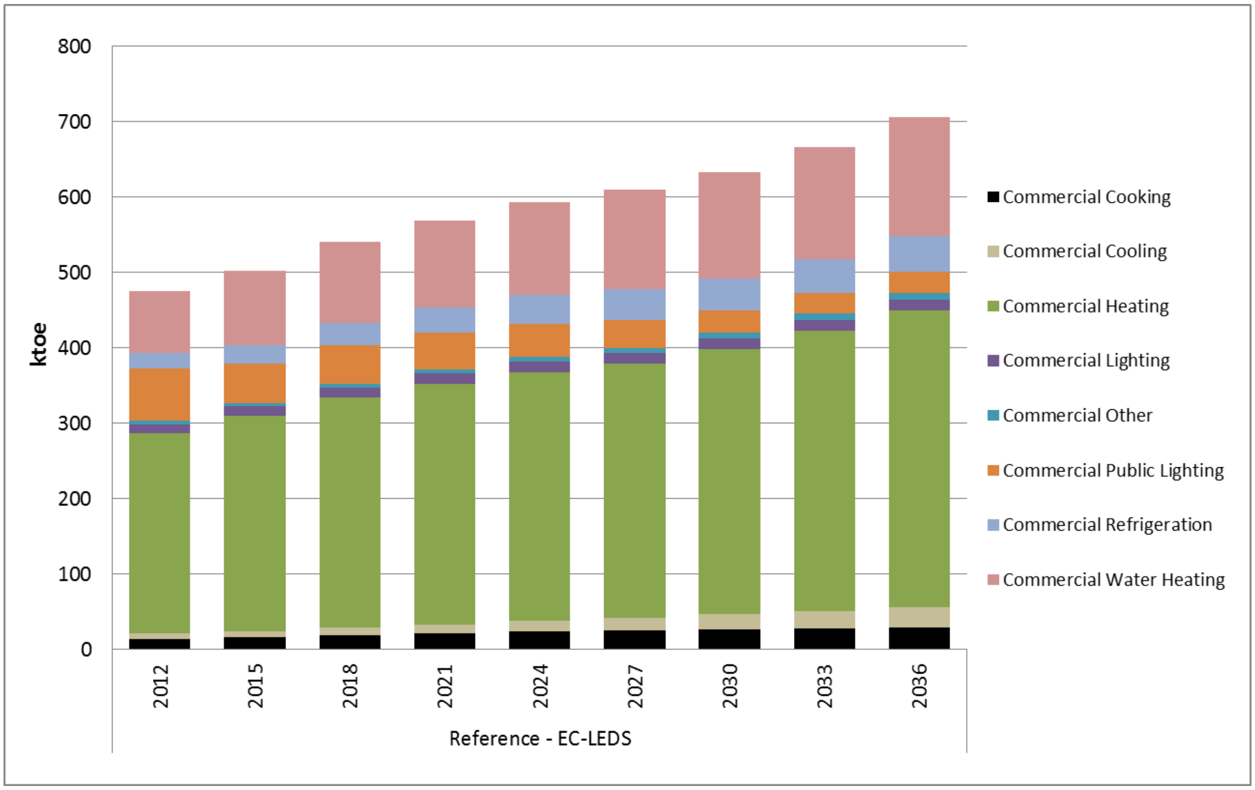

Figure 15: Commercial Energy Use by Energy Service

Figure 16, which provides CO2 emissions from commercial sector energy use, shows these emissions are also dominated by space heating (increasing 285 kt) and water heating (increasing 62 kt).

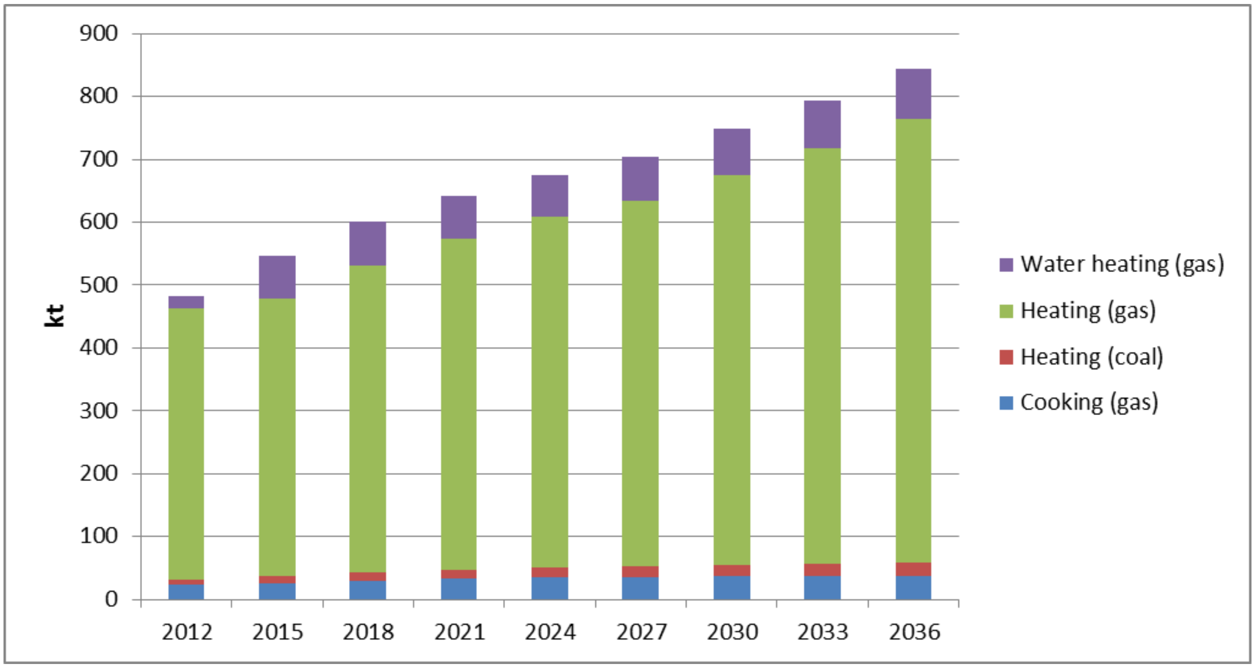

Figure 16: Commercial Emissions by Energy Service and Fuel

A simplified RES diagram of the commercial sector is presented in Figure 17, and shows the fuels, technology types and end-use services included in the model. In addition to energy efficient devices for all the technologies identified, the model also includes measures to reduce overall building energy demand.

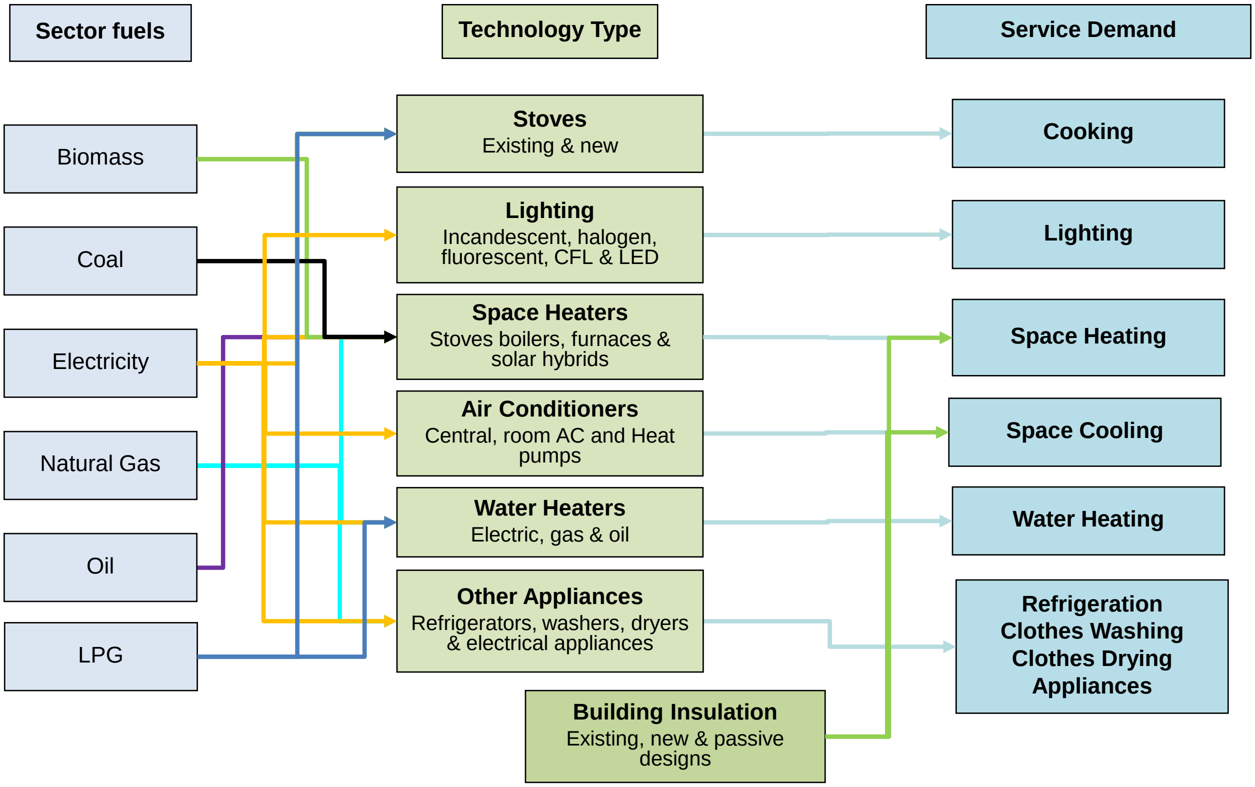

Figure 17: Residential Buildings RES

Residential sector energy use, which is shown in Figure 18, increases most significantly for natural gas (441 ktoe) and electricity (105 ktoe). The natural gas share increases from 27% to 44%, while biomass share reduces from 51% to 40%. Electricity remains at about 15%.

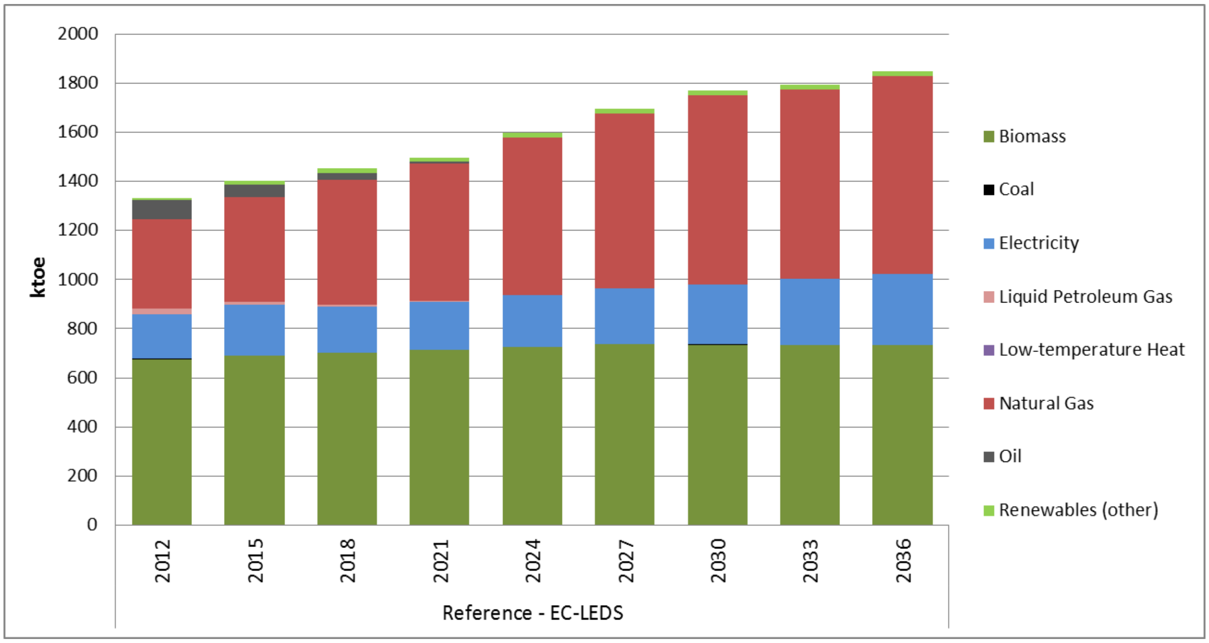

Figure 18: Residential Energy Use by Fuel

Figure 19 shows that residential sector energy use is dominated by water heating (increasing 227 ktoe), cooking (increasing 85 ktoe) and space heating (increasing 78 ktoe).

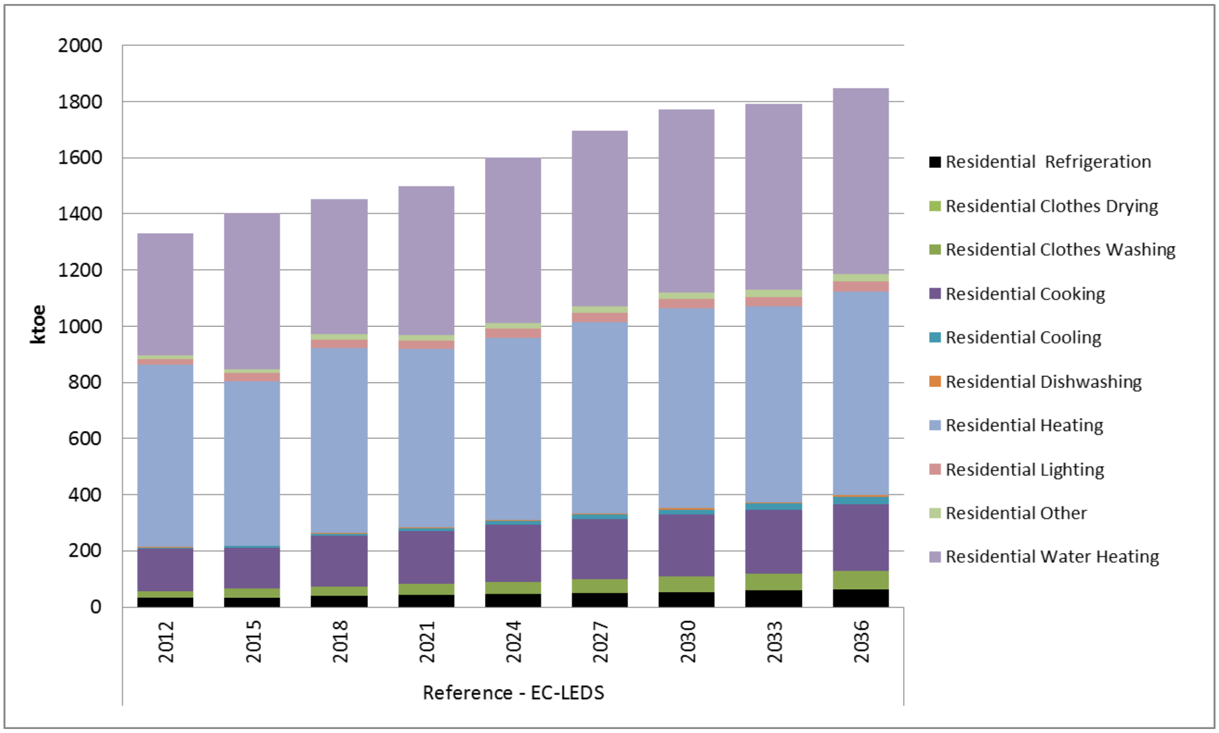

Figure 19: Residential Energy Consumption by Use

As shown in Figure 20, CO2 emissions from residential sector energy use are dominated by space heating and water heating. In the chart below some water heating emissions are included in heating.

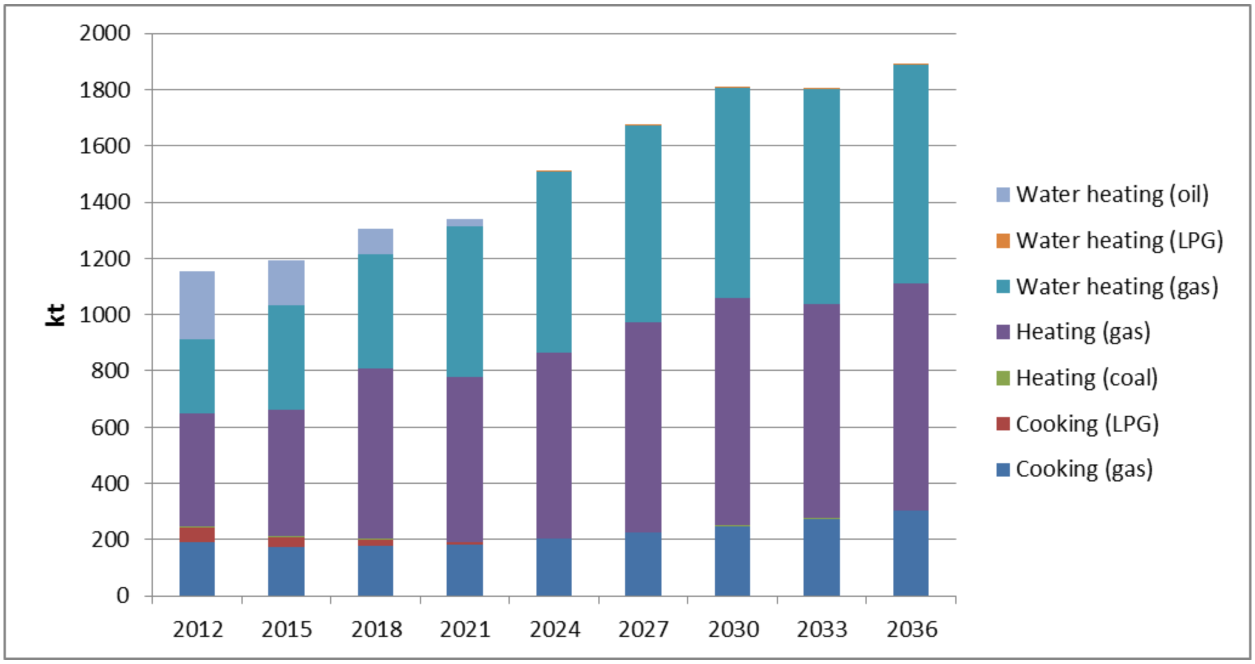

Figure 20: Residential Emissions by Energy Service and Fuel

Direct Emissions from Industry

The RES for the Industrial sector is shown in Figure 21. Each industrial sub-sector requires process heat and mechanical drive services to produce their associated products.

