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Guidance to the *Greenhouse Gas Abatement Cost Model* (GACMO)

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ICAT Initiative for Climate Action Transparency

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Guidance to the Greenhouse Gas Abatement Cost Model (GACMO)

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PREPARED UNDER

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[1] Jacob Ipsen Hansen and Trupti Yargattimath have been responsible for the programming and coding of the version 2.1 of the GACMO tool in Excel.

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GACMO COPYRIGHTS

The GACMO tool has been developed by the UNEP Copenhagen Climate Centre (UNEP-CCC).[2] This version of the tool has been developed under the Initiative for Climate Action Transparency (ICAT).

The tool is regularly updated. The last version of the GACMO tool is always made available on the UNEP-CCC website at https://unepccc.org/gacmo-tool/

All the versions of the GACMO tool can be downloaded and used free of charge by any user and can be installed on a personal computer. However, commercial use of the GACMO tool without the prior authorization of UNEP-CCC is not permitted.

For any inquiries and authorization requests, please contact UNEP-CCC at unep-ccc@un.org.

[2] The GACMO tool has been developed by our colleague Jørgen Fenhann. Jørgen has worked for the UNEP Copenhagen Climate Centre for more than 40 years. The first version of the GACMO tool was developed about twenty years ago. Since then, the tool has evolved to include new mitigation options and to account for the new IPCC requirements in terms of calculating GHG emission reductions.

What is GACMO?

The GACMO (Greenhouse Gas Abatement Cost Model) tool is a bottom-up greenhouse gas (GHG) emissions modelling tool developed by UNEP Copenhagen Climate Centre (UNEP-CCC). The model has been developed over the course of more than twenty years.

The GACMO tool allows countries to carry out rapid but accurate evaluation of how a variety of mitigation options impact GHG emissions. The tool is used to calculate the GHG emissions reductions resulting from specific mitigation actions and to establish a mitigation scenario built on the specific mitigation actions compared to a business as usual (BAU) scenario. The GACMO tool can thus support technical experts and decision-makers to assess and understand the GHG emissions impacts of climate mitigation actions.

The GACMO tool can also be used to monitor the GHG emission reductions achieved through the effective implementation of mitigation options. Therefore, it can be used as a tool for tracking the progress in achieving emissions reductions from the implementation of climate change mitigation options, for example in the context of tracking the progress in implementing and achieving the Nationally Determined Contribution (NDC).

The GACMO tool can be used at the national level (country level) but can also be adapted to be used at the sub-national level (region or city). It can be very useful for the preparation of national reports such as national communications, biennial update reports (BURs), biennial transparency reports (BTRs) including the common tabular format tables (CTF), or for the preparation and update of NDCs.

This version of the GACMO tool includes seven spreadsheets with technical data that the user needs to consider following a stepwise approach. The interface of the tool is made so that the user is taken from the first spreadsheet to the last spreadsheet following a logical order. The calculations and the generation of graphs are done in an automated way. This means that the user, who has the data required to use the GACMO tool, does not need to be familiar with the calculations themselves in order to use the tool, but only with how to enter the inputs and interpret the results.

The GACMO tool also includes a series of default values, that are already pre-loaded in the tool and that the user does not have to update unless the user has better inputs and wants to make more precise estimates. These default values are all visible and accessible to the user. The first group of data with default values are those of key mitigation parameters, such as the IPCC database of emission factors (2006 IPCC Guidelines) and the global warming potential (GWP). In the case of GWP, the GACMO tool uses by default the values of the fifth assessment report published by the IPCC, as established in the Modalities, Procedures, and Guidelines (MPGs) adopted in the Katowice Climate Package through decision 18/CMA. However, previous GWP values are also available in the tool. The second group of data with default values are those for the mitigation potential parameters and economic-financial parameters of each mitigation option and their corresponding reference option in the baseline situation. In this case, the GACMO tool uses by default, average values calculated from

relevant CDM projects available on the CDM website and summarized in the project pipeline developed at UNEP-CCC. Experience has shown that the use of default values for data related to baseline and mitigation options works well in the tool. However, it is recommended for a GACMO user to modify those default values for the data related to the mitigation and reference options, by replacing them with values specific to their case (e.g., country, city, region, industrial activity). This allows the user to adapt the GACMO tool to the specific national/local context.

The main data required to use the GACMO tool are those of the energy balance for a specific year (considered as the start year), that is, the data on the sectoral energy consumption of fossil fuels and electricity of a country, as well as the GHG emissions for the other non-energy sectors for the same year (taken, for example, from a national GHG inventory report). From these data, GACMO estimates CO_2 emissions from fuel combustion and summarizes the GHG emissions for the start year, that is, for the year in which the data were collected (generally the most recent year for which the necessary data is available). Then, applying growth factors for each sector (these factors are specific to the country and are estimated and entered in the tool by the user), the GACMO tool will project the GHG emissions to build a reference scenario (also called baseline scenario or business as usual - BAU), that includes calculations for the years 2025, 2030, 2035, 2040, 2045, and/or 2050.

To build the GHG mitigation scenario, the GACMO tool proposes a list of 119 mitigation options for different sectors. These mitigation options are organized into 24 categories of activities, such as agriculture, biomass energy, energy efficiency in homes, forestry, as well as geothermal, hydroelectric, solar, and wind energy, among others. It must be noted that some mitigation options included in the GACMO tool still imply the use of fossil fuels (e.g., energy efficiency improvement, natural gas power plant). Those mitigation options may lead to emissions reductions, though may be insufficient to be in line with a 1.5°C degree climate goal which implies global net anthropogenic CO_2 emissions reaching net zero around 2050. Though the GACMO tool does not seek to promote such options, they are included in the list of mitigation options because some countries still consider using (or are in the process of implementing) them to reduce their emissions compared to the use of high-emitting technologies. In this context, the GACMO tool can also help to analyse whether the mitigation actions adopted and/or planned by a country are in line with certain climate goals (e.g., net-zero goal), and if not, help to select which mitigation options could be implemented to meet those goals.

Once the mitigation options of interest have been selected by the user, the tool calculates the emissions based on the defined growth factors and establishes a mitigation scenario towards the years 2025, 2030, 2035, 2040, 2045, and/or 2050. The GACMO tool calculates also the GHG emissions reductions and an approximation of the investment costs, as well as operation and maintenance costs that result from each selected mitigation action.

In summary, the key data used as inputs and required for running the GACMO tool are:

- Basic data about the country, such as population, GDP, discount rate;

- Key assumptions (e.g., grid emission factor, energy prices, emission factors, calorific values of fuels, etc.);
- Energy balance data in the start year, that is, the production/consumption data on fossil fuels and electricity for a country;
- Data on the GHG emissions for the key non-energy sectors in the start year: Agriculture, Forestry, Waste, Industrial processes and Fugitive emissions;
- Growth factors estimated over specific time periods for different sectors of activities;
- The number of units of each mitigation option (selected by the user) penetrating toward the years 2025, 2030, 2035, 2040, 2045, and/or 2050;
- Technical and economical parameters of the technology/mitigation options (e.g., solar insolation, annual distance for transport, number of hours usage of lighting, etc.)

