Introduction and guidelines to the *Greenhouse Gas Abatement Cost Model* (GACMO)

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November 2020

Initiative for Climate Action Transparency - ICAT -
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November 2020

The ICAT project is managed by the United Nations Office for Project Services (UNOPS)

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What is GACMO?

The GACMO model (Greenhouse Gas Abatement Cost Model) is a modelling tool developed at UNEP DTU Partnership (UDP) over more than 20 years. It aims to provide countries, mainly developing countries, with a tool that allows them to carry out rapid but accurate evaluations of the greenhouse gas emissions impact of a variety of mitigation options.

The GACMO tool is based on Excel and can be freely downloaded onto an individual computer from the UDP website (https://unepdtu.org/publications/the-greenhouse-gas-abatement-cost-model-gacmo/). GACMO includes around 40 spreadsheets built in such a way that the calculations and the generation of graphs are done in an automated way. The formulas and the default data included in GACMO are based on the mitigation methodologies proposed under the Clean Development Mechanism (CDM) as well as on the information from the projects presented under this same mechanism. Finally, GACMO uses the IPCC database of emission factors (2006 IPCC Guidelines).

The main data required to use GACMO are those of the energy balance, that is the data of the sectoral energy consumption of fossil fuels and electricity of a country (or region, or city). From these data, GACMO calculates greenhouse gas (GHG) emissions for a "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 - or region - and are entered in GACMO by the user), GACMO will project the emissions for the reference scenario also called baseline scenario (Business As Usual - BAU), towards the years 2025, 2030 and / or 2050.

In addition to the baseline scenario, a user can choose from approximately 100 mitigation options included in GACMO. 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, wind energy, among others. Once the mitigation options of interest of a user have been selected, the tool projects the emissions based on the previous growth factors and establishes a mitigation scenario towards the years 2025, 2030 and / or 2050. GACMO calculates also the GHG emissions reduction and an approximation of the investment costs, as well as operation and maintenance costs, which result from each selected mitigation action.[1]

Finally, GACMO also allows monitoring the GHG emission reductions achieved through the effective implementation of mitigation options. Therefore, GACMO can be used additionally as a tool for Monitoring, Reporting and Verification (MRV) of climate change mitigation options.

GACMO can be used at the national level (country level) and can then be very relevant in the framework of the preparation of reports such as National Communications, Biennial Update Reports (BURs), or for the preparation of the Nationally Determined Contributions (NDCs). To date, GACMO has been used in several countries including Afghanistan, Angola, Antigua and Barbuda, Colombia, Eritrea, Ghana, Guinea Bissau, Lesotho, Maldives, Macedonia, Mozambique, Myanmar, North Korea,

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[1] It has to be noted that GACMO does not integrate the interactions among measures assessed simultaneously. GACMO calculates the GHG emissions reduction specific to each mitigation option selected by the user.

USE OF GACMO IN MALDIVES AND GHANA

Between 2009 and 2015, Maldives used the GACMO tool to identify new mitigation opportunities in different sectors. Based on 22 new mitigation options, the country has used GACMO to develop the baseline scenario and the mitigation scenario for its INDC. The implementation of the 22 mitigation options would have allowed the Maldives to reduce its emissions by 35.7% in 2020 compared to the baseline scenario. By implementing these 22 options, the Maldives would have saved $111 million a year.

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 GACMO 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.

Panama, Sao Tome and Principe, Senegal, Swaziland, Zambia, Zimbabwe and others. GACMO has also been used to make a global study of GHG reduction potential at the level of the Latin American region.[2]

GACMO COPYRIGHTS

The GACMO tool has been developed at UNEP DTU Partnership and has been partially funded by UNOPS (United Nations Office for Project Services) and ICAT (Initiative for Climate Action Transparency).

The tool is regularly updated and the last version of GACMO is always made available on the UNEP DTU Partnership website at https://unepdtu.org/publications/the-greenhouse-gas-abatement-cost-model-gacmo/.

All the versions of GACMO can be downloaded and used free of charge by any user and can be installed on a personal computer. However it is not allowed to make any commercial use of the GACMO tool without the prior authorization of UNEP DTU Partnership.

For any inquiries and authorization requests, please contact UNEP DTU Partnership at unep@dtu.dk.

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

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

Therefore GACMO is usually used to establish a baseline/reference 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 nationally determined contribution of the country or in a sectorial mitigation plan.