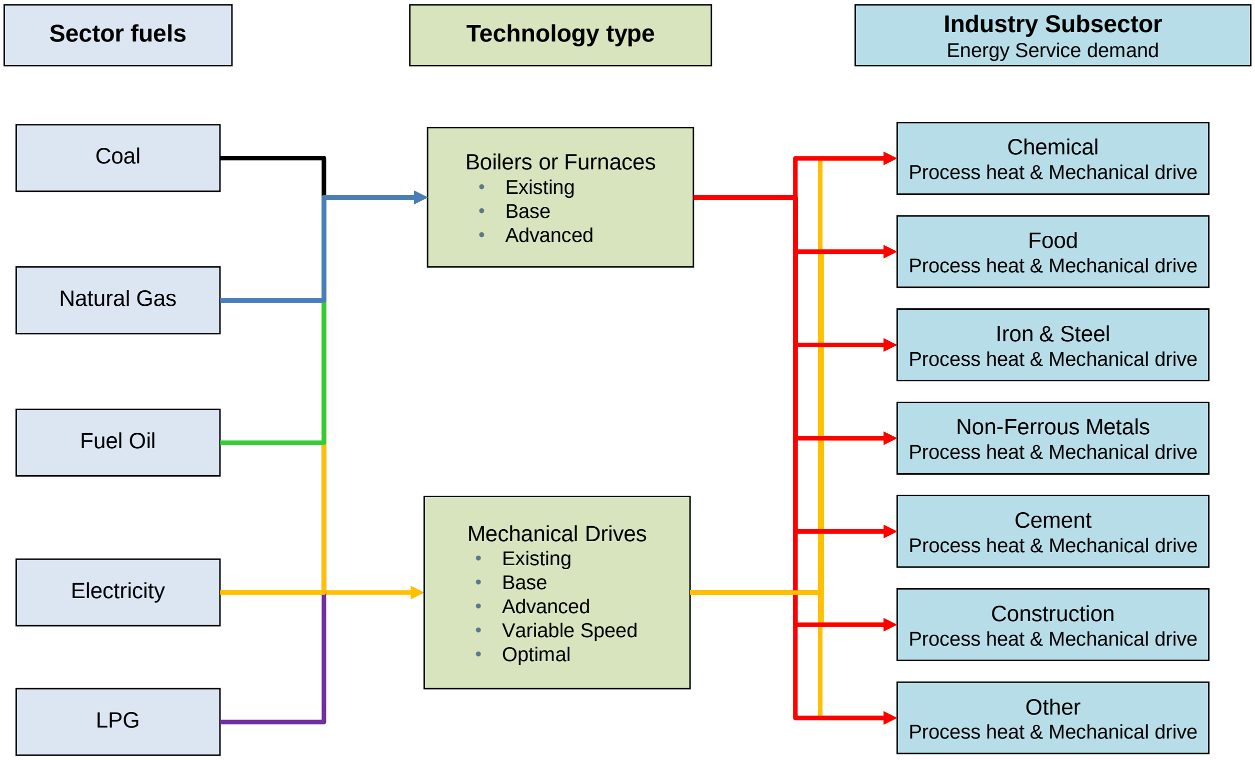

Figure 21: Industry Sector RES

As shown in Figure 22, industrial energy use grows by 100% between 2012 and 2036. Although cement and iron & steel are the largest, each industrial subsector grows proportionally, as the demand projection for each sector is determined by the same GDP and elasticity drivers.

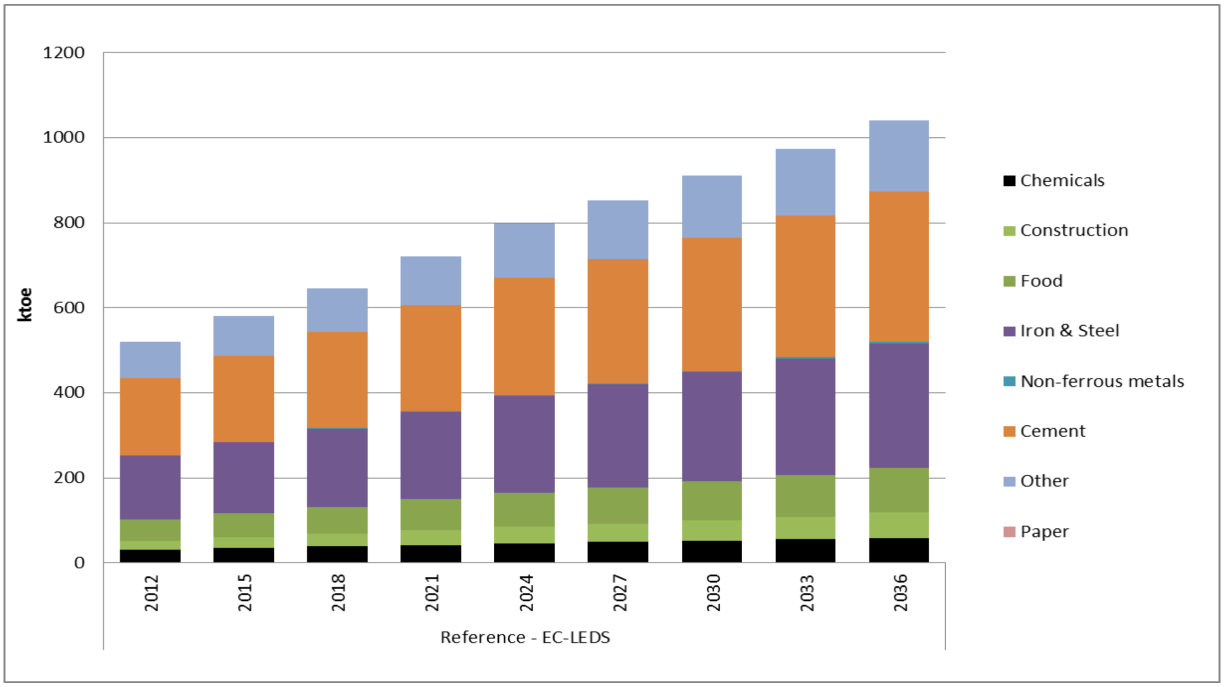

Figure 22: Industrial Energy Use by Sector

As shown in Figure 23, electricity comprises 50% of industrial energy use, so the primary GHG emissions from the sector come from coal (36% of final energy) and natural gas use (11% of final energy).

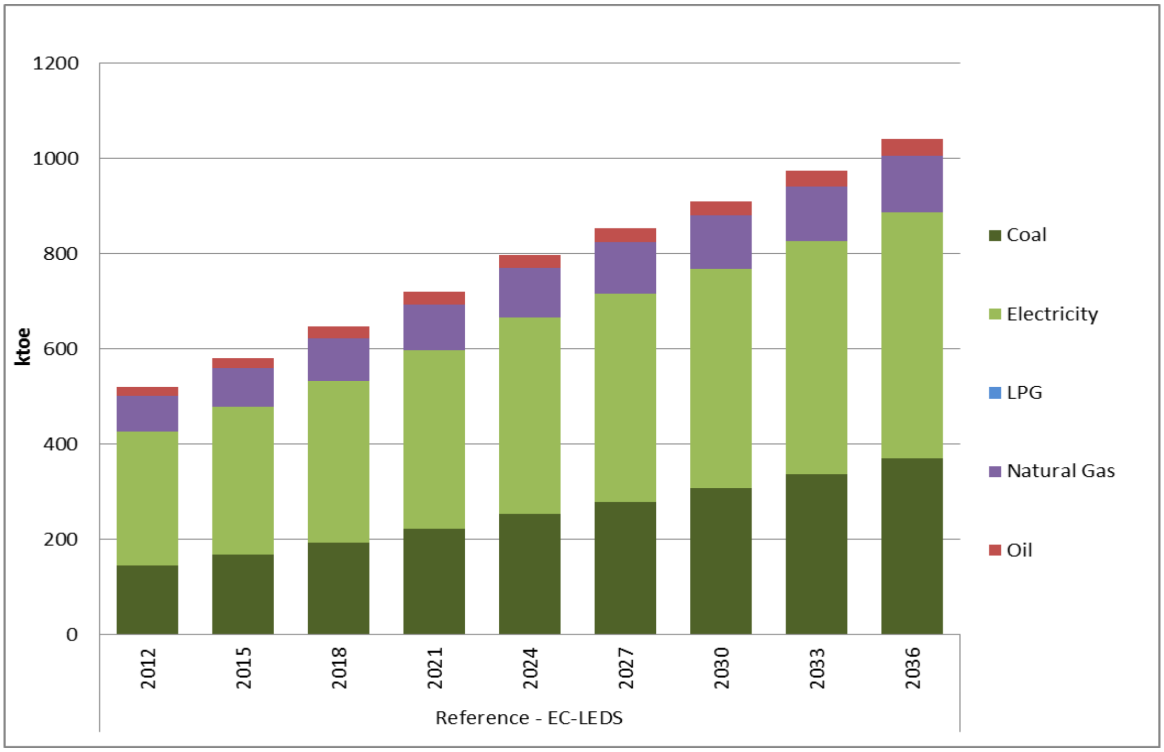

Figure 23: Industrial Energy Use by Fuel

Figure 24 shows that industry sector CO_2 emissions come primarily from cement production (65%), with all other subsectors accounting for less than 10% each.

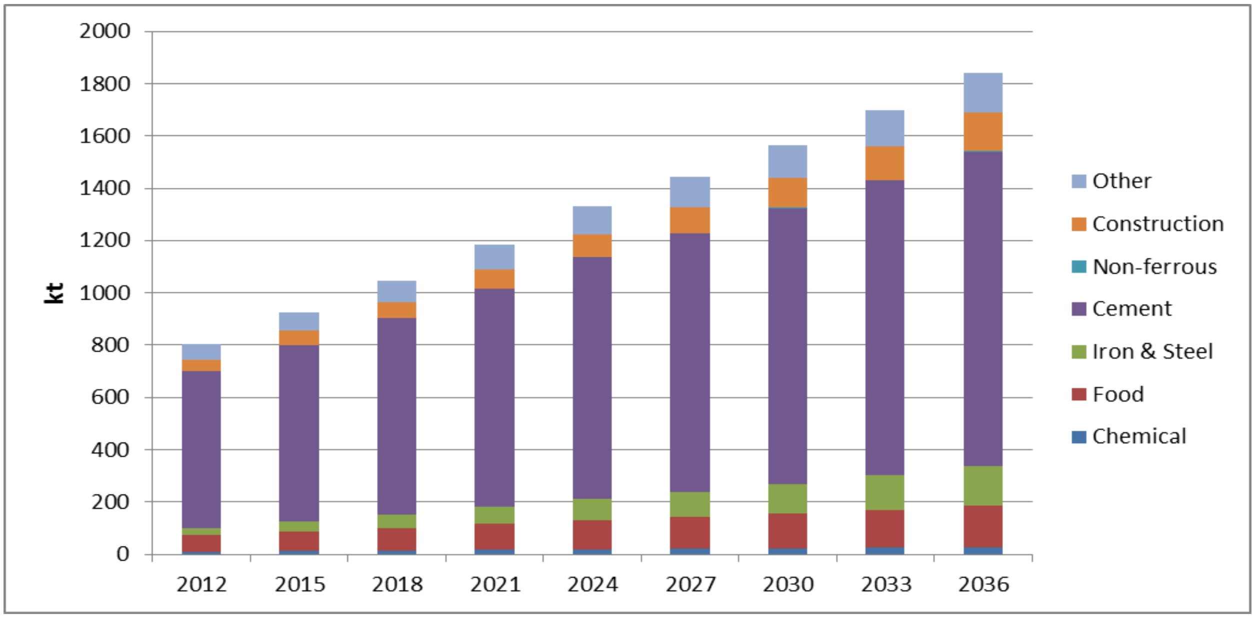

Figure 24: Industrial CO_2 Emissions by Sector

Direct Emissions from Transportation

The RES for the passenger Transportation is shown in Figure 25. Each passenger transportation demand uses a suite of vehicle types to deliver the associated service.

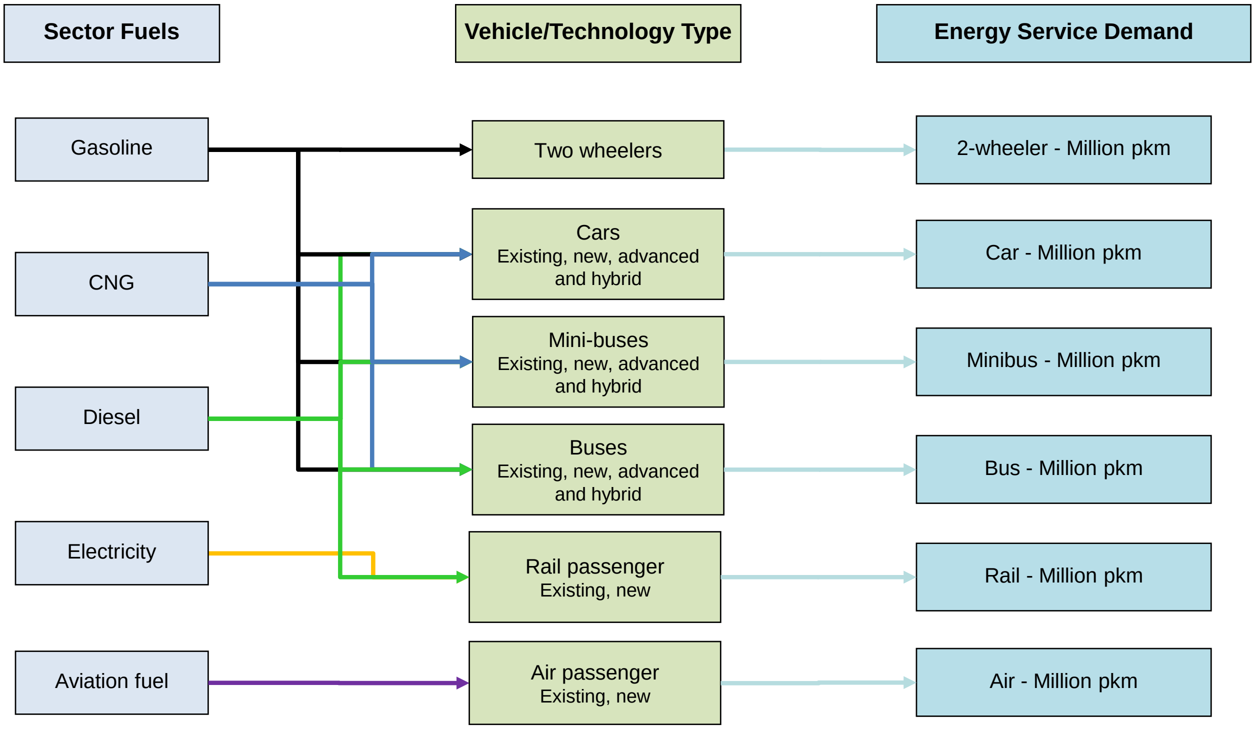

Figure 25: Transportation Passenger Travel RES

As shown in Figure 26, passenger transport is dominated by gasoline consumption, which increases by 127% between 2012 and 2036. Diesel use remains flat as natural gas (CNG) use grows by (285 ktoe), a 7 fold increase, with most used in Light Duty Vehicles (LDVs).