What is GACMO used for and what are the main results?

The GACMO tool is a "bottom-up" modelling tool. The GHG emissions projections are based on mitigation options implemented on the ground (and not on macro data defined at the country level such as macro-economic data).

Therefore, the GACMO tool is usually used to establish a business-as-usual (BAU) scenario and a mitigation scenario based on a set of mitigation options chosen by a country. These options can be, for example, the mitigation options chosen by a country to be taken into consideration in the NDC of the country or in a sectorial mitigation plan.

If a country has a mitigation goal that has been pre-defined, a user can also test different mitigation options included in the tool to determine how this mitigation goal could be achieved through different sets of mitigation options.

Finally, the GACMO tool can be used to estimate the individual GHG emissions reduction impact of a specific mitigation option considering different levels of implementation.

The GACMO tool is a GHG emissions accounting tool that can be used at the national level (country level) or sub-national level (region or city level) to estimate the aggregated GHG emissions and develop the corresponding baseline scenario, as well as one (or more) mitigation scenarios based on specific mitigation options. Therefore, the GACMO tool can be used ex-ante (that is, before implementing mitigation options and before emissions occur). In this case, it allows "planning" and estimating the GHG emissions that will occur.

The GACMO tool can also be used ex-post, that is, after implementing mitigation options. In this case, the tool allows the country (region or city) to estimate and track the reductions in GHG emissions resulting from the implementation of its mitigation options. In addition, the results from the GACMO tool can be used as inputs for the biennial transparency report (BTR), in particular for the Common tabular formats (CTF) for the electronic reporting of the “information necessary to track progress made in implementing and achieving nationally determined contributions under Article 4 of the Paris Agreement”. For a more detailed explanation of how to use the results of the tool as inputs to the CTF tables, the user can refer to the description of STEP 9 (The Tracking progress sheet) in this guidance.

In summary, the main results obtained from the use of the GACMO tool are:

1. The establishment of a GHG emissions BAU scenario (towards the years 2025, 2030, 2035, 2040, 2045, and/or 2050);
2. The establishment of a GHG emissions mitigation scenario (towards the years 2025, 2030, 2035, 2040, 2045, and/or 2050);
3. The estimation of the expected (in the case of ex-ante) or achieved (in the case of ex-post) GHG emission reduction associated with each mitigation option chosen by the user;

4. The establishment of a "marginal abatement revenue curve" (graph) that compares, among all selected options, the abatement cost/revenue for an option to reduce one unit of CO_2 emissions, with the total potential of emissions reduction of this option.

Use of the GACMO tool in Ghana

Between 2017 and 2018, Ghana used the GACMO tool to identify new mitigation opportunities in different sectors. Based on 27 new mitigation options, the country has used the tool to update the baseline scenario and the mitigation scenario of its NDC. The implementation of the 27 mitigation options would allow Ghana to reduce its emissions by 53% in 2030 compared to the baseline scenario. By doing this, they would have saved $622 million a year.

In addition to the GACMO tool, there are a large number of models that can be used for developing projections of GHG emissions and analyzing the impact of mitigation measures (e.g., LEAP, TIMES, Prospects, etc.). Each model can answer different research questions and provide numerical (quantitative) assessments of the baseline emissions and of the impact of mitigation measures on emissions. However, their use may be limited by the high requirement for data and the license costs to carry out the assessments. In addition, some models require high levels of expertise to use the software, which might not be available in some countries and might take time to build.

Among all the other models available, LEAP is probably the model which shows the most similarities to the GACMO tool. Therefore, it is interesting to discuss the advantages and disadvantages of GACMO versus LEAP, and how they can eventually complement each other:

- GACMO modelling is based on the methodology of trend/regression analysis, while LEAP modelling is based on an accounting framework model.
- The GACMO tool is relatively simple and quicker to develop with low initial input data requirements compared to LEAP. However, a disadvantage is its reliance on strong (sometimes oversimplified) assumptions, its greater reliance on the quality of inputs, and its lack of accounting for sectoral interactions.
- The advantage of the LEAP model is its accounting for sectoral linkages, high temporal granularity, extensive user support, multi-scenario analysis, flexibility in its structure, etc. The disadvantage of the LEAP model is its relatively high level of expertise requirement, higher input data requirements, and the greater amount of time needed to develop the model.
- While GACMO is a free and open-source Excel-based model, LEAP requires software and a license (provided for free to low-income and lower-middle-income countries).

In this context, GACMO can complement the LEAP model, by providing a quick and simple assessment of emission reduction and abatement costs from the individual mitigation options (without having the need to build an entire energy system model).

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What is the structure of GACMO?

When a user installs the GACMO tool on a personal computer and opens the "Excel GACMO file", only two spreadsheets are visible:

- Introduction: this spreadsheet provides an overview of what the GACMO tool is and what its structure is.
- Guidance: this spreadsheet provides a quick step-by-step explanation for using the GACMO tool.

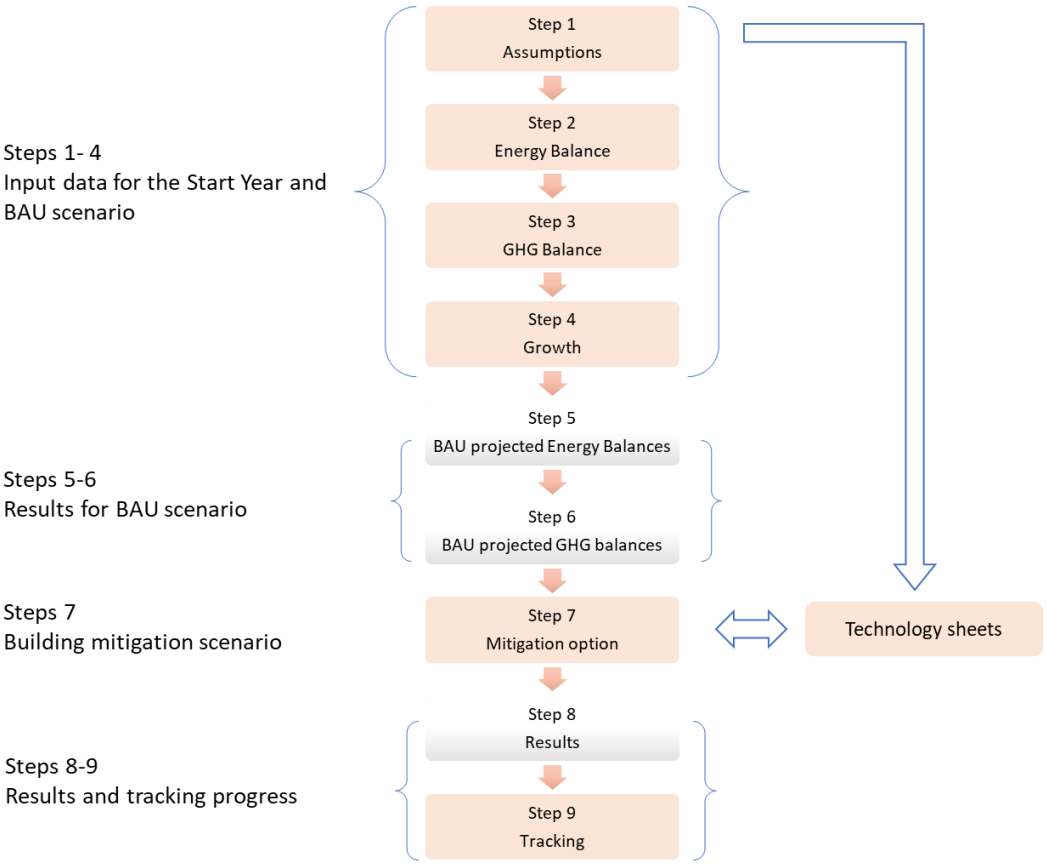
The GACMO tool includes then seven spreadsheets with technical data that the user needs to consider following a stepwise approach. The interface of the tool is made so that the user is taken from the first spreadsheet to the last spreadsheet following a logical order. These spreadsheets are:

- Assumptions: this spreadsheet includes all the basic country data, fuel prices, and technical data that the GACMO tool needs as inputs for the calculations. This sheet must be filled in by the user.
- Energy Balance: this spreadsheet includes the energy data disaggregated by sector of activity for the start year. This sheet must be filled in by the user.
- GHG Balance: this spreadsheet includes the GHG emissions data disaggregated by sector of activity for the start year. The CO_2 emissions from fuel combustion are estimated by the GACMO tool automatically. The CH_4 and N_2O emissions from fuel combustion and emissions from the non-energy sectors must be filled in by the user.
- Growth: this spreadsheet includes the expected growth in energy consumption for the different sectors of activity for different periods of time. This sheet must be filled in by the user.
- BAU projected Energy Balances: this spreadsheet includes the future energy balances for the years 2025, 2030, 2035, 2040, 2045, and 2050. The data in this sheet are automatically calculated by the GACMO tool.
- BAU projected GHG Balances: this spreadsheet includes the future GHG emissions for the years 2025, 2030, 2035, 2040, 2045, and 2050. The data in this sheet are automatically calculated by the GACMO tool.
- Mitigation Options: this spreadsheet includes all the mitigation options that the user may select depending on the national context, as well as the data relative to those mitigation options that the GACMO tool needs as inputs for the calculations. This sheet must be filled in by the user. In addition, this spreadsheet includes data about the emission reduction potential of the mitigation options as well as data about their costs which are automatically calculated by the tool.

In addition, the GACMO tool includes two additional spreadsheets:

- Results: this spreadsheet includes all the final results for the GHG emissions projections, reductions and costs calculations. The sheet also displays the graphical results from the data analysis.
- Tracking progress: this spreadsheet is used by the user to monitor the progress made in implementing each mitigation action. The Tracking progress sheet is thus used ex-post, that is, once the mitigation options are under implementation or have been implemented, to estimate achieved reductions of the GHG emissions.

The figure below shows the schematic for building the GACMO tool. The boxes in orange depict the sheets where the user inserts the data. The steps 1-4 involve input data for Start Year and BAU scenario. The steps 5-6 present the results for BAU scenario. The step 7 involves input data for the mitigation scenario and technology sheets (that is partially filled from the Assumptions sheet). Final modelling results and tracking progress are done in the steps 8-9.



Note that once the user clicks “Go to Step 5”, the sheets corresponding to steps 1-4 will be hidden. This is because the step 4 finishes the process of input data collection for the Start Year and the BAU scenario, and because the next steps depict the results for the BAU scenario (steps 5-6) and steps for building the mitigation Scenario (step 7). If the user needs to change the input data for the BAU

scenario or the Start Year after viewing the results for BAU scenario, the user can unhide the steps 1-4 by clicking on “Go back to Step 1-4”.

Finally, the GACMO tool includes a list of Technology sheets organized by categories of activities ("Agriculture", "Biomass Energy", "CCS", "Cement", "Coalmine CH_4", "EE households", "EE Industry", "EE own generation", "EE service", "EE supply side", "EE distribution", "Forestry", "Fossil fuel switch",….) which includes the tables with the default technical and cost values for each specific mitigation option. These Technology sheets are not directly visible in the tool, but the user can access the table with the default technical and cost values for a specific mitigation option by clicking on the name of the corresponding mitigation option in column C of the Mitigation Options sheet. A user should always take the time to review the tables including all the values for technical and cost data of the relevant mitigation options. If the user has values specific to the country’s national context for some of the technical and cost data of the relevant mitigation options, the user should replace the corresponding default values with these specific values. By doing so, the user will increase the quality of the results from the GACMO tool.

STEP-BY-STEP GUIDE ON THE USE OF GACMO

The interface of the tool is made so that the user is taken from the first spreadsheet to the last spreadsheet following a logical order.

When using the GACMO tool, the user should only insert new numbers in the cells highlighted in yellow. Some of these cells contain already default values. These values can be modified when the user considers it necessary. When inserting data into the model, it is very important to insert the data as per the unit indicated in the tool for each data.

STEP 1 = The Assumptions sheet:

This spreadsheet includes eight tables with all the basic country data, energy prices and technical data that the GACMO tool needs as inputs for the calculations. This sheet must be filled in by the user.

All the cells in the eight tables displayed on the sheet must be considered by the user. Some of these cells may already include default values for some data, but the user should try to adjust those values with national values. Note that the data inserted on this sheet are transferred automatically by the GACMO tool into the other sheets where they are used for calculations.

The data to insert in this sheet are:

First table:

- Country = name of the country / geographic region of study (C9)
- Start year (latest inventory) = the year corresponding to the year of the energy balance which will be used in the "Start year balance" sheet (C10)
- Currency = Currency of the country (C11)
- Exchange rate used (1US$=) = the exchange rate for the country currency to US$ (C12)
- Discount rate = the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows (C13)

Second table:

- Crude oil / LNG / Coal = the energy prices for the future period for Crude oil (C17), Liquefied Natural Gas (LNG) (C19), and coal (C21). Note that the units for those data are respectively US$/bbl, US$/MBTU, and US$/tonne. The model uses these as constant fuel prices and as estimates for the inputs in future timesteps.

Third table:

- Distillate price/crude oil price (litre/litre) = the ratio between the price of the distillate product and the price of the crude oil (C27 to J27). Data should be inserted for the fossil fuels that are part of the energy mix of the country. Note that the GACMO tool includes default values for those data, but the user should adjust them with country-specific data.