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[2]   https://unepdtu.org/publications/zero-carbon-latin-america-a-pathway-for-net-decarbonisation-of-the-regional-economy-by-mid-century/

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

Finally GACMO can be used to establish the individual greenhouse gas emission reduction impact of a specific mitigation option considering different levels of implementation.

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

GACMO can also be used by the country (region or city) to identify and choose mitigation options potentially of interest, and estimate ex-ante the GHG emission reductions associated with each mitigation action (that is, the emission reductions that would occur in the event that the mitigation action is implemented) as well as the associated costs.

Finally, GACMO 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 monitor the reductions in GHG emissions resulting from the implementation of its mitigation options.

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

1. The establishment of a baseline scenario of GHG emissions (towards the years 2025, 2030 and/or 2050);

2. The establishment of a GHG emissions mitigation scenario (towards the years 2025, 2030 and/or 2050);

3. The estimation of the potential GHG emission reduction associated with each mitigation action chosen by the user;

4. The estimation of the investment cost and implementation cost (CAPEX and OPEX) associated with each mitigation action chosen by the user. Such costs are calculated as the additional cost or cost saved compared to a reference action;

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

What is the structure of GACMO?

GACMO has around 40 spreadsheets contained in an Excel file. These sheets can be divided into 3 large groups:

1. Sheets of data or *inputs*, including "Start year balance", "Growth", "Assumptions", "Main 25/30/50". These are the sheets in which the user enters the data required to define the particular inputs of the case under study;

2. Sheets of outputs or *results*, including "Growth", "Graph". These are the sheets in which the main results are found;

3. *Technology* sheets, including "Agriculture", "Biomass Energy", "CCS", "Cement", "Coalmine CH4", "EE households", "EE Industry", "EE own generation", "EE service", "EE supply side", "E distribution", "Forestry", "Fossil fuel switch",…. These are the sheets in which the specific data of each mitigation option, as well as of the corresponding reference option, are found. The appendixes 1 and 2 list respectively all the categories of activities and all the mitigation options included in GACMO.

In addition, GACMO includes a spreadsheet called "MRV" in which the progress in implementing each mitigation action selected by the user can be monitored. This sheet is used ex-post, that is, once the mitigation options have been implemented, to estimate and monitor the effective reductions of the GHG emissions.

How does GACMO work?

The emissions calculations carried out with GACMO are based on the methodologies and emission factors established by the IPCC, as well as the methodologies established in the framework of the Clean Development Mechanism (CDM). The data used for defining the mitigation options in GACMO are based on the most recent literature. Therefore, GACMO is in line with the most recent internationally approved GHG emission calculation methodologies.

GACMO includes a series of formulas and macros that automate the calculations performed by the tool. This means that a user, who has the data required to use GACMO, does not need to be familiar with the calculations themselves in order to use the tool, but only with how to enter the inputs, as well as interpret the results.

GACMO 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 they have better inputs and want to make a more precise estimate. These *default* values are thus all visible and accessible by the user. The first group of data with *default* values are those of key mitigation parameters, such as the global warming potential (GWP) of each GHG (in the "*Assumptions*" sheet). In that case, GACMO uses by *default* the most recent values of those parameters established by the IPCC, although previous GWP values are also available in GACMO. 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 the *"Technology"* sheets). In this case, GACMO uses by *default*, average values calculated from relevant CDM projects available on the CDM website[3], and summarized in the project pipeline developed at UNEP DTU Partnership[4]. Experience has shown that the use of *default* values for data related to baseline and mitigation options works well in GACMO.

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[3] https://cdm.unfccc.int/
[4] https://www.cdmpipeline.org/

However, it is possible for a GACMO user to modify those *default* values for data related to the mitigation and reference options to replace them with values specific to their case (country, city region, industrial activity). This allows for even more accurate results at the end of the GACMO application.

In summary, the key data required for running GACMO are:

1. The energy balance data, that is, the production/consumption data of fossil fuels and electricity energy for a country (region or city). These data must be included in the "Start Year Balance" sheet;

2. The data corresponding to GHG emissions for the key sectors: Agriculture, Forests, Waste and Industrial processes. These data must be included in the "Start Year Balance" sheet;

3. Activity data on quantities and costs related to each energy source, as well as electricity. These data must be included in the "Assumptions" sheet;

4. Basic data about the country, such as the local currency, the exchange rate with the dollar, the discount rate,… These data must be included in the "Assumptions" sheet;

5. The number of units of each mitigation option (that the user choses to select) penetrating towards the years 2025, 2030 and/or 2050. These data must be included in the "Main25" / "Main30" / "Main50" sheets.