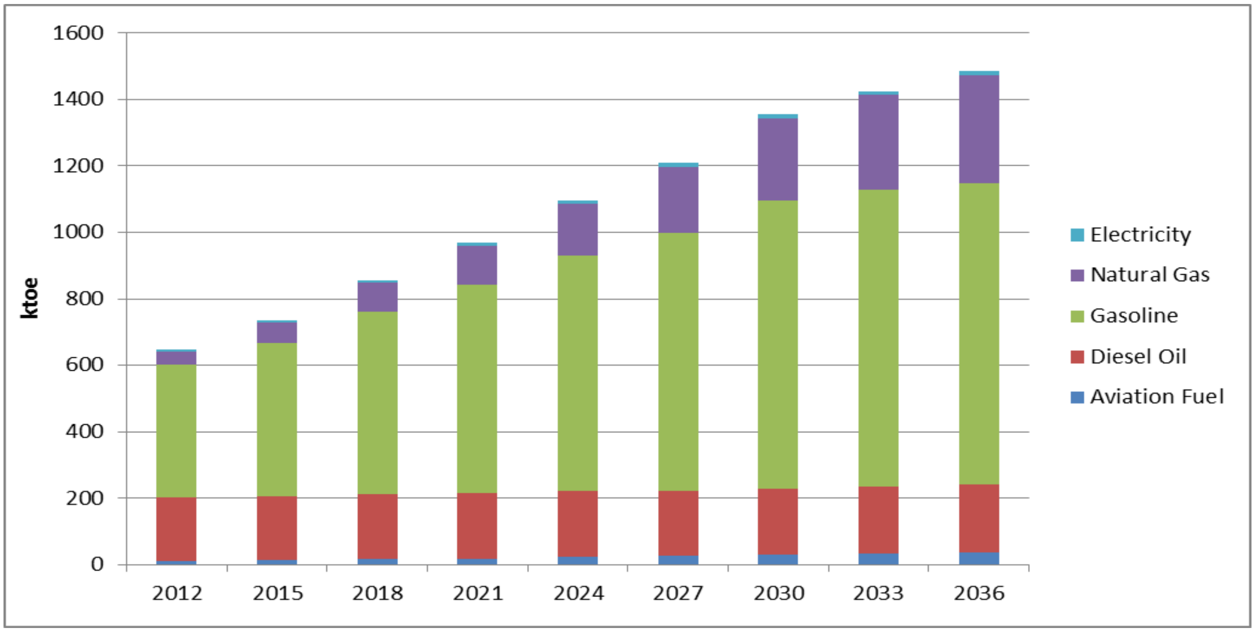

Figure 26: Fuel Consumption for Passenger Travel

Figure 27 shows that passenger transport by LDVs grows to 80% of all passenger transport energy use, although there is small growth in the other modes.

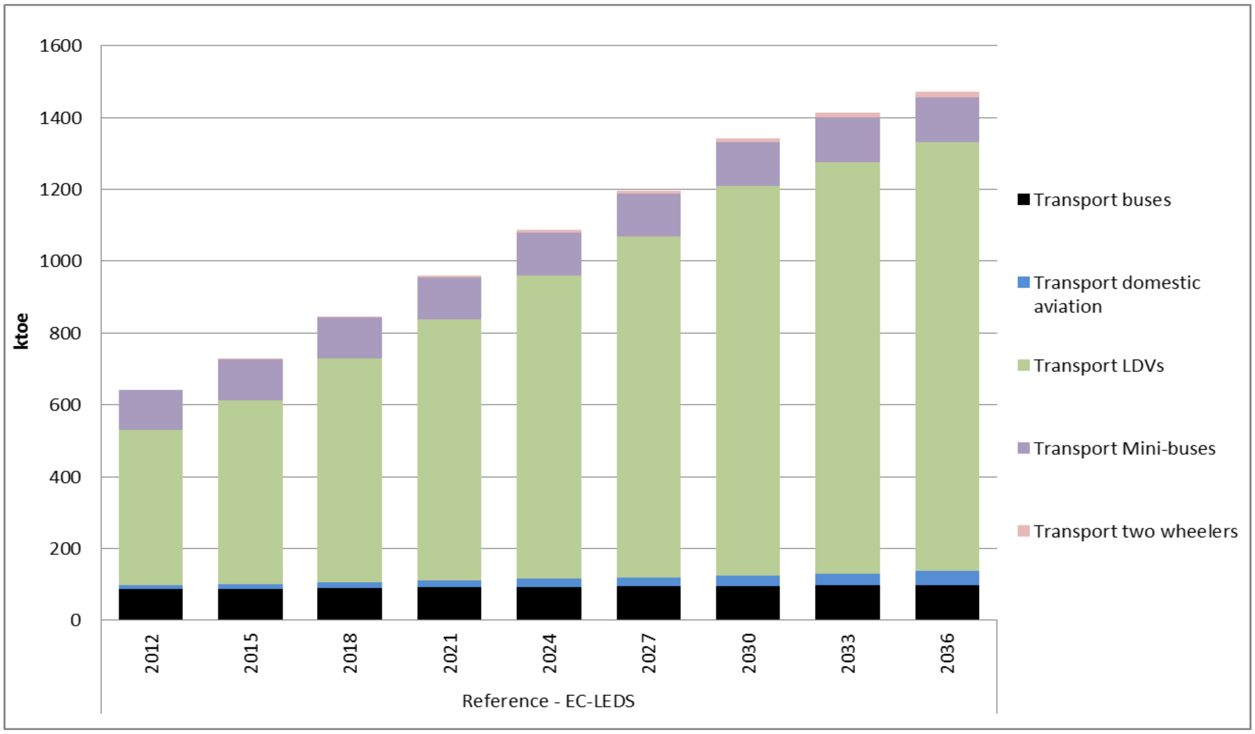

Figure 27: Fuel Use for Passenger Travel by Sector

As shown in Figure 28, passenger transport emissions grow by 120% between 2012 and 2036, and LDVs account for 80% of all passenger transport GHG emissions as fuel switching from gasoline to CNG does not result in emission reductions, although there is a cost savings.

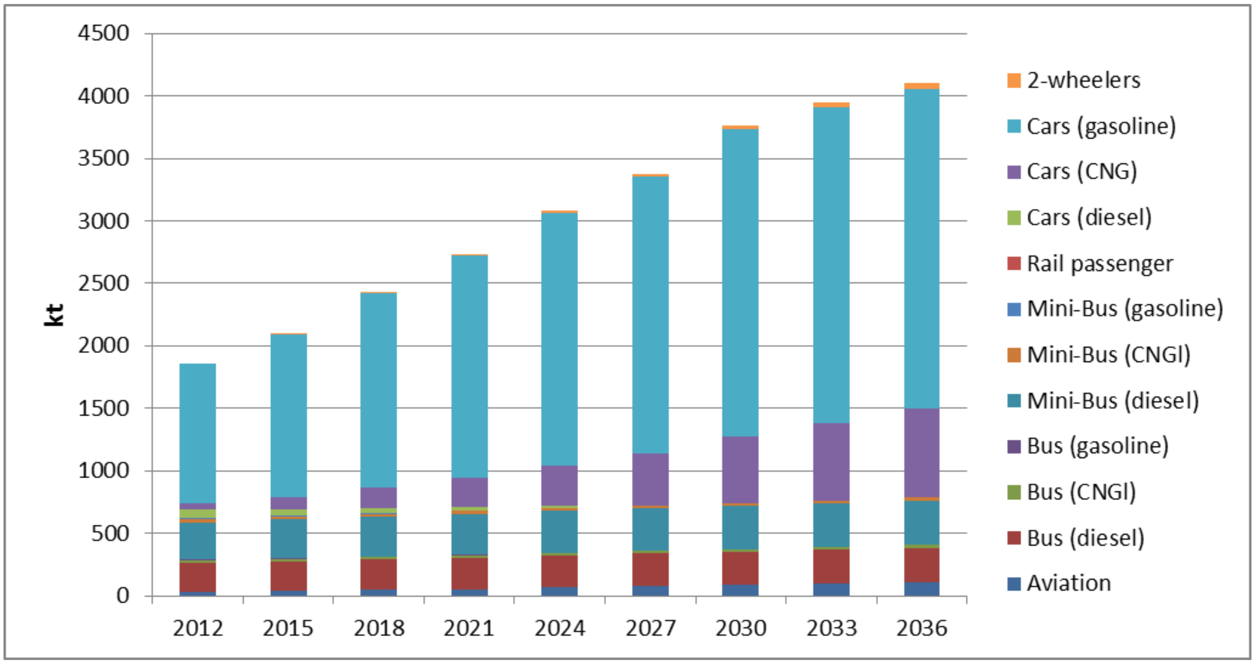

Figure 28: CO_2 Emissions from Passenger Travel by Vehicle Type and Fuel

Figure 29 shows a simplified RES diagram for freight transportation. Each freight transportation demand uses a suite of vehicle types to deliver the associated service.

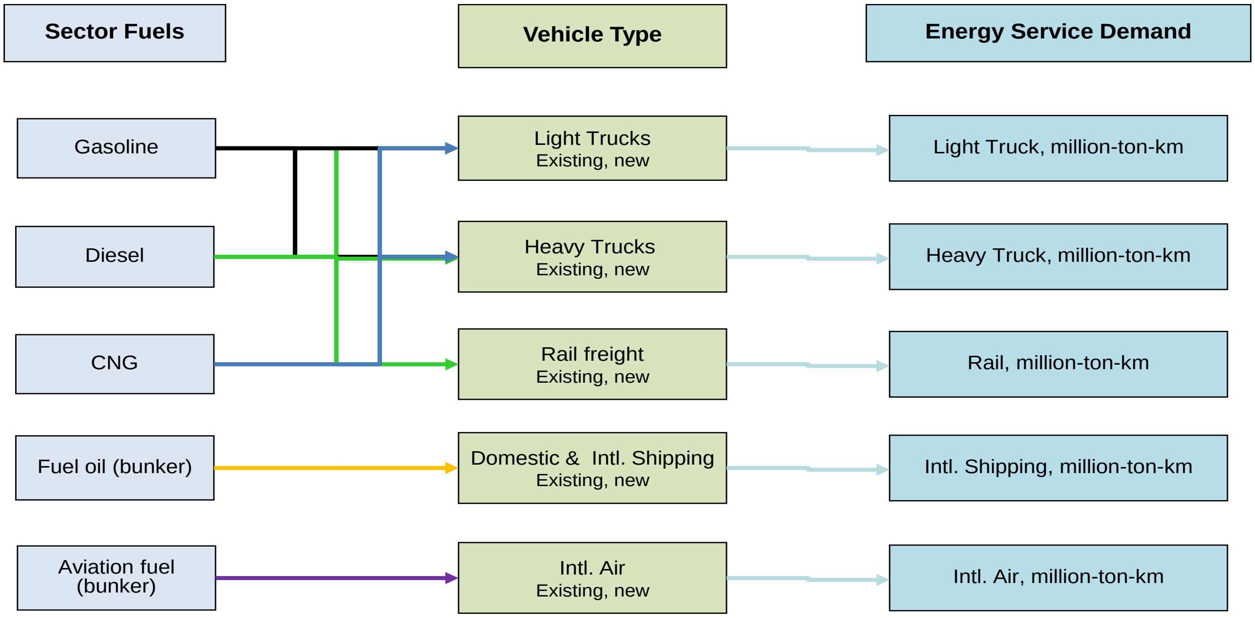

Figure 29: Transportation Freight Traffic RES

As shown in Figure 30, freight transport energy use increases most significantly for natural gas (600 ktoe), and diesel fuel use decreases because of economically driven fuel switching to CNG in light and heavy trucks. As a result, the natural gas share increases to 67% of the total in 2036. International bunker fuels are not counted in the national GHG inventory.

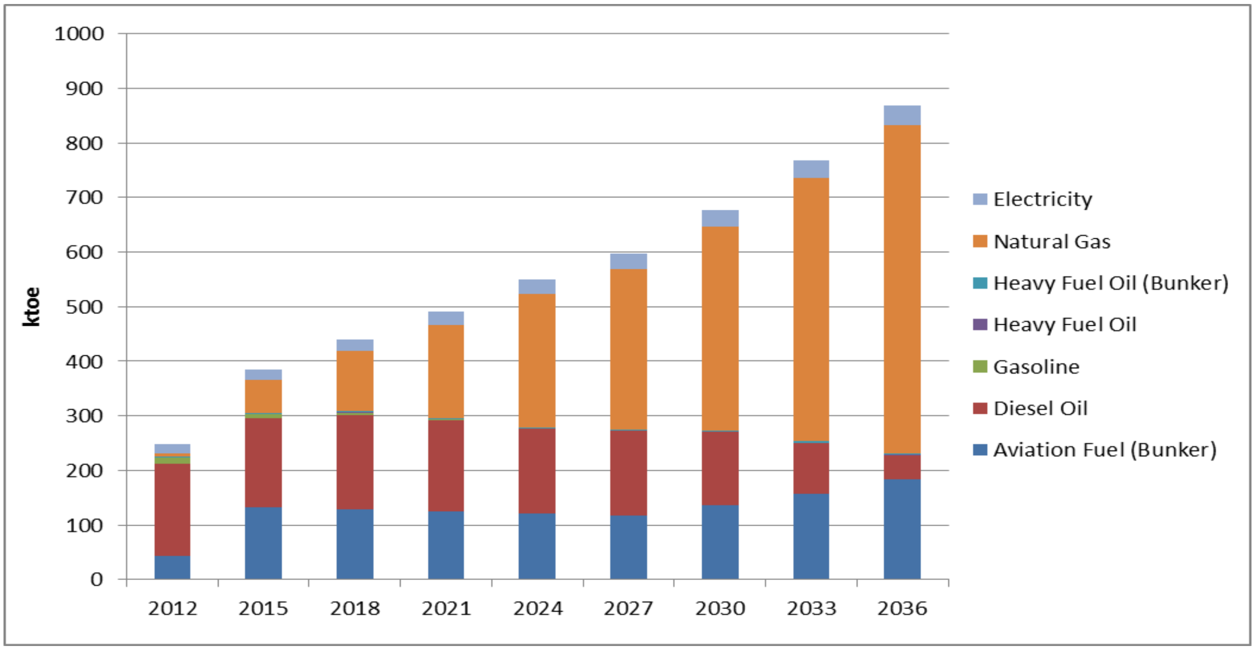

Figure 30: Fuel Consumption for Freight Travel

Figure 31 shows that freight transport energy use (including bunkers) grows by 250% between 2012 and 2036, with light and heavy trucks accounting for the bulk of the growth.

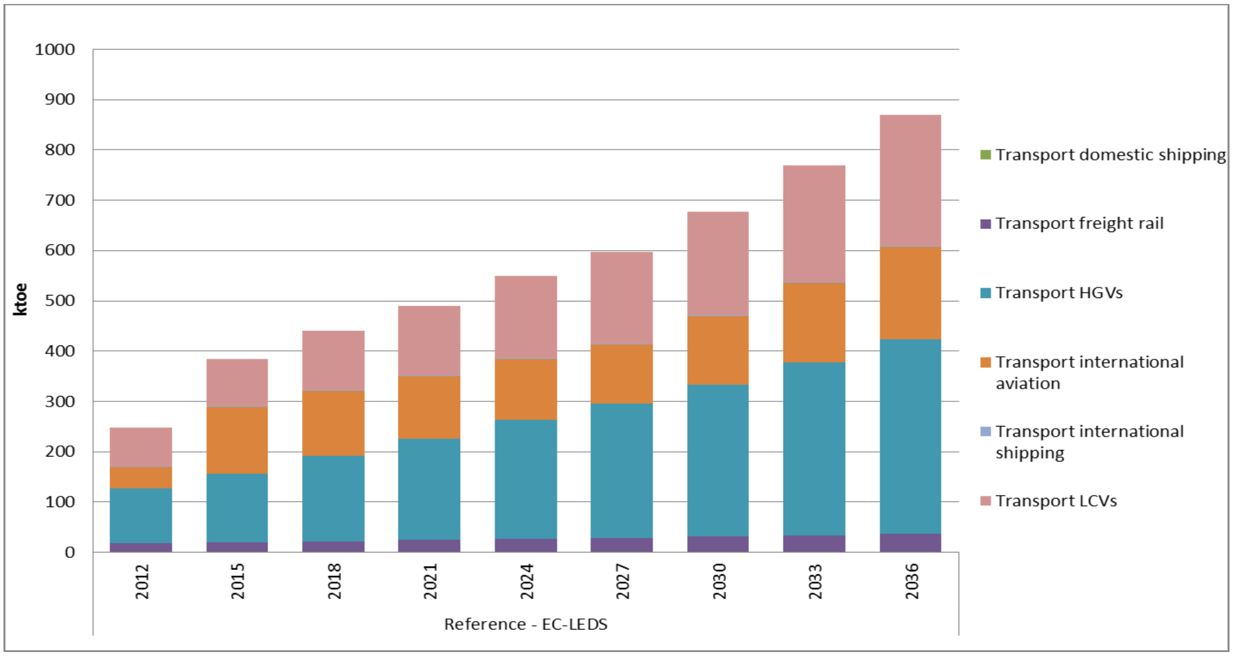

Figure 31: Fuel Consumption for Freight Traffic by Type

As shown in Figure 32, freight transport emissions (excluding bunkers) grow by 175% and the fuel switching from diesel to CNG, which is driven by economics not emission reductions, can be seen for both light and heavy trucks.