- t/m3 = density of the fossil fuels (C30 to J30). Data should be inserted for the fossil fuels that are part of the energy mix of the country considered. Note that the GACMO tool includes default values for density of fossil fuels.
- GJ/t = energy content of the fossil fuels (C31 to O31). Data should be inserted for the fossil fuels that are part of the energy mix of the country. Note that the GACMO tool includes default values for those data, but the user can adjust them if it is considered necessary.

Fourth Table:

- US$/kWh = current electricity price without taxes and subsidies (D35)

Fifth Table

- Average grid emission factor = Grid emission factor used by GACMO in the technology sheets to estimate the emissions for the reference option (with no mitigation option in place) (D39)
    - For the use of the GACMO tool at the national scale, the user specifies the national average grid emission factor.
    - In the case that the geographical location of the mitigation option is known, it is recommended to specify local grid emission factor for this mitigation option. The user can indicate the corresponding grid emissions factor value in the respective technology sheet.
    - For the use of the GACMO tool at the city or state level, the local-specific grid emission factor must be used.
- Electricity grid losses & own consumption = percentage of electricity grid losses (D40). Note that this value will be imported automatically by the GACMO tool from the Energy Balance sheet (Step 2).

Sixth Table:

- Sector-specific Emission factors (kg GHG/GJ) for CO_2 = emission factors of the different fossil fuels used in the energy mix of the country (D45 to D53). Note that the GACMO tool already includes default values based on the IPCC methodologies. The user can, however, modify these values if country-specific emission factors are available.
- Sector-specific Emission factors (kg GHG/GJ) for CH_4 and N_2O = The emission factors for CH_4 (methane) and N_2O (nitrous oxide). Note that the GACMO tool already includes default values based on the IPCC methodologies (AR5). The tool will convert these CH_4 and N_2O values into CO_2 equivalent by using the Global Warming Potential (GWP) for these gases mentioned in the table below.

Seventh Table:

- Global warming potentials = GWP for CH_4 (F64) and N_2O (F65). The GWP values are also default values based on the IPCC methodologies (AR5).

Eighth Table:

- Population (thousands)= population in the start year (C88).
- GDP (current MUS$) = Gross Domestic Product (GDP) in the start year (C89).

Once all the data have been inserted in the tables above, you can move to the next step by clicking "Go to Step 2".

STEP 2 = The Energy Balance sheet:

This spreadsheet includes the energy data disaggregated by sector of activity for the start year. This sheet must be filled in by the user.

The user must fill in one of the two tables with the energy data expressed in terajoules (TJ) and volume/mass in terms of million cubic meter (million m^3) and mega tonnes (Mt). To do so, the user chose the relevant table by clicking "Select unit for input" and by selecting either Energy value or Volume/Mass value.

The structure of the two tables *Energy balance in TJ – Country X - Start year energy balance in Mt and Million m^3* are the same. They include the list of categories of activity for energy use in column C. For each category of activity relevant to the national context of the country, the user must introduce the amount of each fossil fuel used for this specific category expressed in the selected unit (TJ or *Million m^3*/Mt). Data should only be inserted in the yellow cells. In case a category of activity is not relevant to the national context, no data should be inserted in the corresponding cell.

Once the user has inserted the energy balance data in TJ or Mass/volume units, the GACMO tool automatically calculates the energy balance in 1000 tonnes of oil equivalent (ktoe). The table for the energy balance expressed in ktoe can be seen or hidden by the user by clicking "See/Hide table in ktoe values".

On the same spreadsheet, the user must also fill in the table called *Start year electricity balance in GWh*. This table corresponds to the electricity balance for the start year. The user must introduce the electricity consumption in GWh for each category of activity relevant to the national context of the country (D103 to D122) as well as the electricity production from the different types of fossil fuels (G105 to G110) or from renewable sources (G112 to G116) relevant to the national context. Finally, the user needs to introduce the data on electricity import and export for the Start Year (G119 to G120). The GACMO tool will then calculate the Net import, which is the difference between the total imports and the total exports.

Once all the data have been inserted in the tables above, the user can move to the next step by clicking "Go to Step 3". Note that the button "Go to Step 3" only appears after the operations in the Energy balance sheet have been completed.

STEP 3 = The GHG Balance sheet:

This spreadsheet includes GHG emissions data disaggregated by sector of activity for the start year. The CO_2 emissions from fuel combustion sectors are estimated by the GACMO tool automatically. Non-CO_2 emissions from fuel combustion, non-fuel combustion sectors must be filled in by the user.

The user should not insert or modify the data in the first table called *CO2 Emissions – Country X - Start year*. This table includes the estimates of CO_2 emissions from fuel combustion at the start year. The GACMO tool automatically calculates the data in this table from the Energy Balance data inserted in the previous sheet.

The user must fill in the second table *Non-CO_2 emissions from fuel combustion, non-fuel combustion sectors* corresponding to the GHG data, expressed in ktCO_2 equivalents, for each sector or sub-sector as defined by the IPCC categories (D41 to D53). In case a sector or sub-sector is not relevant to the national context, no data should be inserted in the corresponding cell. Also, if the user wants to ignore specific sectors or sub-sectors, then no data should be inserted in the corresponding cells. For example, if a user wants to include only the emissions for the waste sector, then data will only be inserted in D51/D52. If a user wants to estimate only CO_2 emissions from fuel combustion, this second table should be left empty.

It is thus important to note that the user should include data only for the sectors or sub-sectors relevant to the national context and/or only for the sectors or sub-sectors that the user wants to cover in the GACMO tool analysis.

Once all the data have been inserted in the tables above, you can move to the next step by clicking "Go to Step 4".

STEP 4 = The Growth sheet:

This spreadsheet includes the expected growth in energy consumption for the different sectors of activity for different periods of time. The growth rates should assume the absence of mitigation options as those growth rates are used to estimate the BAU scenario. This sheet must be filled in by the user.

The user must fill in the table called *Growth from the start year – Country X*. The data should be inserted for different periods of time from the start year to 2025, 2025-2030, 2030-2035, 2035-2040, 2040-2045, and 2045-2050. The data to insert are:

- Population growth = Annual growth factor (%) for the population (D16-F16)
- GDP growth = Annual growth factor (%) for the GDP (D16-F16)

- Energy consumption growth = Annual growth factor for each category of activity (D19-F38). In case a category of activity is not relevant to the national context, no data should be inserted in the corresponding cell.[3]

The energy consumption annual percent growth data must be inserted in the table. The GACMO tool will use these growth factors to project the energy and the GHG data from the start year towards future years (2025, 2030, 2035, 2040, 2045, and 2050) in the BAU scenario. The population and GDP growth data are not used in the projections themselves and are only used by the tool to express the resulting GHG emissions calculated as intensity data in tCO_2e per capita or tCO_2e per GDP.

After the user clicks "Go to Step 5", the sheets with steps 1-4 will be hidden. The user can unhide the steps 1-4 by clicking on "Go back to Step 1-4".