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

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

GACMO includes 115 mitigation options

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
Energy efficiency in households	Efficient residential airconditioning
	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
Energy efficiency in industry	Efficient electric motors
	Energy efficiency in industry
	Building materials
Energy efficiency - own generation	Waste heat recovery at cement plant
	Waste heat recovery at steel plant
Energy efficiency - service	Efficient electric motors
	Efficient office lighting with CFLs
	Efficient office lighting with LEDs
	Efficient street lights
	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
Energy efficiency - supply side	New high efficiency coal power plant
	New natural gas power plant
	Switch from fuel oil to diesel
	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 waste water
N2O	Nitric acid plant (N2O destruction)
Solar	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 street lights
	Parabolic through CSP, no storage
	Solar tower CSP, with storage
Transport	5% 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
	Shifting passengers from car to rail (1Mill. personkm/day)
	Shifting freight transport from road to rail (1000 tonkm/day)
	Electric heavy trucks
	Electric light trucks
	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, on-shore
	Wind turbines, on-shore with 24 storage
	Wind turbines, off-shore

APPENDIX 3 - STEP BY STEP GUIDE ON THE USE OF GACMO

GACMO is available in English and French on the website of the UNEP DTU Partnership
https://unepdtu.org/publications/the-greenhouse-gas-abatement-cost-model-gacmo/

The text below describes a step-by-step approach to use the GACMO tool. All the information and data which need to be inserted by the user are highlighted in blue in the text below.

General considerations

The first sheet of the model "Guidance" includes a quick description of how to use GACMO. In addition, this sheet always refers to the version number of the GACMO tool. GACMO is indeed in constant development to include additional mitigation options or take the last IPCC recommendations into account, and new updated version of GACMO are regularly uploaded on the UNEP DTU Partnership website.

When using GACMO, 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.

1) Inserting basic information and data

The first sheet that the user must fill in is the sheet "Assumptions". This sheet includes all the information and data relating to the country of the user. These information and data are then transferred automatically by the tool into the other sheets where they are used for calculations.

The info and data to include in this sheet are:

- **Name of the country** / geographic region of study (B2)[5].
- **Start year** (B3) = this is the year corresponding to the year of the energy balance which will be used in the "Start year balance" sheet.
- **Currency of the country** (B4).
- **Exchange rate to US$** (B5).
- **Discount rate** (B6) = this is the interest rate used in discounted cash flow (DCF) analysis to determine the present value of future cash flows.
- **The energy prices for the future period**, for Crude oil (B9), Liquefied Natural Gas - LNG (B11), and coal (B13). The model used these prices as constant fuel prices estimated for the future.
- **The current fuel prices** for each of the fuel used in the energy mix of the user´s country (B21 to I21; and B22 to N22).
- **The current electricity price** _without taxes and subsidies_ (B25 to D25).
- **The grid emission factor** (C29 and C30).
- **The percentage of Electricity grid losses** (B33).

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[5] All the coordinates included between brackets are the cells of the excel GACMO tool where the information or data should be included.

- **The emission factors of the different fossil fuels** used in the energy mix of the country (C36 to C44). Note that GACMO already includes default values based on the IPCC methodologies. A user can however modify these values if the user considers it necessary to align them with the country national context.
- **The emission factors for CH$_4$ (methane) and N$_2$O (nitrous oxide)**. Note that GACMO already includes default values based on the IPCC methodologies.[6] GACMO will convert these CH$_4$ and N$_2$O values into CO$_2$ equivalent by using the Global Warming Potential (GWP) for these gases mentioned in the cells E55 and E56. The GWP values are also default values based on the IPCC methodologies.

2) Building the baseline/reference scenario

The emission projections made by GACMO are among other based on the energy balance of a country and the growth factors for the different categories of activities.

2.1 Start Year Balance sheet

The second sheet that the user must fill in is the sheet "Start Year Balance".

In the Start year Balance sheet, a user has to introduce:

- The data related to **the energy balance** of the user´s country (yellow cells in the able A3 to N27). Note that the year of the energy balance data corresponds to the start year mentioned in the sheet Assumptions. In principle, it is the most recent year for which a user has data for the energy balance. However, in some circumstances, a user could chose a year which would not correspond to the most recent one. The input unit for this energy balance is TJ. If the user has the data in units of mass or volume (Mt or millions of cubic meters), the user can convert the units to TJ using the sheet named "kT to TJ". The data have to be introduced for each of the fossil fuels making of the energy mix of the country (columns B to M) and for each category of activity relevant in the context of the user´s country.