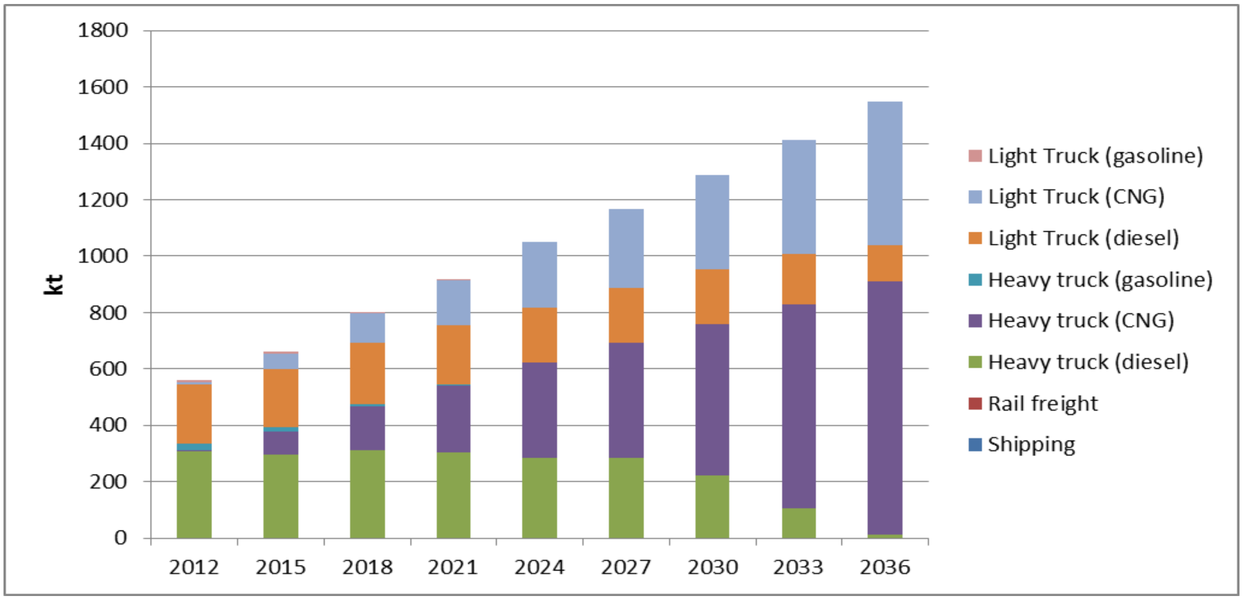

Figure 32: CO$_2$ Emission from Freight Traffic by Vehicle Type and Fuel

Non-Energy Sector Emissions and Removals

Industrial Process Emissions

Figure 33 shows that between 2012 and 2036, non-energy CO$_2$ industrial process emissions increase by 973 kt for Mineral Products, 714 kt for Metal Production and 330 kt for the Chemical Industry.

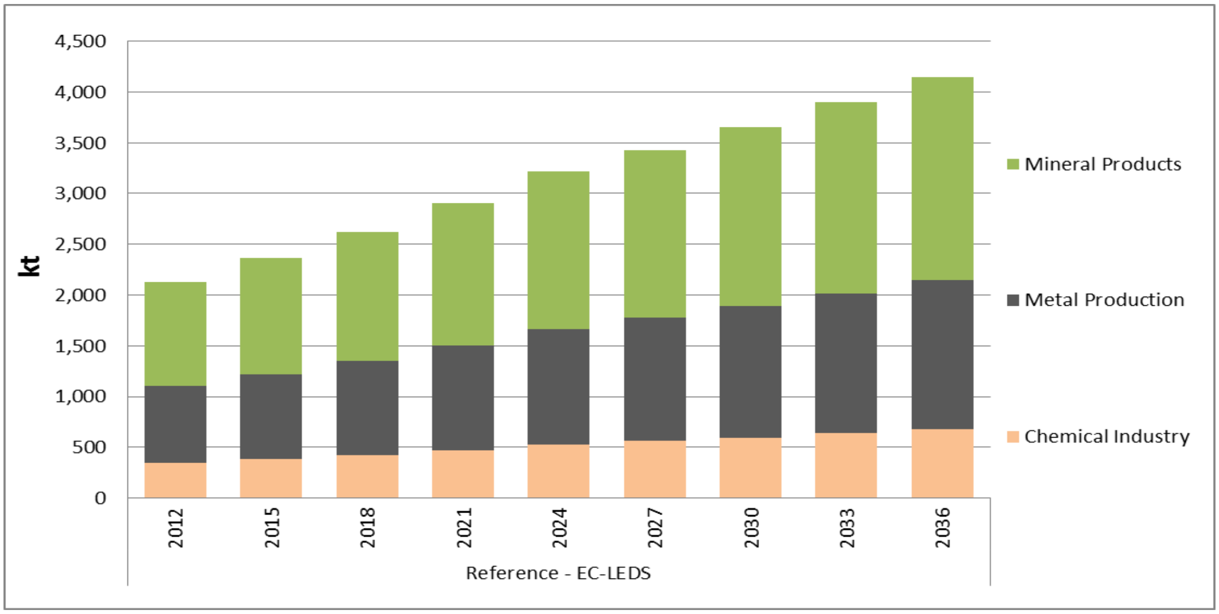

Figure 33: CO$_2$ Emissions from Industrial Processes

Figure 34 shows that HFC emissions are significant portion of the total GHG emissions, projected to increase over 400% because of the growth in air conditioning for both commercial and residential buildings.

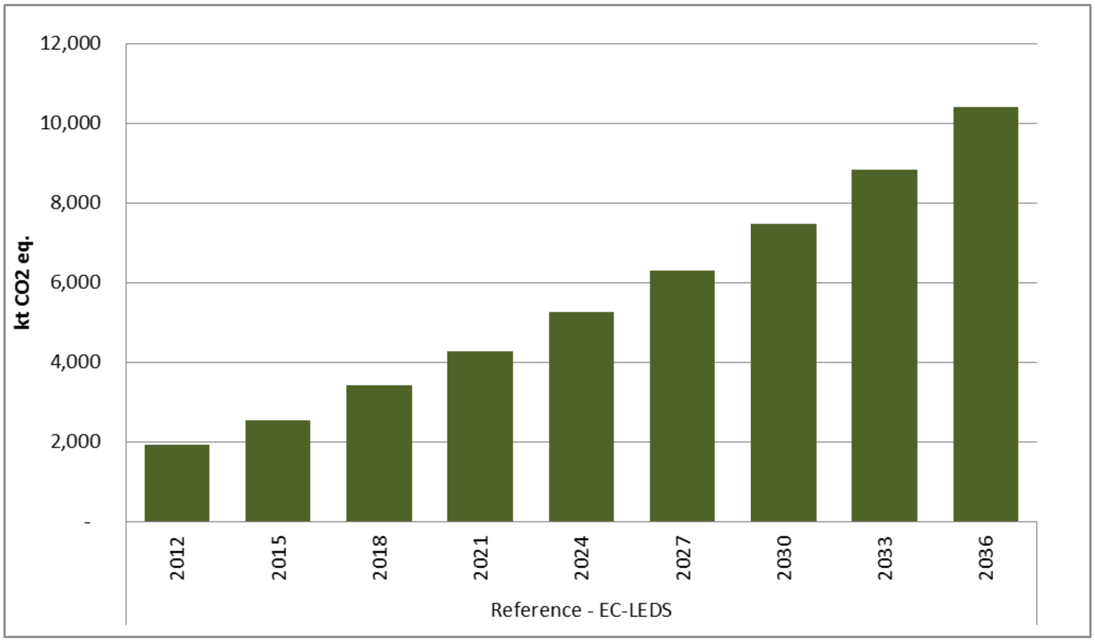

Figure 34: HFC Emissions from Industry

Agriculture Sector Emissions

Figure 35 shows that non-energy methane emissions (CO2 eq.) from Agriculture are predominantly due to enteric fermentation (1400 kt) and manure management (250 kt), more than doubling overall.

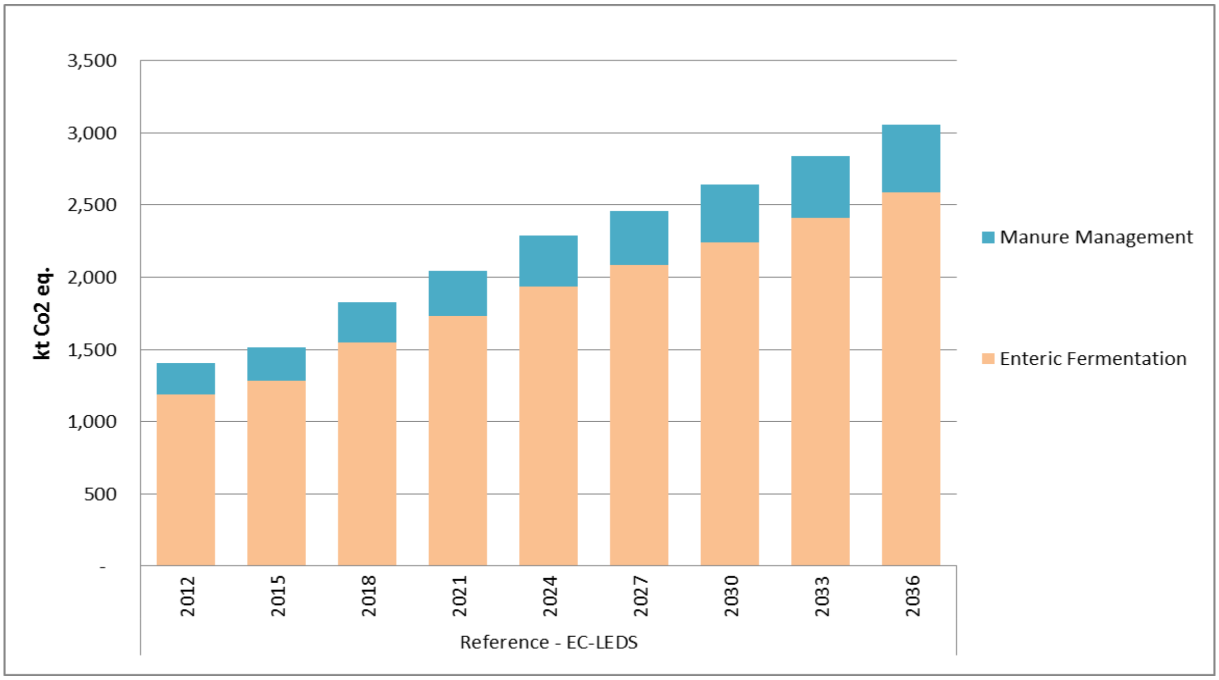

Figure 35: Non-Energy Methane Emissions from Agriculture

Forestry/Land Use Sector Emissions

CO2 emissions and removals from the Forestry/Land use sector are shown in Figure 36, which shows that forest lands and grass lands are CO2 sinks, while agricultural soils are a source of emissions. The proxy BAU does not increase over time, assuming current land use practices continue into the future. This will be replaced by actual BAU projection once that is available.

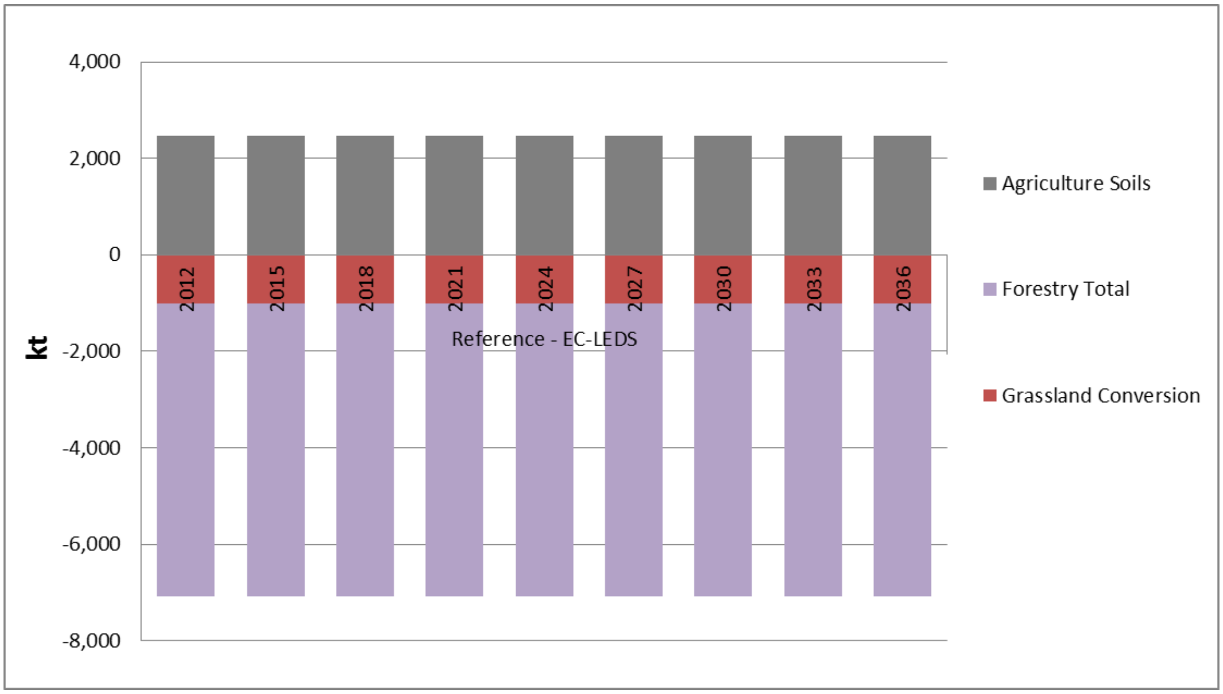

Figure 36: GHG Emissions from Land Use by Source

Waste Sector Emissions

Figure 37 shows that non-energy methane emissions from Waste are predominantly due to solid waste disposal (1400 kt) and wastewater handling (250 kt). The proxy BAU does not increase over time and will be replaced by actual BAU projection once that is available.

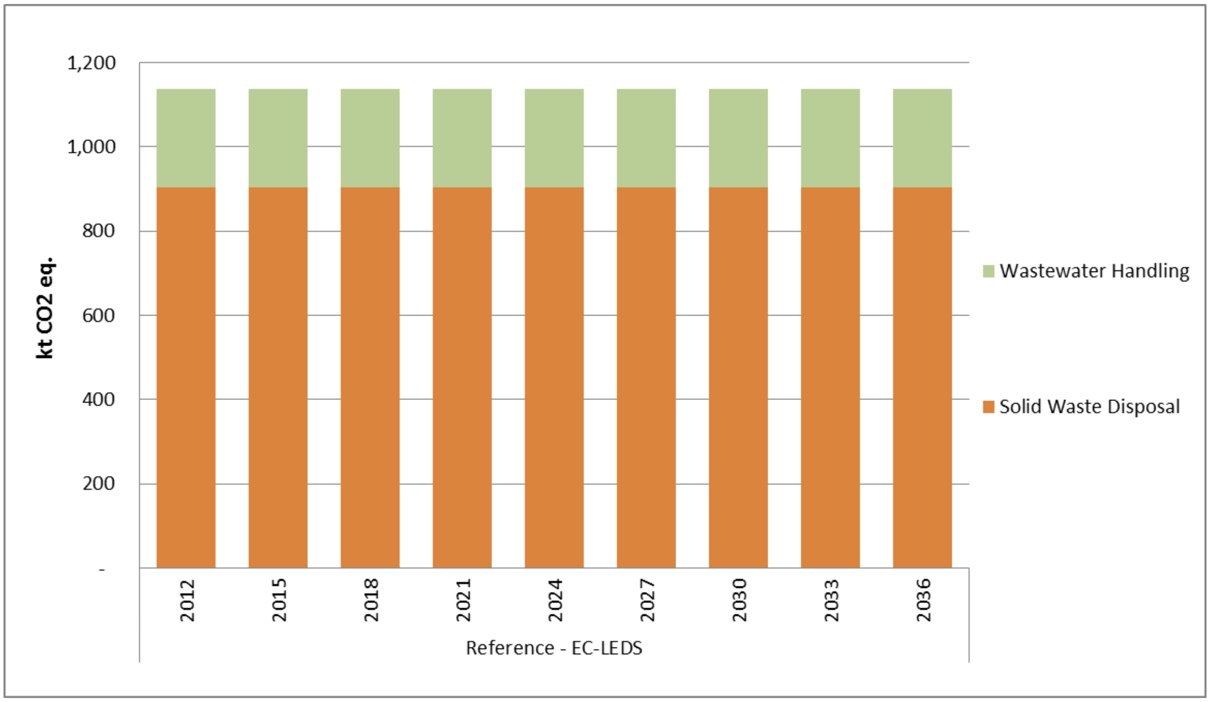

Figure 37: Methane Emissions from Waste

Non-energy Sector Methane Emissions

As shown in Figure 38, total non-energy methane emissions increase by 1650 kt due to the projected growth in the Agriculture sector. Waste and Forestry emissions are currently assumed to be constant. This proxy data will be replaced by actual BAU projections once they are available.