Once all the data have been inserted in the tables above, the user can move to the next step by clicking "Go to Step 5".

STEP 5 = The BAU projected Energy Balances sheet:

This spreadsheet includes the tables for the future energy balances for the years 2025, 2030, 2035, 2040, 2045, and 2050 in BAU scenario. The data in this sheet are automatically calculated by the GACMO tool. The user can navigate between the tables of the different years by clicking on the Year that needs to be displayed.

Two tables are available on this sheet: the *Fossil fuel balance – year – Country X* and the *Electricity balance – year*.

The first table *Fossil fuel balance – year – Country X* can be displayed with the data in TJ or in ktoe unit. The user can navigate between the two types of units by clicking on the Unit that needs to be displayed.

The user should in principle not modify any of the data either in the table *Fossil fuel balance – year – Country X*, or in the table *Electricity balance – year*. Exceptionally, a user may decide to modify a specific data in one of these tables in the case that the user would like to reflect a change in the energy balance which is not taken into account by the projections made by the GACMO tool. The user should only make such a change if he/she is completely familiar with those types of data as the change will have an impact on the emissions scenarios and results obtained.

[3] A recurrent question by a user is *How should we establish the energy consumption growth factors for the future period?* First, those factors might have been estimated and available with specific Ministries or other stakeholders in the country. If such factors have not been established yet, they could be estimated from historical data series for the energy consumption of the categories of activity. Finally, if no data are available, they might be estimated by national experts to the best of their knowledge.

Once the data of the tables have been reviewed, the user can move to the next step by clicking "Go to Step 6".

STEP 6 = The BAU projected GHG Balances sheet:

This spreadsheet includes the tables for the GHG emissions in the BAU scenario for the years 2025, 2030, 2035, 2040, 2045, and 2050. The data in this sheet are automatically calculated by the GACMO tool. The user can navigate between the tables of the different years by clicking on the Year that needs to be displayed. ***Based on the projections toward the years 2025, 2030, 2035, 2040, 2045, and 2050, the GACMO tool will draw a curve in a graph made of the years (as X-axis) and the emissions (as Y-axis) by connecting the points. This curve is the BAU scenario.***

The formulas behind the calculations of the GHG emission in the BAU scenario for the future years are shown below.

$$Emissions_{BAU\ scenario} = \sum Emissions_{CO2\ emissions\ from\ fuel\ combustion} + \sum Emissions_{Non-CO2\ emissions,non-fuel\ combustion\ sectors}$$

$$Emissions_{CO2\ emissions\ from\ fuel\ combustion} = \sum Energy\ consumption\ in\ BAU\ scenario\ _{Sector,Fuel} \times Emission\ factor_{Sector,Fuel}$$

$$Energy\ consumption\ in\ BAU\ scenario\ _{Sector,Fuel} = Energy\ consumption_{Start\ Year,Sector,Fuel} \times Growth\ Rate_{Sector,Fuel}$$

$$Emissions_{non-CO2\ emissions,non-fuel\ combustion\ sectors} = \sum Emissions_{Start\ Year} \times Growth\ Rates_{sector}$$

Two tables are available on this sheet: the *CO_2 emissions from fuel combustion – year – Country X* and the *Non-CO_2 emissions from fuel combustion, non-fuel combustion sectors balances*.

In principle, the user should not modify any of the data either in the table *CO_2 emissions from fuel combustion – year – Country X*, or in the table *Non-CO_2 emissions from fuel combustion, non-fuel combustion sectors*. In exceptional cases, a user may choose to modify a specific data point in one of these tables if they would like to reflect a change in the GHG emissions that is not taken into account by the projections made by the GACMO tool. The user should only make such a change if they are completely familiar with those types of data as the change will have an impact on the emissions scenarios and results obtained.

Once the data of the tables have been reviewed, the user can move to the next step by clicking "Go to Step 7".

STEP 7 = The Mitigation Option sheet:

This spreadsheet includes the data relative to the mitigation options that the user will include in the mitigation scenario. This sheet must be filled in by the user.

The mitigation scenario is established by estimating the emission reduction potentials (compared to the BAU) in the years 2025, 2030, 2035, 2040, 2045, and 2050 using different user-selected mitigation options that depend on the national context. ***Based on the emission reduction potentials estimated in the years 2025, 2030, 2035, 2040, 2045, and 2050, the GACMO tool will draw a curve in a graph made of the years (as X-axis) and the emissions (as Y-axis) by connecting the points. This curve is the mitigation scenario.***

The formulas behind the calculations of GHG emissions in the mitigation scenario are shown below.

$$Emissions_{mitigation\ scenario} = Emissions_{BAU\ scenario} - Total\ Emissions\ reduction_{selected\ mitigation\ options}$$

$$Total\ Emissions\ reduction_{selected\ mitigation\ options} = \sum Emission\ reduction_{mitigation\ option}$$

$$Emission\ reduction_{mitigation\ option} = Emissions_{reference\ option} - Emissions_{reduction\ option}$$

To estimate the emission reduction potentials in the years 2025, 2030, 2035, 2040, 2045, and 2050 the user must fill in the respective tables for those years. The user can navigate between the tables of the different years by clicking on the Year that needs to be displayed. It must be noted that, depending on whether a user wants to estimate emission reduction potentials for all the years or only for 2025 and/or 2030 and/or 2035 and/or 2040 and/or 2045 and/or 2050, the user must fill in one or many of these tables. If the user fills in only one table, then the emission reduction will be estimated for the year chosen. It means that the GACMO tool will not be able to draw a mitigation curve (scenario) but that the emission reduction will be represented by a point for this year in the graph.

The approach to filling in the different tables is the same for each table and is described below.

The table includes a list of all the mitigation options included in the GACMO tool, grouped by category of activities. These options are listed in column C. Each option has been built into the tool by introducing default parameters relative to each of these options. All these parameters are found in the tables corresponding to each mitigation option in the Technology sheets. The user can access the table of each mitigation option by clicking on the name of the mitigation option (in column C). Further explanation on the Technology sheets is provided in this chapter below.

It is important to understand that the default parameters for one mitigation option have been inserted in the GACMO tool in correspondence to a specific unit for this mitigation option. For example, the default parameters for the mitigation option Efficient domestic lighting with LEDs (Row 49) have been

inserted for a unit of 1000 LEDS bulbs (E49). All the units specific to each mitigation option are listed in the column E.

It is recommended that the user consider all the mitigation options suggested in the GACMO tool. However, if the user would like to limit the mitigation options to a specific category of activity, the user can select the categories to be considered by clicking on "Select reduction option sector/type".

To fill in each table (2025, and/or 2030, and/or 2035, and/or 2040, and/or 2045, and/or 2050), the approach below can be followed:

- Identify all the mitigation options, among the list of options available in column C, which need to be considered in the context of the user's country and/or for the purpose of the analysis made in the GACMO tool. For example, a mitigation scenario could be built in the context of an NDC or a Long-Term Strategy. The mitigation options considered for those two cases might be different. The mitigation options which are chosen by the user will be the options that will be used to build the mitigation scenario of the country.

  To make the choice among all the options, a user can refer to national reports such as sectoral policy planning documents, national development strategies, national communications, nationally determined contributions, etc. This choice can also be made on expert-based judgment. Therefore, when running a GACMO process, it is good practice to involve a representative group of national experts from the different sectors/ministries which are being considered in the tool.

- For each mitigation option chosen, the user will have to insert the number of units that are expected to be under implementation by the year 2025, 2030, 2035, 2040, 2045, or 2050 (depending on the table). These numbers are inserted in column I. ***It is very important that the number of units inserted in column I takes into account the unit of the corresponding mitigation option indicated in column E*.** For example, if the number of LEDs bulbs expected under implementation by 2025 is 200,000 bulbs, then the number to include in column I for this mitigation option (Efficient domestic lighting with LEDs - Row 49) will be 200, as 200 x 1000 (which is unit value in E) equal 200,000. The same reasoning between columns I and E has to be made for each number inserted by the user in column I.

  Again, to estimate these numbers, the user will have to refer to national reports or consult national experts from respective sector/ministries.

Note that the tables in this Mitigation Option sheet already include information and results that might be quite relevant for the user (these results are also summarized in the Results sheet). The user will find:

- In column D: **the abatement cost for the mitigation option**, that is the cost of reducing 1 tonne of CO_2e for the mitigation option. This value is calculated from the parameters of the respective Technology sheet.
- In column F: **the emission reduction potential per unit** (defined as per Column E) of the mitigation option expressed in tCO_2e per unit. This value is calculated from the parameters of the respective Technology sheet.
- In column G: **the investment cost** (million USD) for the mitigation option compared to a reference option. This value is calculated from the parameters of the Technology sheet *and* from the data inserted in column I.
- In column H: **the annual costs** (annualized costs in million USD per year) for the mitigation option compared to a reference option. This value is calculated from the parameters of the Technology sheet and from the data inserted in column I. Note that a negative number in column H indicates that the implementation of a mitigation option will allow a savings compared to the implementation of the reference option. These cost savings can take the form of lower maintenance costs for the mitigation option and/or reduced energy use for the mitigation option resulting in lower operational costs for this option compared to the reference option.
- In column J: **the emission reduction potential *in* the year considered** in the table for the mitigation option compared to a reference option in $ktCO_2e$. This value is calculated from the parameters of the Technology sheet *and* from the data inserted in column I.
- In column K: **the aggregate emission reduction potential *in* the year considered** achieved with the mitigation options (listed above).
- In column L: **the aggregated % of emission reduction** achieved with the mitigation options (listed above).

Technology sheets

It is important to note that, in all the tables of the Technology sheets, the user can insert data or modify the default data ONLY in the cells which are highlighted in yellow.

It is recommended for the user to review the input data (highlighted in yellow) in the technology sheets. While some input data can be similar in many countries (e.g. average electricity consumption by electric light-duty vehicle, emission factor by fuel), other input data can vary from country to country (e.g. daily solar insolation, grid emission factor, electricity price, etc.).

The GACMO tool includes twenty-six spreadsheets referred to as Technology sheets. These spreadsheets are not visible to the user, but the user can access them by clicking on the name of the mitigation option in column C of the Mitigation Option sheet.

There is one spreadsheet for each type of mitigation option as defined in the CDM pipeline.[4] Each spreadsheet corresponds to a type of mitigation option (for example Solar) and includes all the mitigation options belonging to this type (for example 12 mitigation options in the Solar spreadsheet). Each mitigation option and its reference option are then summarized in a table showing all the parameters relative to these mitigation and reference options. All the tables for the mitigation options in one spreadsheet are shown below the other. It must be noted that for one mitigation option, there may be different tables for 2020, 2025, 2030, 2035, 2040, 2045, and 2050 next to each other.[5]

All the tables for the different options are built in the same way in all the Technology sheets:

- The top line contains the name of the option and the unit for this option.
- The upper left part of the table contains the economic calculation with a column for the mitigation option (reduction option), a column for the reference option (without the implementation of the mitigation action), and a column showing the impact (positive or negative) on the costs which would result from the implementation of the mitigation option compared to the reference option.
- In this upper left part of the table, the user will find:
  - ✓ The total investment (in US$) for the mitigation option and for the reference option (calculated as the ***additional*** cost compared to the cost of the reference option).
  - ✓ The project life (in years) corresponding to the number of years over which the option will be implemented (lifetime of an option).
  - ✓ The levelized investment (in US$) corresponding to the ***annual*** investment based on the discount rate used (shown in the table of general inputs to the upper right) and the project life in years.
  - ✓ The annual cost of Operation and Maintenance (in US$) for the mitigation option and for the reference option.
  - ✓ The annual electricity cost, the annual fuel cost, or in some cases, the annual material costs (in US$) needed for the mitigation option and for the reference option.
  - ✓ The total annual costs for the mitigation option and for the reference option.
- The lower left table contains the GHG emissions calculations with a column for the mitigation option, a column for the reference option, and a column with the GHG reduction achieved by implementing the mitigation option compared to the reference option (that is, the difference between the mitigation option and the reference option).

[4] https://unepccc.org/cdm-ji-pipeline/

[5] If a user notices that a specific mitigation option relevant to the country is not included in the GACMO tool, the user can contact UNEP Copenhagen Climate Center and we will try to include the missing option.

- The last line in the left part of the table is the average abatement cost expressed in US$/tonne CO_2-eq.
- The right part of the table includes all the entries for the parameters needed to make the GHG emissions calculations and the costs calculations.
  - ✓ The upper right part of the table shows the general inputs used for the reference option and for the mitigation options. Several of these inputs are taken from the Assumptions sheet.
  - ✓ The middle right part of the table shows all the entries for the mitigation option (reduction option). These entries include technical parameters and unit costs.
  - ✓ The lower right part of the table shows all the entries for the reference option. These entries include technical parameters and unit costs.
- At the bottom of each table, there are notes that provide details about the option (if applicable) and/or literature references where additional information about the option and their associated parameters can be found. Often, the references are related to the CDM projects used to establish the default data.

Example of estimating CO_2 emission reduction from the mitigation option Efficient domestic lighting

One of the mitigation options available in GACMO is "Efficient domestic lighting with LEDs (1000 bulbs)". This mitigation options assumes replacing 1000 inefficient incandescent light bulbs with efficient LED lighting.