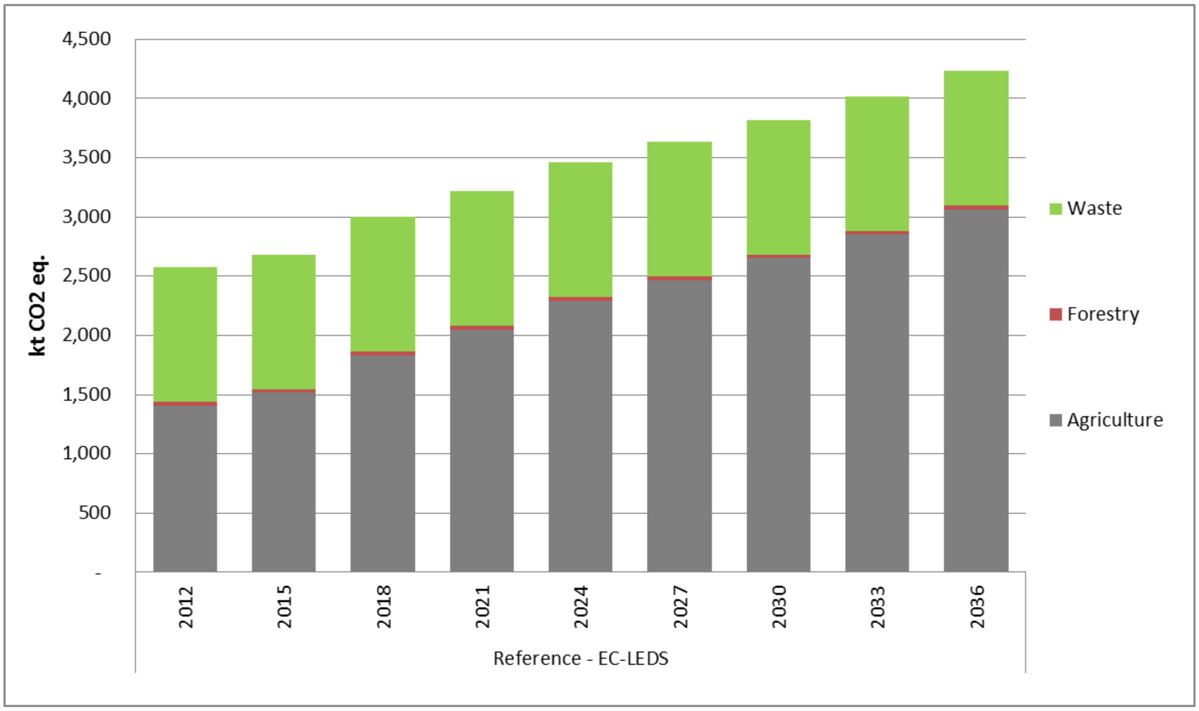

Figure 38: Non-Energy Methane Emissions by Source

Non-Energy N2O Emissions

As shown in Figure 39, non-energy nitrous oxide emissions are predominantly due to agricultural soils (1170 kt) and the chemical industry (685 kt), increasing 105% overall.

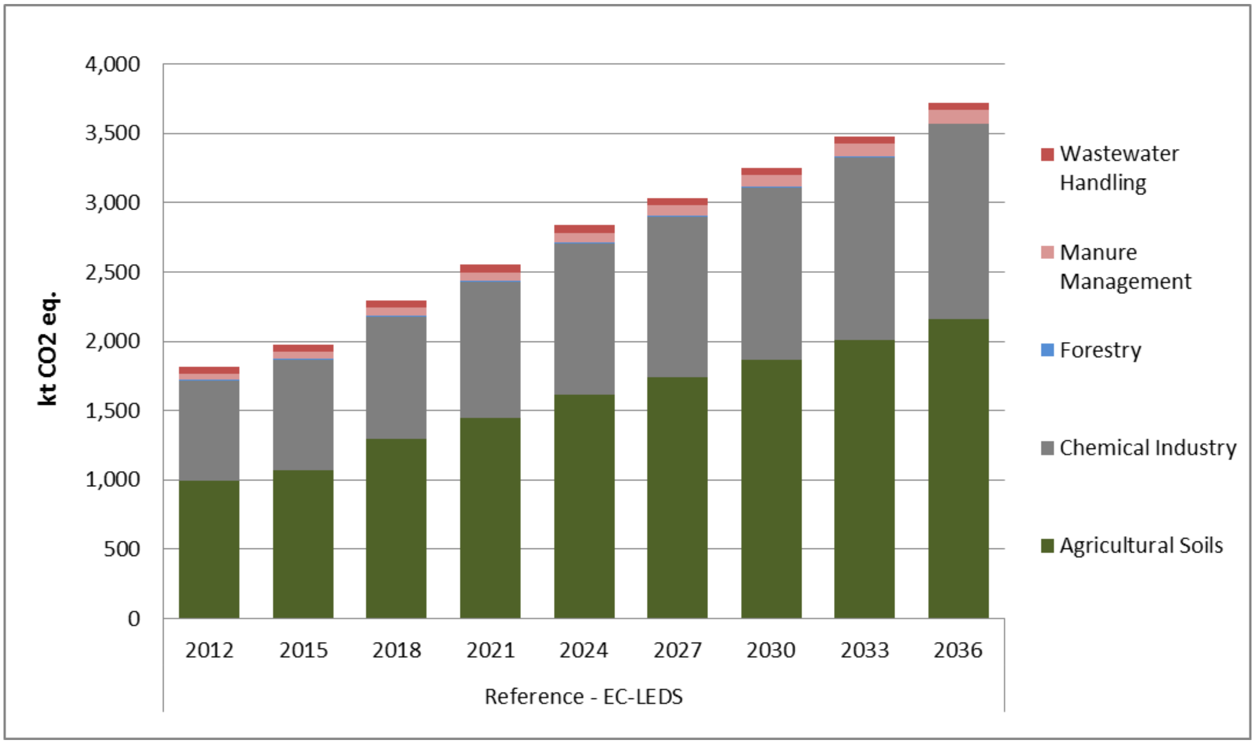

Figure 39: Non-energy N_2O Emissions by Source

Aggregated GHG Emissions BAU

Figure 40 shown total GHG emissions in CO2 equivalent units from the four main GHGs. Of total GHG emissions about 33% are due to CO_2 from energy and non-energy sources, and that proportion stay relatively constant. The proportion of N2O emissions decreases from 16% to 12% between 2012 and 2036, while the methane portion decreases from 36% to 22% because of the HFC emissions increase from 16% to 32%.

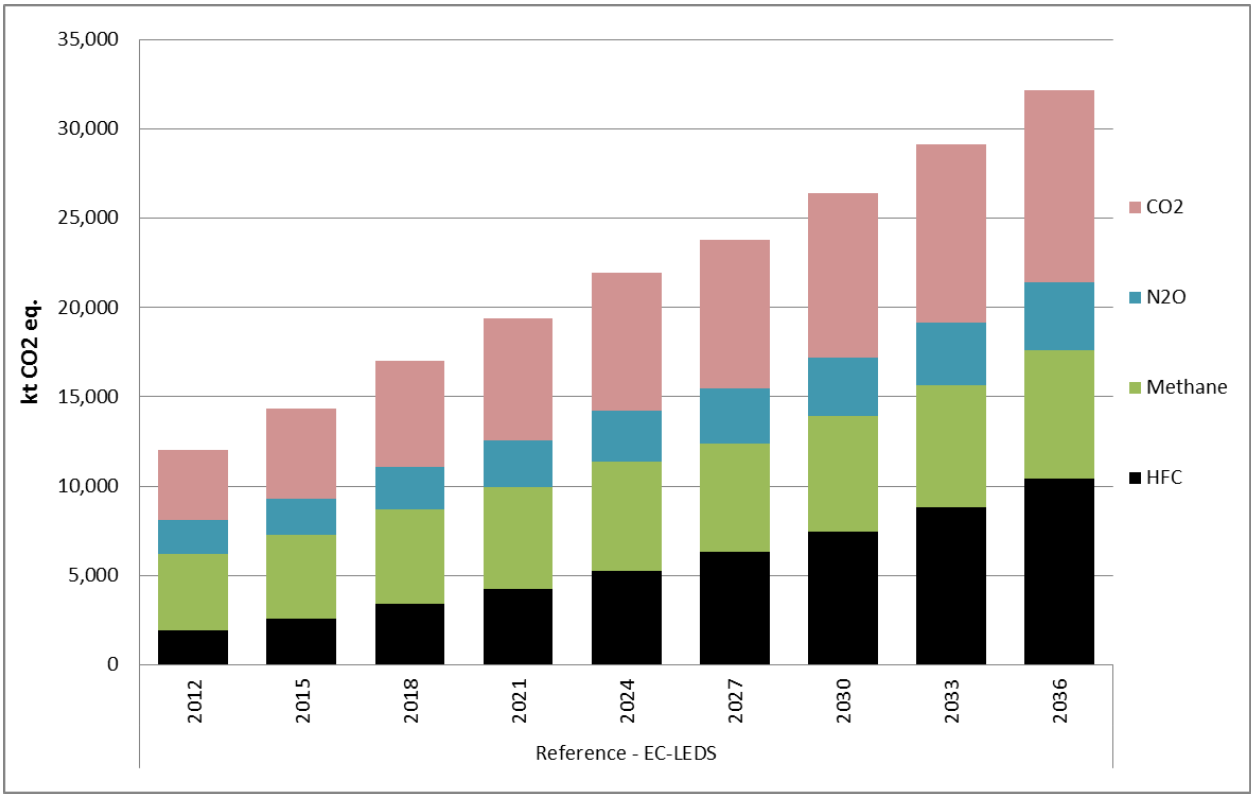

Figure 40: Total GHG Emissions by Type

ANNEX A: MARKAL-GEORGIA IMPROVEMENTS AND NEW TECHNOLOGY CHARACTERIZATIONS

A.1 Background

In preparing the Georgia MARKAL model for LEDS analyses, it was agreed that DWG would make the following model improvements and enhancements based on its experience and new data available:

1. Update base year transport technology characterizations relative to new technology options;
2. Add commercial buildings retrofit technologies;
3. Add efficient technologies for public lighting;
4. Add CNG compressing technologies for filling stations, and
5. Introduce hurdle rates for residential and commercial retrofit technologies (and review hurdle rates for transport)

This annex documents these improvements and enhancements.

A.2 Base Year Transport Technology Characterizations

Early runs of the transport sector indicated that the model preferred to keep the base year transport technologies rather than adopt many of the new transport technologies. A review of the base year vehicle efficiencies relative to the new technology options indicated that base year values were too high and appeared to be new vehicle efficiencies that had not been adjusted for on-road driving conditions. The base year vehicle efficiencies were corrected along with the average annual distance per vehicle values were then adjusted to maintain the base year energy balance for each road vehicle type.

In addition, the base year data on buses and mini-buses was averaged into a single bus type that did not have an analogous new technology type. To improve the representation of these two vehicle types, separate bus and mini-bus base year technologies were created and the passenger transport demand was disaggregated for buses and mini-buses. The corrected and updated transport sector base year data is shown in Table 1. USDOE data was used for the new bus technology characterizations, and data from the Sultan tool[4] was used for the new mini-bus technology characterization

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[4] EU Transport GHG: Routes to 2050 project, http://www.eutransportghg2050.eu/cms/?flush=1.

Table 1: Revised Road Transport Vehicle Data

Vehicles	Light Duty Vehicles	Buses	Mini-Buses	Light Commercial Vehicles (Below 2-tonnes)	Heavy Goods Vehicles
Registration by fuel type	**2012**	**2012**	**2012**	**2012**	**2012**
on gasoline	522,963	433	824	3,874	989
on diesel	27,524	7,528	14,334	71,273	12,858
on CNG	23,085	692	1,318	2,324	283
total	**573,573**	**8,653**	**16,476**	**77,471**	**14,130**
Performance Characteristics					
Annual mileage (km/vehicle)	9,600	34,672	31,864	7,100	28,000
Passenger per vehicle (passenger/vehicle)	2.00	15	8		
Annual passenger-kms (millions)	11,013	4,500	4,200		
Freight per vehicle (tonnes/vehicle)				2	15
Annual tonnes-kms				886	5,780
Average fuel consumption per vehicle gasoline (liter/100 km)	9.5	32.8	24.8	15.8	31.8
Average fuel consumption per vehicle diesel (liter/100 km)	8.8	31.0	23.0	14.8	30.0
Average fuel consumption per vehicle CNG (cubm/100 km)	9.7	32.0	20.0	15.0	31.0
Annual Fuel Consumption					
Total gasoline consumption(liters)	476,942,263	4,920,000	6,510,000	4,345,354	8,806,946
Total diesel consumption (liters)	23,252,587	80,910,000	105,052,500	74,894,101	108,009,720
Total CNG consumption (cubm)	21,497,053	7,680,000	8,400,000	2,475,202	2,452,968
Total gasoline consumption(PJ)	16.31143	0.1683	0.2226	0.1486	0.3012
Total diesel consumption (PJ)	0.89755	3.1231	4.0550	2.8909	4.1692
Total CNG consumption (PJ)	0.93082	0.3325	0.3637	0.1072	0.1062
Efficiency gasoline (mln passenger-km/PJ, or mln tonne-km/PJ)	616	1,337	943	298	1,343
Efficiency diesel (mln passenger-km/PJ, or mln tonne-km/PJ)	589	1,254	901	282	1,262
Efficiency CNG (mln passenger-km/PJ, or mln tonne-km/PJ)	476	1,083	924	248	1,088

A.3 Commercial Building Retrofits

In a 2014 study for the Energy Community Secretariat[5], SEVEn Energy, a Czech energy services company (ESCO), developed data for commercial building retrofits based on its experience with such projects in Eastern Europe, the Western Balkans and Ukraine. Table 2 provides a realistic estimate of an average investment cost for the Energy Community (EnC) countries. The estimated costs are lower per unit of energy saved compared to typical EU countries because the level of building energy consumption in the EnC countries is much higher (250 kWh/m2 compared to 100 kWh/m2) and there are a lot of relatively low cost measures that can be pursued.

Table 2: Estimate of the retrofit building costs for the Balkan countries and Ukraine

Building category	**Unit Investment cost (M€/PJ)**			
	Measures to reduce heating losses of building envelope	**Regulation of a heating system**	**Installation of a heat recovery unit**	**Complete building retrofit**
Single family house	170	80	100	140
Apartment building	210	70	140	180
Offices	250	70	160	210
Education	210	50	150	180
Health	250	100	200	220

The basic elements of each measure are:

- To reduce heating losses by means of thermal insulation of the building shell (external walls, roof, eventually floor or ceiling below the lowest heated floor) and replacement of windows and doors;
- Better regulation of a heating system involves primarily measurement and control systems, eventually an installation of valves, or replacement of pumps, and
- Installation of a heat recovery unit to reduce ventilation losses, including the distribution system.

The "measures to reduce heating losses," including thermal insulation of the envelope and replacement of windows, also lower cooling requirements. This is the most expensive option because thermal insulation of existing buildings is the most expensive measure per unit of energy saved, but the lifetime is longer than other measures, so the life cycle cost can still be very attractive. A complete building retrofit (reducing for example 75% of heating requirement) consists of building insulation (45%), improved temperature regulation and control (10%) and efficient heat recovery system (20%). As the latter two measures are cheaper per unit of energy saved, the average investment cost is lower than building insulation. Total savings for a complete building retrofit is roughly the sum of all three measures, but the investment cost is a weighted average. The percentage of energy savings achieved (on average) by each measure for each building type, based upon SEVEn's calculations, is shown in

Table 3.

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[5] Final Report for Assessment of the impact of the Energy Efficiency Directive, 2012/27/EU, if this is adopted by the Contracting Parties of the Energy Community, Submitted to the Energy Community Secretariat, Volume 2: Appendix D: New Commercial Building Retrofit Data, By DecisionWare Group, July 7, 2014.

Table 3: Percentage of energy savings achieved for each measure and building type

Building category	Energy savings (%)		
	Measures to reduce heating losses of building envelope	Regulation of a heating system	Installation of a heat recovery unit
Single family house	50	7	17
Apartment building	50	8	
Offices	40	9	
Education	45	9	
Health	50	8	

Energy conservation processes were created for both the large and the small building categories for each of the retrofit measures. Table 4 and **Error! Reference source not found.** provide the process names and data for the heating and cooling applications of these building retrofit measures.

Table 4: Percentage of heating energy savings achieved for each measure and building type

Measure	Large Building Investment Cost (M€/PJa)	Small Building Investment Cost (M€/PJa)	Heating Saving Potential (%)	Cooling Saving Potential (%)
Building Envelope	250	210	45	40
Regulation of a Heating System	70	50	9	9
Heat Recovery	160	150	17	17
Complete Building Retrofit	210	180	64	59

A.4 Public Lighting

Previously, Georgia-MARKAL had only a single generic street lighting technology, and that has the cost and performance characteristics of an incandescent bulb technology. Although the overall energy consumption for this application is small compared to the overall energy use, it is an area of low-cost savings that should be considered under the LEDS process, so three new technology options were added; halogen, fluorescent, and LED technologies. The efficiency data from similar residential lighting technologies were used and the cost data was scaled from the generic technology cost using the same cost ratios as for the residential lighting technologies.