The CO_2 emission reduction from efficient lighting mitigation measure is estimated as a difference in emissions in the reference option (incandescent lighting) and emissions in the reduction option (LED lighting), as shown in the formula below:

$$Emission\ reduction_{mitigation\ measure}\left(\frac{tCO_2}{year}\right) = Emissions_{\ reference\ option}\left(\frac{tCO_2}{year}\right) - Emissions_{\ reduction\ option}\left(\frac{tCO_2}{year}\right)$$

The emissions in the reference option (incandescent lighting) are estimated using the following formula:

$$Emissions_{reference\ option}\ (tCO_2/year) = \frac{Electricity_{\ incandescent\ lighting}(MWh/year) \times Grid\ emission\ factor(\frac{tCO_2}{MWh})}{(1 - Grid\ losses\ \%)}$$

Emissions in the reduction option (LED lighting) is estimated using the following formula:

$$Emissions_{reduction\ option}(tCO_2/year) = \frac{Electricity_{\ LED\ lamps}(MWh/year) \times Grid\ emission\ factor(\frac{tCO_2}{MWh})}{(1 - Grid\ losses\ \%)}$$

The annual electricity consumption by the incandescent lighting bulbs is estimated using the following formula:

$$Annual\ electricity\ consumption_{incandescent\ lighting}(MWh/year) = \frac{Capacity\ (W)_{incandescent\ bulb} \times Daily\ usage\ (hours/day) \times 365\ \left(\frac{days}{year}\right) \times number\ of\ bulbs}{1000000\ (W/MW)}$$

The annual electricity consumption by LED lighting is estimated using the following formula:

Once the user has reviewed the data in the table corresponding to a specific technology in the Technology sheet, the user can come back to the Mitigation Option sheet by clicking on "Return to Mitigation options". The same can be done for all the other relevant mitigation options.

Once the data have been inserted and reviewed in the tables of the Mitigation Option and Technology sheets, the user can move to the next step by clicking "Go to Step 8".

STEP 8 = The Results sheet:

This spreadsheet sheet includes all the results for the GHG emissions by year and by scenarios and Marginal Abatement Revenue Curves. The sheet also displays the graphical results from the data analysis. In the Results sheet, the user will find the following information:

- A table with the total GHG emissions levels reached in different years (start year, 2025, 2030, 2035, 2040, 2045, and 2050) for the BAU scenario and for the mitigation scenario.
- A graph showing the curves for the total emissions in the BAU and the mitigation scenarios.
- A table showing the sectoral split of the emissions in different years (start year, 2025, 2030, 2035, 2040, 2045, and 2050) for the BAU scenario.
- A graph showing the curves for the sectoral emissions in the BAU scenario.
- A table showing the sectoral split of the emissions in different years (start year, 2025, 2030, 2035, 2040, 2045, and 2050) for the mitigation scenario.
- A graph showing the curves for the sectoral emissions in the mitigation scenario.
- A Marginal Abatement Revenue Curve (MAR curve) comparing the relevant mitigation options for years 2025, 2030, 2035, 2040, 2045, or 2050.

The user can change the name of the scenario (e.g., scenario without measures, scenario with measures, scenario with additional measures).

The GACMO tool can generate one BAU scenario and one mitigation scenario within one GACMO file. A second mitigation scenario can be added by the user. To do this, a second GACMO file needs to be created. To compare three scenarios, the results of the second mitigation scenario from the other GACMO should be copied to the table with GHG emissions from all sectors in the cells named Mitigation scenario 2. If there is one mitigation scenario, the user can delete/hide rows with the second mitigation scenario.

The Results sheet can be printed by the user as a pdf file by clicking on "Make PDF report".

Marginal Abatement Revenue Curve (MAR curve)

In order to easily compare the cost efficiency of the different mitigation options in regard to their respective GHG emissions reduction potential, the GACMO tool establishes a Marginal Abatement

Revenue curve (MAR). This curve is built on the revenue of an option to reduce one tonne of CO_2 equivalent (expressed in US$/t$CO_2$-eq) (y-axis), and the total GHG emission reduction potential of an option (expressed in ktCO_2-eq / year) (x-axis). The data to build the curve are based on the data found in the Mitigation Options sheet.

The MAR curve corresponds to a traditional marginal abatement cost curve (MAC curve) which has been inverted. In the case of a MAC curve, the curve is based on the *cost*, while in the MAR curve, the curve is based on the *revenue*.

The MAR curve allows a user to have a quick graphical comparison among all the selected options in terms of their cost efficiency in reducing GHG emissions.

To update the MAR curves in 2025, 2030, 2035, 2040, 2045, and 2050 in the Results sheet the user can press the "Adjust MAR curves" button for each year in the Mitigation options" sheet.

In the graph of the MAR curve made by the GACMO tool, all the options which are located above the X-axis are "win-win" options. It means that their implementation would allow reducing the GHG emissions compared to the reference option while, at the same time, their implementation would allow the country to make a cost saving in comparison to the implementation cost of the reference option. The size of the area representing one mitigation option in the graph is proportional to the total amount of GHG emissions reduced by the option.

If the user would like to use the GACMO tool for Tracking purposes, the Tracking progress sheet can be accessed by clicking "Go to Step 9".

STEP 9 = The Tracking progress sheet:

This spreadsheet is used to monitor the progress made in implementing each mitigation action. The Tracking progress sheet is used ex-post, that is, once the mitigation options are under implementation or have been implemented, to estimate and monitor the effective reductions of the GHG emissions.

The Tracking progress sheet can be used for tracking progress and achievement of specific mitigation options, for example in the context of an NDC. This sheet can thus be used as a tool for supporting the monitoring of the progress in implementing and achieving a country´s NDC.

The results from the GACMO tool can be used as inputs for the biennial transparency report (BTR), in particular for the Common tabular formats (CTF) for the electronic reporting of the "information necessary to track progress made in implementing and achieving nationally determined contributions under Article 4 of the Paris Agreement".

The following CTF tables can be partially or fully filled with the results of the GACMO tool, particularly with GHG emissions projections in the BAU and mitigation scenarios:

- CTF Table 7. Information on projections of greenhouse gas emissions and removals under a 'with measures' scenario

- CTF Table 8. Information on projections of greenhouse gas emissions and removals under a 'with additional measures' scenario
- CTF Table 9. Information on projections of greenhouse gas emissions and removals under a 'without measures' scenario
- CTF Table 10. Projections of key indicators

The Assumptions used in the GACMO tool (e.g., growth rates) should be reported in the CTF Table 11 "Key underlying assumptions and parameters used for the projections".

The GACMO tool can be used to estimate expected and achieved emissions reductions from the policies and measures. Thus, it can be used to partially fill in CTF Table 5 "Mitigation policies and measures, actions and plans, including those with mitigation co-benefits resulting from adaptation actions and economic diversification plans, related to implementing and achieving a nationally determined contribution under Article 4 of the Paris Agreement".