Table 5: Efficient Lighting Technologies Characteristics

Bulb type	Start	Life (years)	Efficiency (relative to Incandescent)	Investment Cost (M€/PJa)	Variable O&M (M€/PJa)
Halogen	2015	3	2.00	32.64	0.0008
Fluorescent	2015	5	4.00	21.76	0.0008
LED	2015	10	10.00	55.49	0.0008

Due to their substantive performance advantages over conventional bulbs their rate of penetration is controlled so that they gradually enter the system in the BAU scenario, alternate LEDS policy scenarios will examine acceleration of their introduction as a potential mitigation measure.

A.5 CNG Infrastructure

MARKAL-Georgia currently has a variety of CNG vehicles (buses, trucks and cars) that receive natural gas with only a delivery costs for compression and no losses in the compression, storage and distribution processes. The most current source for data on CNG infrastructure costs is a 2011 report prepared by TIAX for America's Natural Gas Alliance[6]. The report identified four strategies used historically in the North America market, of which the model of independent retailers established by local gas distribution company was selected as the most applicable in Georgia. The following model improvements were made, and the key model inputs are provided in Table 6:

1. The stock and a leakage rate for existing CNG distribution processes were added, where the former is based on the total 2012 CNG vehicle activity levels, and a proxy leakage rate of 2% was assumed based on US experience;
2. A new CNG compression and distribution station technology was added with appropriate investment and operating costs, and a proxy leakage rate of 2% was assumed, and
3. The delivery cost calculated for the existing CNG stations was used for the new CNG station.

Table 6: CNG Distribution Station Technology Characteristics

New CNG Distribution Station Technology Characteristics		
Typical Capacity	0.38816	PJa
Investment Cost	1.54577	MEuro/PJa
Fixed O&M	0.26665	MEuro/PJa
Variable O&M	0.21830	MEuro/PJ
INP(ENT)p =	0.03456	PJ/PJ
Delivery Cost	4.522	MEuro/PJ

A.6 Technology Hurdle rate Adjustments

To Come.

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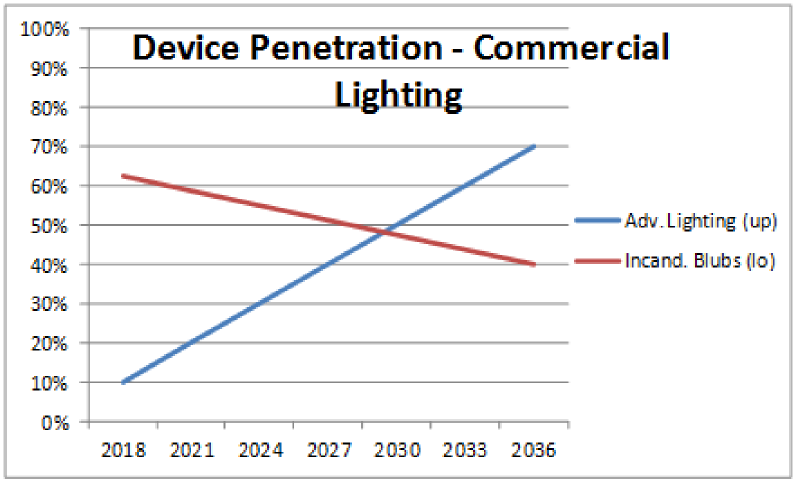
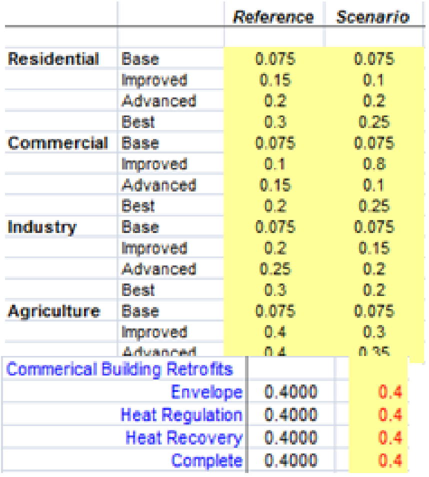
[6] U.S. and Canadian Natural Gas Vehicle Market Analysis: Compressed Natural Gas Infrastructure, America's Natural Gas Alliance.

Methods for Guiding the Evolution of the Energy System – Device Penetration





		Reference	Scenario
Residential	Base	0.075	0.075
	Improved	0.15	0.1
	Advanced	0.2	0.2
	Best	0.3	0.25
Commercial	Base	0.075	0.075
	Improved	0.1	0.8
	Advanced	0.15	0.1
	Best	0.2	0.25
Industry	Base	0.075	0.075
	Improved	0.2	0.15
	Advanced	0.25	0.2
	Best	0.3	0.2
Agriculture	Base	0.075	0.075
	Improved	0.4	0.3
	Advanced	0.4	0.35

Commerical Building Retrofits		
Envelope	0.4000	0.4
Heat Regulation	0.4000	0.4
Heat Recovery	0.4000	0.4
Complete	0.4000	0.4

- Used to limit rate at which advanced technologies may be adopted, in combination with hurdle rates, and inefficient ones leave
- Varied according to the scenario analyzed (accelerated vs. slower efficient device penetration)

ANNEX B: METHODOLOGY FOR ADDING NON-ENERGY GHG EMISSION SOURCES TO THE MARKAL-GEORGIA MODEL

B.1 Methodology

The starting point for incorporating non-energy GHG emissions into MARKAL-Georgia is the draft 2011 National GHG Inventory currently under review for submission by Georgia to the United Nations Framework Convention on Climate Change (UNFCCC) in its Third National Communication. That document identifies four non-energy GHG sectors that are important to Georgia, as shown in Table 7. These sectors are Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste.

For each sector, the methodology addresses current emission levels, the approach to developing the future business-as-usual (BAU) emissions, and the types of mitigation technologies to be considered. In all cases, the BAU emission levels will be inputs to MARKAL-Georgia, either in the form of projected emission levels over time, or in the form of emission intensity factors that can be tied to industrial activity levels already existing in the model. In some cases, these BAU emission levels will be linked to drivers, such as GDP or population growth, to allow alternate scenarios to be examined in a consistent manner. In addition, the cost and performance of the non-energy sector mitigation measures will also be inputs to MARKAL-Georgia. Figure 41 provides an overview of the proposed approach, which is described in more details in the following sections.

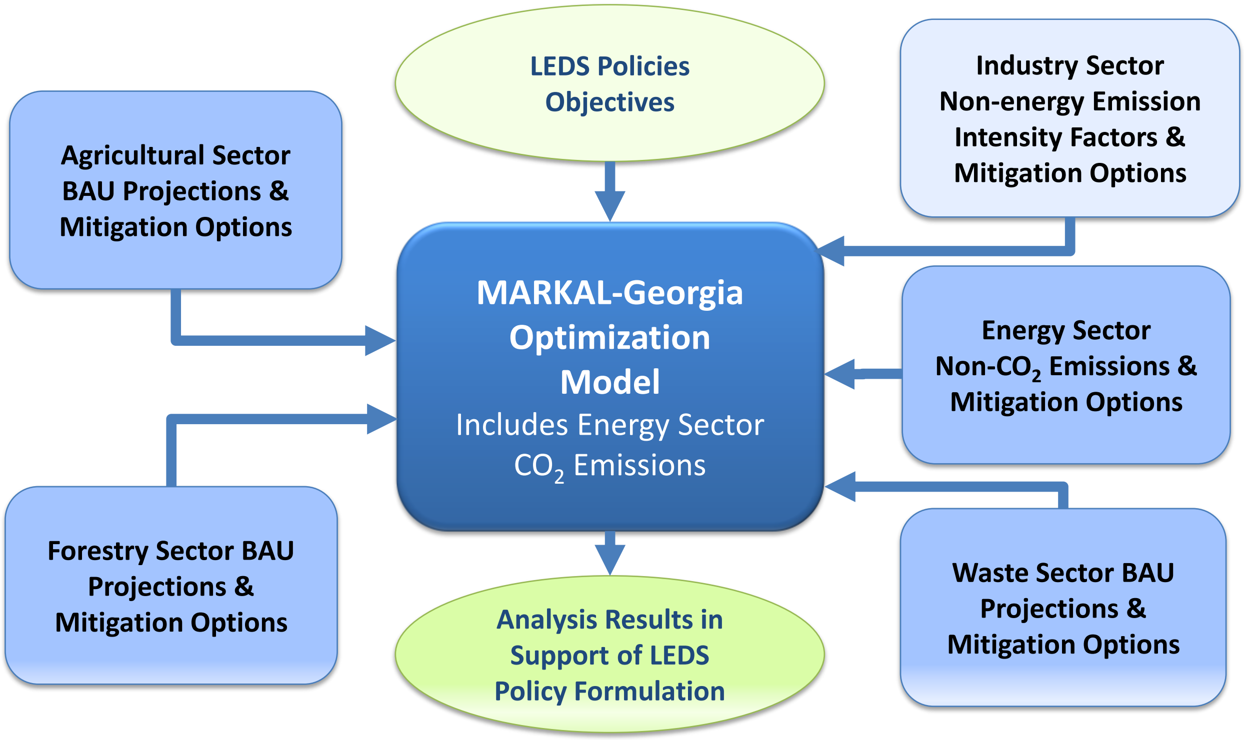


Figure 41: Fully Integrated GHG Accounting and Mitigation Analysis with MARKAL-Georgia

Table 7: Summary Report For National Greenhouse Gas Inventories - Non-Energy Emissions – 2011 (Gg)

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs	PFCs	SF_6
2 Industrial Processes	**2,129**	**0**	**0**	**2.3**	**4.3**	**1.5**	**64**	**0**	**1.5**	**0**	**0**
A Mineral Products	1,027					0	63	0			
B Chemical Industry	348		0	2.3	4.1	1.5	1	0			
C Metal Production	754		0	0	0	0	0	0	0	0	0
D Other Production	0				0	0	0	0			
E Production of Halocarbons and Sulfur Hexafluoride									0	0	0
F Consumption of Halocarbons and Sulfur Hexafluoride									1.5	0	0
4 Agriculture			**67**	**3.3**	**0.1**	**4.4**					
A Enteric Fermentation			57								
B Manure Management			10	0.1							
C Rice Cultivation			0								
D Agricultural Soils				3.2							
E Prescribed Burning of Savannas			0	0	0	0					
F Field Burning of Agricultural Residues			0	0	0.1	4.4					
G Other (please specify)			0	0							
5 Land-Use Change & Forestry	**2,470**	**7,095**	**1.4**	**0**	**0.1**	**20.6**					
A Changes in Forest and Other Woody Biomass Stocks	0	6,089	1.4		0.1	20.6					
B Forest and Grassland Conversion	0	1,066	0	0	0	0					
C Abandonment of Managed Lands		0									
D CO2 Emissions and Removals from soil	2,470	0									
E Other (please specify)	0	0	0	0							
6 Waste			**54**	**0.2**							
A Solid Waste Disposal on Land			43								
B Wastewater Handling			11	0.2							
C Waste Incineration											
D Other (please specify)			0	0							

B.2 Industrial Process Non-Energy Emissions

Mineral Products process-related, non-energy emissions come primarily from Cement Production and Lime Production, which in 2011 accounted for almost half of the non-energy CO_2 emissions, with cement production accounting for the bulk of the emissions.

GREENHOUSE GAS SOURCE (Gg)	CO_2	NMVOC
A Mineral Products	**1,027**	**63**
1 Cement Production	983	
2 Lime Production	40	
3 Limestone and Dolomite Use	4	
6 Road Paving with Asphalt		63

The Mineral Products industry subsector is modelled in MARKAL-Georgia as an integrated cement and lime production industry with high-temperature and mechanical drive energy needs. Non-energy emissions from this subsector can be linked to the projected demand for cement, using an emission intensity factor, such as CO_2 per ton of cement produced. These emissions are represented in the model as a new sector emission, with mitigation options that result in emission reductions at a cost. The emission intensity factor was derived from 2011 data, which is kept constant or can be adjusted over time based on inputs from local experts. As MARKAL-Georgia does not contain any cement process information, the mitigation options will need to take the form of a mitigation cost curve, identifying the amount of reduction per unit expenditure along with a maximum level of possible mitigation that can potentially be achieved, which can be derived from international data adapted to conditions in Georgia.

This sub-sector also produces some non-methane volatile organic compounds (NMVOC) emissions, which have an indirect GHG effect when chemical reactions in the atmosphere involving these gases change the concentrations of GHGs Discussions with local experts will be held to determine if these emissions should be included in MARKAL-Georgia and if so, what global warming potential (GWP) should be used.

Chemical Industry process-related non-energy emissions come almost entirely arise from Ammonia Production, but Nitric Acid Production produces small amounts of N2O, which has a GWP of 310, and NOx which is another indirect GHG.

GREENHOUSE GAS SOURCE (Gg)	CO_2	N_2O	NO_x	CO	NMVOC
B Chemical Industry	**348**	**2**	**4**	**1**	**1**
1 Ammonia Production	348			1	1
2 Nitric Acid Production		2	4		

The Chemical Industry is modelled in MARKAL-Georgia as an integrated process with high-temperature and mechanical drive energy needs. Non-energy emissions from this subsector can be linked to the projected demand for the Chemical Industry, using an emission intensity factor, such as CO_2 per ton of product produced. The emission intensity factor can be derived from 2011 data, which can be kept constant or adjusted over time based on inputs from local experts. These emissions are represented in the model as a new sector emission with mitigation options that result in emission reductions at a cost. As with the Mineral Products, MARKAL-Georgia does not contain any chemical industry process information, and the mitigation options will need to take the form of a mitigation cost curve, which can be derived from international data adapted to conditions in Georgia.

Metal Production produces about one-third of the non-energy sector CO2 emissions, consisting of both Iron and Steel Production and Ferroalloys Production.

GREENHOUSE GAS SOURCE (Gg)	CO_2
C Metal Production	**754**
1 Iron and Steel Production	341
2 Ferroalloys Production	413

The Metal Production industry is modelled in MARKAL-Georgia as an integrated production industry with high-temperature and mechanical drive energy needs. Non-energy emissions from this subsector can be linked to the projected demand for product, using an emission intensity factor, such as CO_2 per ton of metals produced. These emissions would be represented in the model as a new sector emission with mitigation options that result in emission reductions at a cost. The emission intensity factor was derived from 2011 data, which can be kept constant or adjusted over time based on inputs from local experts. Similar to the other two industrial processes, the mitigation options will need to take the form of a mitigation cost curve, which can be derived from international data adapted to conditions in Georgia.

Halocarbons: The final component of industrial process GHG emissions in Georgia comes from emissions of halocarbons (specifically HFCs) from the use of Refrigeration and Air Conditioning Equipment. Although the size of this emission is small, HFCs have a very high GWP, and so their emissions should be tracked.

These non-energy emissions can be linked to the projected demand for air conditioning in all buildings, and an emission intensity factor was derived from 2011 data on leakage rates and the types of HFCs currently used. The BAU emission intensity factor should be adjusted over time based on any currently required changes in HFCs types. These emissions would be represented in the model as a new sector emission with mitigation options that could include new cooling technologies using lower GWP refrigerants and/or having lower leakage rates.

B.3 Agriculture

The agriculture sector produces GHG emissions of methane and N2O, primarily from Enteric Fermentation and Manure Management, with small, but important N2O emissions from soil management.

GREENHOUSE GAS SOURCE (Gg)	CH_4	N_2O	NO_x	CO
Total Agriculture	**67.02**	**3.35**	**0.15**	**4.39**
A Enteric Fermentation	**56.64**			
1 Cattle	51.53			
2 Buffalo	1.73			
3 Sheep	2.98			
4 Goats	0.29			
8 Swine	0.11			

B Manure Management	**10.17**	**0.14**		
1 Cattle	9.44			
2 Buffalo	0.06			
3 Sheep	0.10			
4 Goats	0.01			
8 Swine	0.44			
9 Poultry	0.12			
10 Anaerobic		0.003		
11 Liquid Systems		0.003		
12 Solid Storage and Dry Lot		0.110		
13 Other (please specify)		0.027		
C Agricultural Soils		**3.201**		
D Field Burning of Agricultural Residues	**0.209**	**0.004**	**0.145**	**4.393**

Enteric Fermentation: Cattle are the predominant source of methane from enteric fermentation, with buffalo and sheep making small contributions. BAU emissions from this subsector can be projected based on expected growth in livestock populations, feed types, and emission rates. The BAU emissions out to 2036 are to be generated by local experts using approved methodologies and input to the model as a process producing CO2-EF. Mitigation options will also need to be developed based on mitigation cost data from local and international sources for changing livestock feed types and/or practices.

Manure Management: Methane emissions from manure management are almost entirely from cattle with small contributions from swine, poultry and sheep. BAU emissions from this subsector can be projected based on expected growth in livestock populations, manure production and volatile solids data and methane generation potentials. Because actual methane production depends on how the manure is handled (dry, liquid slurry, anaerobic lagoon, etc.), and because mitigation options include other manure management practices, some of which capture methane for energy use, the modeling of this subsector starts with a manure production resource followed by current manure handling processes, which were developed from the 2011 data. Any currently required changes in manure management practices would also need to be incorporated into the model to produce the BAU projection. Mitigation technologies, such as composting and different forms of anaerobic digesters, will be developed from local and international data, and captured methane could be used within MARKAL-Georgia to substitute for other forms of energy for cooking, heating or electricity generation.

Soil Management: BAU emission projections are calculated outside MARKAL-Georgia based upon current emissions rates (derived from 2011 data) and the expected changes in agricultural acreage under production, using an approved methodology. Mitigation measures, such as Soil Carbon Management via No-Till/Conservation Tillage and Nutrient Management via Precision Agriculture and Use of Nitrification Inhibitors, need to be developed based on mitigation cost data from local and international sources. Key input parameters for these measures are provided in Table 8 and **Error! Reference source not found.**Table 9.

Table 8: Parameters for Soil Carbon Management via No-Till/Conservation Tillage

Parameter	Units
No-Till Area	hectares
Conservation Till Area	hectares
No-Till Soil Carbon Accumulation Rate	tCO2e/ha-yr
Conservation Till Soil C Accumulation Rate	tCO2e/ha-yr
No-Till Fuel Reduction	tCO2e/ha-yr
Conservation Till Fuel Reduction	tCO2e/ha-yr
Gallons Diesel Reduced, No-Till	gal/ha-yr
Gallons Diesel Reduced, Cons. Till	gal/ha-yr
Diesel Direct Combustion Emission Factor	tCO2e/gal
Diesel Fuel Cycle EF	tCO2e/gal
Potential Yield Loss	%
Value of Crop Production	2007$/ha
Diesel Fuel Cost	2007$/gal
Fixed and Other Variable Costs	2007$/gal

Table 9: Parameters for Nutrient Management via Precision Agriculture and Use of Nitrification Inhibitors

Parameter	Units
Targeted Area for Precision Ag	Mha
Targeted Area for Nitrification Inhibitors	Mha
N Fertilizer Rate Reduction Benefit	tCO2e/ha-yr
PA N Fertilizer Reduction %	%
NI N Fertilizer Reduction %	%
Avg. Cost of N Fertilizer	(2007$/short ton)
Cost Increase of Fertilizer N with Nitrifications Inhibitors	%
Growth Rate in Fertilizer Costs	%/yr
N Fertilizer Application Rate	lb N/acre
PA Capital Equipment Costs	$2007/acre
NI Material Costs	$2007/acre

B.4 Land-Use Change & Forestry

There are three components to Land Use, Land-Use Change and Forestry emissions and removals: Forest land, Cropland and Grassland. The sector contains significant emissions and removals of CO_2 and CH4.

GREENHOUSE GAS SOURCE AND SINK CATEGORIES (Gg)		CO_2 Emissions	CO_2 Removals	CH_4	NO_x	CO
Land Use, Land-Use Change and Forestry		**2,470.2**	**7,094.6**	**1.4**	**0.1**	**20.6**
A. Forest Land		**0.0**	**6,088.5**	**1.4**	**0.1**	**20.6**
	1. Forest Land Remaining Forest Land		6,088.5	1.4	0.1	20.6
	2. Land Converted to Forest Land		0.0	0.0	0.0	0.0
B. Cropland		**0.0**	**1,006.1**	**0.0**	**0.0**	**0.0**
	1. Cropland Remaining Cropland		1,006.1	0.0	0.0	0.0
	2. Land Converted to Cropland		0.0	0.0	0.0	0.0

C. Grassland		**2,470.2**	**0.0**	**0.0**	**0.0**	**0.0**
	1. Grassland Remaining Grassland	2,470.2	0.0	0.0	0.0	0.0
	2. Land Converted to Grassland		0.0	0.0	0.0	0.0

BAU emission and removal estimates will be generated by local experts based on expected changes in land use patterns within each component using approved methodologies. Mitigation options can include activities such as forest retention programs, reforestation and afforestation activities, and urban forestry programs. The first two of these mitigation measures requires a program of action to evaluate forest land conserved, reforested, or afforested, and therefore increased CO_2 sequestration, along with increased hardwood production and biomass resource production. Urban forestry provides CO_2 sequestration but it also reduces heating and cooling demands in urban buildings due to the shading and sheltering benefits of the urban trees. Cost and performance data for these and other possible mitigation measures will be generated by local and/or international experts based on international data adapted to Georgia conditions.

B.5 Waste

For Georgia, emissions from this sector come from solid wastes and waste water handling, and consist primarily of CH4 emissions with small N_2O emissions.

GREENHOUSE GAS SOURCES (Gg)	CH_4	N_2O
Total Waste	**54.2**	**0.17**
A Solid Waste Disposal on Land	**43.1**	**0.00**
1 Managed Waste Disposal on Land	22.9	
2 Unmanaged Waste Disposal Sites	20.2	
B Wastewater Handling	**11.1**	**0.17**
1 Industrial Wastewater	0.8	
2 Domestic and Commercial Wastewater	10.4	0.17

Solid Waste: BAU emissions from this sub-sector will be estimated by local experts based on projections of per-capita solid waste generation, organic waste content estimates, and waste disposal methods. Mitigation measures can include shifting new waste to managed disposal sites, implementing waste reduction programs, installing land-fill gas (LFG) collection systems, and either flaring or using the captured LFG for heat or electricity production. Cost and performance of these options are to be generated by local and/or international experts based on international data adapted to Georgia conditions.

Waste Water: BAU emissions from this sector will be estimated by local experts based on projections of domestic, commercial and industrial waste water generation. Mitigation measures can include building new waste water treatment technologies and implementing waste water reduction programs. Cost and performance of these options will be generated by local and/or international experts based on international data adapted to Georgia conditions.

ANNEX C: METHODOLOGY FOR ENERGY SECTOR NON-CO2 EMISSION SOURCES AND MITIGATION MEASURES

C.1 Methodology

The starting point for incorporating energy sector methane emissions into MARKAL-Georgia is the draft 2011 National GHG Inventory currently under review for submitted by Georgia to the UNFCCC in its Third National Communication. That document identifies two categories of emissions: Incomplete Combustion and Fugitive Emissions from fuels.

For each category, the methodology addresses current emission levels, the approach to the business-as-usual (BAU) emissions, and the types of mitigation technologies to be considered.

C.2 Incomplete Combustion

Small quantities of methane (CH_4) and nitrous oxide (N_2O) are produced when fuels are burned incompletely, as a result of faulty design or poor conditions, especially for traditional household stoves. The 2011 inventory provides the following emissions levels, where most emissions come from the residential sector.

GREENHOUSE GAS SOURCE (Gg)	CH_4	N_2O
4 Other Sectors	**3.90**	**0.06**
a Commercial/Institutional	0.43	0.01
b Residential	3.45	0.05
c Agriculture/Forestry/Fishing	0.02	0.00
d Road Transport	0.44	0.00
c Power / Industry	0.12	0.00

The 2011 inventory was prepared in accordance with the IPCC 1996 revised guidelines using the Tier 1 simplified approach in which global default emission factors by fuel type and activity are applied to the fuel consumption levels for each activity. The CH_4 and N_2O emissions factors are shown below in Tables 1-7 and 1-8 from the IPCC Guidelines. In MAKRAL-Georgia, CH4 and N2O emissions factors will be added to each of the existing sector-fuel exchange processes, and the BAU projection will be generated within the model as part of the Reference scenario. No specific mitigation measures will be added for these emission, because any actions taken that reduced fossil fuel consumption will at the same time reduce these GHG emissions.

TABLE 1-7
CH_4 DEFAULT (UNCONTROLLED) EMISSION FACTORS (IN KG/TJ)

			Coal(a)	Natural Gas	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes(c)
Energy Industries			1	1	3	30(b)	200(b)	30
Manufacturing Industries and Construction			10	5	2	30	200	30
Transport	Aviation(d)				0.5			
	Road			50	Gasoline 20(e) Diesel 5			
	Railways		10		5			
	Navigation		10		5			
Other Sectors	Commercial/Institutional		10	5	10	300	200	300
	Residential		300	5	10	300	200	300
	Agriculture/ Forestry/ Fishing	Stationary	300	5	10	300	200	300
		Mobile		5	5			

Note: These factors are considered as the best available global default factors to date.

(a) The emission factors for brown coal may be several times higher than those for hard coal.

(b) These factors are for fuel combustion in the energy industries. For charcoal production, please refer to Table 1-14, Default Non-CO_2 Emission Factors for Charcoal Production.

(c) Includes dung and agricultural, municipal and industrial wastes.

(d) In the cruise mode CH_4 emissions are assumed to be negligible (Wiesen et al., 1994). For LTO cycles only (i.e., below an altitude of 914 metres (3000 ft.)) the emission factor is 5 kg/TJ (10% of total VOC factor) (Olivier, 1991). Since globally about 10% of the total fuel is consumed in LTO cycles (Olivier, 1995), the resulting fleet averaged factor is 0.5 kg/TJ.

(e) Emission factors for 2-stroke engines may be three times higher than those for 4-stroke engines.

TABLE 1-8
N_2O DEFAULT (UNCONTROLLED) EMISSION FACTORS (IN KG/TJ)

			Coal(a)	Natural Gas	Oil	Wood/ Wood Waste	Charcoal	Other Biomass and Wastes(c)
Energy Industries			1.4	0.1	0.6	4(b)	4(b)	4
Manufacturing Industries and Construction			1.4	0.1	0.6	4	4	4
Transport	Aviation				2			
	Road			0.1	Gasoline 0.6(d) Diesel 0.6			
	Railways		1.4		0.6			
	Navigation		1.4		0.6			
Other Sectors	Commercial/Institutional		1.4	0.1	0.6	4	1	4
	Residential		1.4	0.1	0.6	4	1	4
	Agriculture/ Forestry/ Fishing	Stationary	1.4	0.1	0.6	4	1	4
		Mobile		0.1	0.6			

Note: These factors are considered as the best available global default factors to date.

(a) Brown coals may produce less N_2O than bituminous coals; some measurements have shown that N_2O emissions by hard coal combustion in power plants may be negligible. N_2O emissions from FBC are generally about 10 times higher than from boilers.

(b) These factors are for fuel combustion in the energy industries. For charcoal production, please refer to Table 1-14, Default Non-CO_2 Emission Factors for Charcoal Production.

(c) Includes dung and agricultural, municipal and industrial wastes.

(d) When there is a significant number of cars with 3-way catalysts in the country, road transport emission factors should be increased accordingly. Emission factors for 2-stroke engines may be three times higher than those for 4-stroke engines.

C.3 Fugitive Emissions from Fuels

The exploration, production, processing, storage, transmission and distribution of coal, oil and natural gas produces methane emissions. As seen in the table below, there are two significant sources for these emissions in Georgia. Coal mining, where methane is liberated during the mining process and must be ventilated before it creates an explosion risk. The second is the natural gas system, which produces fugitive emissions during production, processing, transmission and distribution of pipeline gas.

GREENHOUSE GAS SOURCE (Gg)	CH_4
B Fugitive Emissions from Fuels	**69**
1 Solid Fuels	**5**
a Coal Mining	5
b Solid Fuel Transformation	
c Other (please specify)	
2 Oil and Natural Gas	**64**
a Oil	0
b Natural Gas	64
c Venting and Flaring	0

Coal Mining

As there is just one coal mine in Georgia, the IPCC tier 1 approach (based on production level) was used, and the 2011 inventory uses the following emission factors, which will be applied in MARKAL-Georgia.

Underground Mines	Emission Factor (m^3 CH_4 / t)
Mining	17.5
Post-Mining	2.45

The MARKAL-Georgia model contains two active coal types: lignite and brown. Each has an import process and a mining process. The combined mining and post-mining emission factors will be added to the mining process for each coal type, and the post-mining emission factor will be added to each import process. The BAU projection will be generated within the model as part of the Reference scenario.

Mitigation measures for this category can include the options listed in the table below, and a data request could be used to:

- Gather data on any applications to date in Georgia,
- Determine which of the options below are applicable in Georgia, and
- Determine if additional options are needed.

Technologies	Description	Applicability	Reduction Efficiency
Initial Mine Degasification and Capture	Coal mines recover methane using vertical wells drilled five years in advance of mining, horizontal boreholes drilled one year in advance, and gob wells. The captured methane is sold to a pipeline.	Applied to a portion of NEW underground, gassy mines only.	57%

Gob Gas Upgrade - Existing Mines	Gas recovery-and-use incremental to degasification and pipeline injection as well as spacing is tightened to increase recovery efficiency. Mines invest in enrichment technologies to enhance the gob gas that is sold to natural gas companies.	Applied to existing underground gassy mines that have installed degas systems.	77%
Gob Gas Upgrade - New Mines	= same =	Applied to new underground gassy mines that have installed degas systems.	77%
Flaring of Coal Mine Methane	Eliminate methane emissions from ventilation air using a flare. A pipeline is needed to transport the gas to a safe distance from the mine.	Applied to all underground, gassy mines.	98%
On/Off site Electric with Coal Mine Methane	Technology uses catalytic oxidation. Data taken from "Technical and Economic Assessment: Mitigation of Methane Emissions from Coal Mine Ventilation Air, EPA Feb 2000.	Applied to all underground mines with medium quality gas.	98%
On/Off site Process Heat with Coal Mine Methane	= same =	Applied to all underground mines with medium quality gas. The technology has not yet been implemented in the U.S.	98%
On/Off site Cogeneration with Coal Mine Methane	= same =	Applied to all underground mines with medium quality gas. The technology has not yet been implemented in the U.S.	98%

Natural Gas System

The 2011 GHG Inventory of Georgia uses the following methane emissions factors for oil and gas fugitive emissions. In addition, natural gas is assumed to consist of 90% methane, so that 1 unit of natural gas emissions is considered to be 0.9 units of methane emissions. The same approach can be applied to MARKAL-Georgia. Currently, almost all emissions in this category come from natural gas production, transmission and distribution, with almost all of the emissions recorded as combined transmission and distribution losses. There is a very small contribution from oil production, but MARKAL-Georgia has there is no domestic crude oil production or imports.

Category	Activity	Emission Factor
OIL		
Production	PJ oil produced	2650 kg CH_4 / PJ
Transport	PJ oil loaded in tankers	
Refining	PJ oil refined	
Storage	PJ oil refined	
GAS		
Production / Processing	PJ gas consumed	227,000 kg CH_4 / PJ
Transmission and Distribution	mln cub.m gas emitted	645,120 kg CH_4 / mln cub.m

The MARKAL-Georgia model contains one mining process and several import processes for natural gas. There are two gas transmission pipelines: existing and new. Each has a leak rate, but the new one has a higher leak rate than the existing one. Gas then goes to existing or new sectoral distribution networks, which currently do not have leakage rates. Emission factors consistent with the leakage rates can be developed for some or all of these distribution process, based on the available data. To this end, it has been determined that:

Losses from transmission are given by the gas transportation company and losses from distribution are provided by the distribution companies. MoE Ad has provided this data to us.

No data is currently available to estimate distributions losses to each demand sector, and so the same distribution loss factor will be applied to each demand sector.

The BAU projection for the methane emissions will be generated within the model as part of the Reference scenario dependent upon the level on natural gas consumed.

Mitigation measures for the natural gas system can include the options listed in the table below, and a data request could be used to:

- Gather data on any mitigation applications to date in Georgia,
- Determine which of the options below are applicable in Georgia, and
- Determine if additional options are needed.

There are clearly a lot of possibilities for mitigation of natural gas leaks, and these (and any other relevant options) should be organized and characterized as best fits the Georgia natural gas infrastructure.