At the stage of the preparation or update of an NDC, the GACMO tool can support the analysis to identify **economy-wide GHG targets** as well as **sectoral targets** (e.g., capacity of renewable energy, hectares of reforestation, number of electric vehicles etc.) which will be **in line with economy-wide GHG emissions target**. Thus, it can indirectly support filling in the following CTF Tables:

- CTF Table 1 "Structured summary: Description of selected indicators"
- CTF Table 2 "Structured summary: Definitions needed to understand NDC":
- CTF Table 3. Methodologies and accounting approaches
    - Key parameters, assumptions, definitions, data sources and models used.
    - Sector-, category, or activity specific assumptions, methodologies ad approaches

The Tracking progress sheet includes a table with a structure similar to the table found in the Mitigation Options sheet. The table includes the 119 mitigation options (Reduction options in column C) grouped by category or activity types (Type in column B). All 119 mitigation options are shown by default. If the user wants to see only the mitigation options for a specific group of category or activity types, the user can select the corresponding category/ies or activity/ies by clicking "Select sector/type for Tracking input".

For each mitigation option under implementation, the user must introduce the number of *additional* units which has been put in operation at the end of a specific year (column K to Y). The user can thus follow the implementation of each mitigation option and monitor how many units have been installed at the end of each year. The GACMO tool will calculate the GHG emissions reduction for each mitigation option and shows the accumulated GHG emissions reduction achieved through the implementation of the different option (column Z). As of now, the progression of the implementation is shown towards 2030 (Column AA) by comparing the total number of units installed with the total number of units planned by 2030.

APPENDIX 1 - List of emitting categories of activity included in the GACMO tool

The categories of activities considered as source of GHG emissions from human activities included in the GACMO tool are based on the categorization established by the IPCC. The categories in the tool are:

For CO_2 emissions:

ENERGY PRODUCTION - Fossil power plants
FINAL CONSUMPTION
Industry - steel
Industry - chemical
Industry - non metallic mineral
Industry - food processing and beverage
Industry - construction
Industry - mining
Industry - machinery
Industry - non ferrous metals
Industry - paper and pulp
Industry - transport equipment
Industry - textile and leather
Industry - miscellaneous
Transport - road
Transport - rail
Transport - domestic air
Transport - navigation
Households
Services
Agriculture & Fishery
Non energy uses

For CH_4 and N_2O emissions:

CH_4 from energy combustion
N_2O from energy combustion
Agriculture
Agriculture - Enteric fermentation
Agriculture - Manure management

Agriculture - Rice cultivation
Agriculture - N_2O from agricultural soils
Agriculture - Burning of agricultural residues
Fugitive (CH_4)
Forestry
Waste
Waste - solid
Waste - liquid

APPENDIX 2 - List of the mitigation options included in the GACMO tool

The GACMO tool currently includes 119 mitigation options. If a user notices that a specific mitigation option relevant to the country is not included in the GACMO tool, the user can contact UNEP Copenhagen Climate Center and we will try to include the missing option.

Type	Reduction option
Agriculture	Rice crop CH_4 reduction
	Zero tillage
	Cover crops
	Nitrification inhibitors (1000 ha)
	Covering slurry stores (1 slurry store)
	Fat supplementation in ruminants' diets (%DM fat added)
	Tobacco curing
Biomass energy	Rice husk cogeneration plants
	Biomass power from biomass residues
	Bagasse power
CCS	CCS plant
Cement	Clinker replacement
Coal bed/mine methane	Coal mine methane
EE households	Efficient residential air-conditioning
	Efficient lighting with CFLs
	Efficient lighting with LEDs
	Efficient lighting with LEDs replacing CFL
	Efficient wood stoves
	Efficient charcoal stoves
	LPG stoves replacing wood stoves
	Efficient electric stoves
	Induction based cooking
	New passive home
	Efficient refrigerators
EE industry	Efficient electric motors
	Energy efficiency in industry
	Building materials
EE own generation	Waste heat recovery at cement plant
	Waste heat recovery at steel plant
EE service	Efficient electric motors
	Efficient office lighting with CFLs

	Efficient office lighting with LEDs
	Efficient streetlights
	Efficient water pumping
	HVAC
	Efficient Chiller > 300 TR
	Efficient Chiller < 300 TR
	Efficient room air-conditioner
	Efficient commercial dishwashing machine
	Efficient hotel refrigerator
	Efficient hotel washing machine
	Energy efficiency in service
	New office building with central cooling
EE supply side	New natural gas power plant
	Switch from fuel oil to natural gas
	Cogeneration in industry
	Single cycle to combined cycle
Energy distribution	Efficient electric grids
	Connection of isolated grid to central grid
	Power factor increase
	District heating network rehabilitation (100,000 flats supplied)
	District cooling network (1 million m2 new city area covered)
Forestry	Reforestation
	REDD: Avoided deforestation
	Assisted forest regeneration
	Reforestation with agroforestry
	Reforestation with silvopasture
Fossil fuel switch	Switch from coal to natural gas in industry
	Switch from fuel oil to natural gas in industry
Fugitive	Reduced flaring at oil field
	Reduced flaring at oil refineries
	Leak reduction in natural gas pipelines
	Charcoal production
Geothermal	Geothermal power
	Geothermal heat
HFCs, PFCs, SF6	Reduced PFCs from aluminium production
Hydro	Hydro power connected to main grid
	Mini hydro power connected to main grid
	Mini hydro power off grid
Landfills	Landfill gas plant with power production

	Landfill gas flaring
	Incineration plant
	Recycling of plastics
	Refuse Derived Fuel (RDF) from MSW
	Biogas from Municipal Solid Waste
	Composting of Municipal Solid Waste
Marine	Tidal
	Wave
Methane avoidance	Biogas at rural farms using kerosene
	Biogas at rural farms using non-renewable fuelwood
	Biogas at big farms
	Biogas from industrial wastewater
N_2O	Nitric acid plant (N_2O destruction)
Solar	PV pump replacing electric pump
	PV pump replacing diesel pump
	Solar water heater, residential
	Solar water heater, large
	Solar PVs, large grid
	Solar PVs, large grid with 24h storage
	Solar house PVs
	Solar cottage PVs
	Solar/diesel mini grid
	Solar LED lamps
	Solar PVs, small isolated grid, 100% solar
	Solar streetlights
	Parabolic through CSP, no storage
	Solar tower CSP, with storage
Transport	10% Biodiesel blend in all diesel
	15% Bioethanol blend in all gasoline
	Bus Rapid Transit (BRT)
	More efficient gasoline cars
	More efficient diesel cars
	Natural Gas cars
	Electric cars
	Electric 18m buses
	Electric 12m buses
	Electric heavy trucks
	Electric light trucks
	Electric rail

	Shifting passengers from car to rail (1Mill. Person-km/day)
	Shifting freight transport from road to rail (1000 tonne-km/day)
	Restriction on import of used cars
	New bicycle lanes
	Electric three-wheelers
	Electric two-wheelers
	Better maintenance and use of motor bikes
Wind	Wind turbines, onshore
	Wind turbines, onshore with 24 storage
	Wind turbines, offshore
GHG reduction options in total:	**119**