Technologies	Description	Applicability	Reduction Efficiency
Compressed air pneumatic devices	Replacing high-bleed pneumatic devices (powered by natural gas) with compressed air systems will completely eliminate the methane emissions from these pneumatic devices.	The technology is applied to the projected production infrastructure needed to meet projected production.	100%
Low-bleed pneumatic devices	High-bleed pneumatic devices (powered by natural gas), which emit a high volume of methane to the atmosphere, can be replaced with low-bleed devices that emit far lower volumes of methane.	The technology is applied to the projected production infrastructure needed to meet projected production.	86%
Directed I&M of Pipeline Leaks	This directed inspection and maintenance option involves surveying Pipelines in the Production sector to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected production infrastructure needed to meet projected production.	60%
Flash Tank Separators	A flash tank separator operates by reducing the pressure of methane rich tri-ethylene Glycol suddenly to cause the ab-orbed CH4 to 'flash' or (vaporize). The flashed CH4 can be collected and used as fuel gas or compressed and returned.	The technology is applied to the projected production infrastructure needed to meet projected production.	54%
Reduce Glycol Circulation Rates in Dehydr (Prod)	During production, tri-ethylene Glycol (TEG) is circulated through dehydrators to absorb water from the gas stream before entering the pipe-line. TEG also absorbs some methane that is vented. Reducing the glycol circulation rate to the optimal level will	The technology is applied to the projected production infrastructure needed to meet projected production.	31%

Technologies	Description	Applicability	Reduction Efficiency
Directed I&M of Chemical Inspection Pumps	This directed inspection and maintenance (DI&M) option involves surveying Chemical Inspection Pumps at Production sites to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected production infrastructure needed to meet projected production.	40%
Portable Evacuation Compressor for Pipeline Venting	This option relates to the use of pump-down techniques to lower the gas-line pressure before venting. An in-line portable compressor is used to lower line pressure by up to 90 percent of its original value without venting.	The technology is applied to the projected production infrastructure needed to meet projected production.	72%
Installing Plunger Lift Systems In Gas Wells	A plunger lift uses the well's natural energy to lift the fluids out of the well to prevent blockage of gas wells due to fluid accumulation and helps maintain the production level, thus removing these liquids and reducing methane emissions.	The technology is applied to the projected production infrastructure needed to meet projected production.	4%
Installation of Electric Starters on Compressors	Small gas expansion turbine motors are used to start internal combustion engines for compressors, generators and pumps in the natural gas (NG) industry. These starters use compressed NG, which is vented to the atmosphere.	The technology is applied to the projected production infrastructure needed to meet projected production.	75%
Surge Vessels for Station/Well Venting	During production, a surge vessel can be used during blowdowns to avoid venting methane to atmosphere. The captured methane can be re-routed to the pipeline or used on site as fuel.	The technology is applied to the projected production infrastructure needed to meet projected production.	50%
Install Flares	Recovered methane is flared to reduce GHG emissions.	The technology is applied to the projected production infrastructure and ro compressor stations.	95%
Fuel Gas Blowdown Valve	When a system is depressurized, emissions can result from "blow down", or venting of the high-pressure gas left within the compressor. Using a fuel gas retrofit, methane that would be vented during a blow down can be routed to a fuel gas system and avoid	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	33%
Catalytic Converter	A catalytic converter is an afterburner that reduces methane emissions resulting from incomplete combustion. Methane is combusted, and the energy produced is unused. Consequently, the benefits are restricted to the value placed on reducing methane.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	56%
Dry Seals on Centrifugal Compressors	Some centrifugal compressors are fitted with 'wet' seals that use circulating oil at the pressure seal face to prevent methane emissions. 'Dry' seals use high-pressure gas to ensure sealing. Dry seals emit far less gas compared to wet seal systems. [Not	The technology is applied to the projected production infrastructure needed to meet projected production.	69%

Technologies	Description	Applicability	Reduction Efficiency
Gas turbines replace reciprocating engines	Natural gas (NG) reciprocating engines are replaced with NG turbines. NG turbines have a better combustion efficiency compared to reciprocating engines; consequently, methane emissions are reduced.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	90%
Static-Pacs on reciprocating compressors	A static-pac seal on a compressor rod eliminates rod-packing leaks during shutdown when the compressor is kept pressurized. An automatic controller activates when the compressor is shutdown to wedge a tight seal around the shaft; it deactivates the seal	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	6%
Portable Evac. Compressor for Pipe. Vent	During processing and transmission, this option relates to the use of pump-down techniques to lower the gas-line pressure before venting. An in-line portable compressor is used to lower line pressure by up to 90 percent of its original value without ventilation.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	72%
Directed I&M to Compressor Stations	This directed inspection and maintenance option involves surveying the Compressor Stations, within the Processing and Transmission sectors, to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	13%
Enhanced I&M to Compressor Stations	This Enhanced directed inspection and maintenance (DI&M) option is a more aggressive DI&M program at P&T Compressor Stations that involves increased frequency of survey and repair. Enhanced DI&M costs more but also achieves greater savings by reducing lea	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	20%
Surge Vessels for Station/Well Venting	During processing and transmission, a surge vessel can be used during blowdowns to avoid venting methane to atmosphere. The captured methane can be re-routed to the pipeline or used on site as fuel.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	50%
Reducing the Glycol Circulation Rates in Dehydrators	During P&T, tri-ethylene Glycol (TEG) is circulated through dehydrators to absorb water from the gas stream before entering the pipeline. TEG also absorbs some methane, which is vented.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	30%
Compressors-Altering Start-Up Procedure during Maintenance	Instead of shutting down centrifugal compressors during “cleaning” maintenance, the turbines are cleaned while on-line (running). This procedure reduces the number of compressor depressurizations required per year.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	100%
Directed I&M to Transmission Pipeline	This directed inspection and maintenance option involves surveying Pipelines within the Transmission sector to identify sources of leaks and performing maintenance on leaks that are most cost effective to repair.	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	60%

Technologies	Description	Applicability	Reduction Efficiency
Installation of Flash Tank Separators	During P&T, a flash tank separator operates by reducing the pressure of methane rich tri-ethylene Glycol suddenly to cause the absorbed methane to 'flash' or (vaporize). The flashed methane can be collected and used as fuel gas or compressed and returned	The technology is applied to the projected processing and transmission infrastructure needed to meet projected consumption and production.	61%
Install Flares	Recovered methane is flared to reduce GHG emissions.	The technology is applied to the projected production infrastructure and compressor stations.	95%
ClockSpring Repair Kits	Methane emissions resulting from venting of pipes that require repair are eliminated with this repair technique that does not require the pipe to be vented.	The technology is applied to the projected transmission system.	50%
Redesign Blowdown	Methane is would normally be vented during system or equipment over-pressure situation is captured for use within the process plant	The technology is applied to the projected process plants system.	95%
Hot Taps	Methane that would normally be vented to allow welding of new pipe openings are avoided because these taps can be connected while the pipe is in operation..	The technology is applied to the projected transmission system.	75%
Directed I&M to Distribution	This directed inspection and maintenance option involves surveying Distribution facilities (e.g., gate, meter and regulating stations) and associated equipment to identify sources of leaks and performing maintenance on leaks that are most cost effective t	The technology is applied to the projected distribution infrastructure needed to meet consumption.	26%
Enhanced I&M to Distribution	DI&M is a method for identifying and reducing leaks. This Enhanced DI&M option is a more aggressive program at Distribution facilities that involves increased frequency of survey and repair. Enhanced DI&M costs more but also achieves greater savings by re	The technology is applied to the projected distribution infrastructure needed to meet consumption.	66%
Electronic Monitor at Service Facilities	Natural gas distribution systems operate at gas pressures that are higher than necessary to ensure that both peak and non-peak operating pressures are met. With electronic monitoring, the distribution system pressure can match real time demand and reduce	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Replacement of Iron/Unprotected Steel Pipes	Cast iron and unprotected steel pipeline are prone to corrosion and leaks. They should be replaced with pipeline made of non-corrosive material that will reduce methane losses from the distribution system.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Replacement of Unprotected Steel Services	Unprotected steel services are prone to corrosion and leaks. They should be replaced with services made of non-corrosive material, such as plastic or protected services, which will reduce methane losses from the distribution system.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%

Technologies	Description	Applicability	Reduction Efficiency
Use smart regulators/clocking solenoids	Leaks in steel services are can be reduced by better regulators that avoid pressure swings caused by changes in demand.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%
Leak detection/walking surveys	Unprotected steel services are prone to corrosion and leaks. Increased surveillance will reduce methane losses from the distribution system.	The technology is applied to the projected distribution infrastructure needed to meet consumption.	95%

C.4 Emissions Commodity Names

Below are suggested names for the new emission commodities.

Commodity Names	Commodity Descriptions
MTH	Methane emissions (kt)
MTHICA	Methane emissions from Incomplete Combustion – AGR sector (kt)
MTHICC	Methane emissions from Incomplete Combustion – COM sector (kt)
MTHICR	Methane emissions from Incomplete Combustion – RSD sector (kt)
MTHICT	Methane emissions from Incomplete Combustion – TRN sector (kt)
MTHICI	Methane emissions from Incomplete Combustion – IND sector (kt)
MTHICP	Methane emissions from Incomplete Combustion – PWR sector (kt)
MTHMC	Methane emissions from Coal Mining (kt)
MTHMN	Methane emissions from Natural gas Mining (kt)
MTHPT	Methane emissions from Natural gas Pipelines (kt)
MTHPD	Methane emissions from Natural gas Distribution (kt)
N2O	Nitrous oxide
N2OICC	Nitrous oxide emissions from Incomplete Combustion – COM sector (kt)
N2OICR	Nitrous oxide emissions from Incomplete Combustion – RSD sector (kt)

ANNEX D: MARKAL-GEORGIA EC-LEDS GHG EMISSIONS ACCOUNTING

D.1 Non-Energy Emission Categories

Current emission carrier names in MARKAL-Georgia are abbreviated as shown below. For the expanded emissions accounting, the naming convention will be expanded to allow for technology level GHG accounting within the energy sector. The expanded GHG names are shown in the table below.

OLD NAME	EXPANDED NAME	DESCRIPTION
COA	CO2-A	Agriculture Carbon Dioxide
COB		Bunker fuel Carbon Dioxide
COC	CO2-C	Commercial Carbon Dioxide
COI	CO2-I	Industry Carbon Dioxide
COP	CO2-P	Power Sector Carbon Dioxide
COR	CO2-R	Residential Carbon Dioxide
COT	CO2-T	Transport Carbon Dioxide

For the non-energy emissions, the core emission names, in addition to CO2, will be MTH for methane (CH4), N2O for nitrous oxide, and HFC for halocarbons. Not all categories produce all emission types, and the emission types relevant to Georgia are listed in the table below.

GHG SOURCE AND SINK CATEGORIES	EMISSION COMMODITY NAMES			
	CO_2	CH_4	N_2O	HFC's
2 Industrial Processes	**CO2NIP**			
A Mineral Products (Cement Manufacturing)	**CO2NIPCM**			
B Chemical Industry	**CO2NIPCH**		**N20CHI**	
C Metal Production	**CO2NIPMP**			
F Consumption of Halocarbons and Sulfur Hexafluoride				**HFC**
4 Agriculture		**MTHAGR**		
A Enteric Fermentation		**MTHENF**		
B Manure Management		**MTHMMG**	**N2OMMG**	
D Agricultural Soils			**N2OAGS**	
F Field Burning of Agricultural Residues		**MTHFBR**		
5 Land-Use Change & Forestry	**CO2LUF**			
A Changes in Forest and Other Woody Biomass Stocks	**CO2FST**	**MTHFST**	**N2OFST**	
B Forest and Grassland Conversion	**CO2CNV**			
C Abandonment of Managed Lands				
D CO2 Emissions and Removals from soil	**CO2SOI**			
6 Waste		**MTHWST**		
A Solid Waste Disposal on Land		**MTHWSD**		
B Wastewater Handling		**MTHWWH**	**N2OWWH**	
C Waste Incineration		**MTHINC**		

The following 100-year global warming potential (GWP) factors[7] will be used to combine all emissions in CO2 equivalent units.

GHG	Lifetime (years)	GWP time horizon	
		20 years	100 years
Methane	12.4	56	21
Nitrous oxide	121	280	310
HFC-134a	13.4	3400	1300

D.2 Industrial Process Non-Energy Emissions

The BAU Industrial process non-energy GHG emissions for the Chemicals, Metals and Cement production industries are represented in the model as a new process producing the projected emissions over time. An emission intensity factor was derived from 2011 data and the base year demand data, as shown in the table below. This emission intensity, which is currently assumed to be constant over time, was multiplied by the demand projection for each industry sector, as shown in the following table.

Industrial Process Non-Energy GHG Emission Factors (kt/PJ) based on 2011 data		
	CO_2	N_2O
Chemicals Industry	319.49	2.13
Metals Industry	146.22	
Cement Industry	200.62	

BAU Industrial Process Non-Energy GHG Emissions (kt)									
	2012	2015	2018	2021	2024	2027	2030	2033	2036
CO_2 from Chemical Industry	348.5	386.4	428.4	474.9	526.6	561.3	598.3	637.7	678.8
N_2O from Chemical Industry	2.3	2.6	2.9	3.2	3.5	3.7	4.0	4.3	4.5
CO_2 from Metals Industry	753.8	835.8	926.6	1027.3	1138.7	1213.7	1293.7	1378.8	1467.7
CO_2 from Cement Industry	1027.0	1138.6	1262.4	1399.7	1551.8	1654.1	1763.1	1879.3	2000.5

An emission intensity factor was derived for halocarbon emission factor from air conditioning equipment from the 2011 data and the base year space cooling demand for both the Residential and Commerical sectors, as shown in the table below, with the resulting BAU emissions projection in the following table..

Halocarbon Emission Factor (kt/PJ) based on 2011 data	
HFCs from Space Cooling	1.42

BAU Halocarbon Emission (kt)									
	2012	2015	2018	2021	2024	2027	2030	2033	2036

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[7] http://unfccc.int/ghg_data/items/3825.php

HFCs from Space Cooling	1.48	1.93	2.55	3.20	3.98	4.79	5.70	6.75	7.99

D.3 Agricultural Sector

The model currently has a placeholder BAU projection for this sector, shown below, based on the 2011 inventory data with the agricultural GDP factor applied as a form of escalation. This projection will be replaced once the official agricultural BAU is developed.

PROXY - Agricultural Sector BAU Projections (kt)									
	2012	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
Methane from Enteric Fermentation	56.64	60.99	73.79	82.52	92.29	99.23	106.70	114.74	123.38
Methane from Manure Management	10.17	10.95	13.25	14.82	16.57	17.82	19.16	20.60	22.15
N2O from Manure Management	0.14	0.15	0.19	0.21	0.23	0.25	0.27	0.29	0.31
N2O from Agricultural Soils	3.20	3.45	4.17	4.66	5.22	5.61	6.03	6.48	6.97
Methane from Field Burning	0.21	0.23	0.27	0.30	0.34	0.37	0.39	0.42	0.46
Agriculture Growth rate		2.50%	6.56%	3.80%	3.80%	2.45%	2.45%	2.45%	2.45%

D.4 Forestry and Land Use Sector

The model currently has a placeholder BAU projection for this sector, shown below, based on the 2011 inventory data with no escalation factor applied. This projection will be replaced once the official forestry BAU is developed.

PROXY - Forestry & Land Use BAU Projections (kt)									
	2012	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
CO2 from Changes in Forests	6088.5	6088.5	6088.5	6088.5	6088.5	6088.5	6088.5	6088.5	6088.5
CO2 from Grassland Conversion	1006.1	1006.1	1006.1	1006.1	1006.1	1006.1	1006.1	1006.1	1006.1
CO2 from Soil	2470.2	2470.2	2470.2	2470.2	2470.2	2470.2	2470.2	2470.2	2470.2
Methane from Changes in Forests	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
N2O from Changes in Forests	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

D.5 Waste Sector

The model currently has a placeholder BAU projection for this sector, shown below, based on the 2011 inventory data with no escalation factor applied. This projection will be replaced once the official forestry BAU is developed.

PROXY - Waste BAU Projections (kt)									
	2012	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**	**2033**	**2036**
Methane from Solid Waste Disposal	43.06	43.06	43.06	43.06	43.06	43.06	43.06	43.06	43.06
Methane from Wastewater	11.15	11.15	11.15	11.15	11.15	11.15	11.15	11.15	11.15

Handling									
Methane from Waste Incineration	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N2O from Wastewater Handling	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17

D.6 Energy Sector CH4 and N2O Emissions

The starting point for incorporating energy sector methane emissions into MARKAL-Georgia is the draft 2011 National GHG Inventory currently under review for submitted by Georgia to the UNFCCC in its Third National Communication. That document identifies two categories of emissions: Incomplete Combustion and Fugitive Emissions from Fuels.

Below are suggested names for the new emission commodities.

Commodity Names	Commodity Descriptions
MTH	Methane emissions (kt)
MTHICA	Methane emissions from Incomplete Combustion – AGR sector (kt)
MTHICC	Methane emissions from Incomplete Combustion – COM sector (kt)
MTHICR	Methane emissions from Incomplete Combustion – RSD sector (kt)
MTHICT	Methane emissions from Incomplete Combustion – TRN sector (kt)
MTHICI	Methane emissions from Incomplete Combustion – IND sector (kt)
MTHICP	Methane emissions from Incomplete Combustion – PWR sector (kt)
MTHMC	Methane emissions from Coal Mining (kt)
MTHMN	Methane emissions from Natural gas Mining (kt)
MTHPT	Methane emissions from Natural gas Pipelines (kt)
MTHPDC	Methane emissions from Natural gas Distribution - COM sector (kt)
MTHPDR	Methane emissions from Natural gas Distribution - RSD sector (kt)
MTHPDI	Methane emissions from Natural gas Distribution - IND sector (kt)
MTHPDT	Methane emissions from Natural gas Distribution - TRN sector (kt)
N2O	Nitrous oxide
N2OICC	Nitrous oxide emissions from Incomplete Combustion – COM sector (kt)
N2OICR	Nitrous oxide emissions from Incomplete Combustion – RSD sector (kt)

D.7 Incomplete Combustion

The CH_4 and N_2O emissions factors (Tables 1-7 and 1-8 from the IPCC Guidelines) are shown in Annex C. In MAKRAL-Georgia, CH_4 and N_2O emissions factors will be added to each of the existing sector-fuel exchange processes, and the BAU projection will be generated within the model as part of the Reference scenario.