GACMO converts then the energy balance expressed in TJ into an energy balance expressed in ktoe (oil equivalent).

- **The electricity consumption for each category of activity** relevant in the context of the user´s country (O37 to O56).
- **The electricity production for each source of energy** relevant in the context of the user´s country (Q37 to Q42; and Q52 to Q56).
- **The Fraction of carbon oxidised** (J59). Note that the default value for this parameter is 1. However some user may consider that the fraction of carbon is never oxidised as 100%. In this case, the user may modify the value of this cell J59 accordingly.

GACMO converts then the whole energy balance into a CO$_2$ emission balance (A61 to N84).

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[6] The GWP of PFC gas is also included in GACMO but it is found in the technology sheet named "HFC PFC SF6".

- **The emissions for CH₄ and N₂O for Energy, Agriculture, Forestry, Fugitive, Waste, and Industrial Processes categories** (B85 to B97). These data can typically be found by a user in the last greenhouse gas inventory of the country. Other national documents can also include these data such as sectoral strategies, national communications, nationally determined contributions,…

2.2 Growth sheet

The third sheet that the user must fill in is the sheet "Growth". This sheet includes the growth factors for different parameters expected for different periods of time in the context of the user´s country.

In the Growth sheet, a user has to introduce:

- **The annual increase expected for population growth** (B5 to E5) and for GDP growth (B6 to E6).
- **The fuel annual increase expected for each category of energy-related activity** (B8 to E32) as well as the non-energy-related activity (B33 to E33).
- **The annual increase for CH₄ and N₂O emissions for Agriculture, Forestry, Waste, and Industrial Processes categories** (B34 to E41).[7]

The user has to introduce these annual growth factors for the periods: base year to 2020; 2020 to 2025; 2025 to 2030; and 2030 to 2050. GACMO converts then automatically all these annual growth factors into growth factors from start year values (table F5 to I41).

Based on the data in traduced by the user for the energy balance of the country (in the Start year balance sheet) and for the growth factors (in the Growth sheet), GACMO calculates automatically the fossil fuels and energy balance of the country as well as the greenhouse gas balance of the country for the years 2020, 2025, 2030 and 2050. The tables corresponding to these projections can be found in the sheets named "Balance 2020","Balance 2025","Balance 2030",and "Balance 2050". **These projections made by GACMO corresponds to the baseline/reference scenario of the country.**

3) Building the mitigation scenario[8]

The fourth, fifth, sixth and seventh sheets that the user must fill in are the sheets "Main20", "Main25", "Main30", and "Main50". It has to be noted that, depending on whether a user wants to build scenarios to 2025, 2030 and/or 2050, the user can fill in one or many of these three sheets. The approach for filling in these different Main sheets is always the same.

The Main sheets includes a list of all the mitigation options included in the GACMO tool and grouped by category of activities. These options are listed in the column B. Each option has been built into GACMO 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. It is important to understand that the default parameters for one mitigation option have been inserted in GACMO in correspondence to a specific unit for this mitigation option. For example, the default parameters for

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[7] Note that some categories have been merged compared to the Start year balance sheet as they have the same growth factor. It is the case of manure management and enteric fermentation, fugitive and industrial processes.
[8] Note that GACMO still includes a Main sheet for the year 2020. The reason is that some countries still use an old start year, which causes the need to make also projections up to 2020.

the mitigation option *Efficient domestic lighting with LEDs* (Row 20) have been inserted for a unit of 1000 LEDS bulbs (D20). All the units specific to each mitigation option are listed in the column D.

In the different Main sheets, a user has to:

- Identify all the mitigation options, among the list of options available in column B, which need to be taken into account in the context of the user´s country. **The mitigations options which are chosen by the user will be the options which will be used to build the mitigation scenario of the country.[9]**

To make the choice among all the options, a user has to refer to national reports such as sectoral policy planning documents, national development strategies, national communications, nationally determined contributions,… Of course this choice can also be made on experts-based judgement. Therefore, when going through a GACMO process, it is good practise to involve a representative group of national experts from the different sectors/ministries which are being covered by GACMO.

- **For each mitigation option chosen, the user will have to insert the number of units which are expected to be under implementation by the year 2025, 2030, or 2050** (depending on the Main sheet filled in). These numbers are inserted in the column H. [10] It is very important that the number of units inserted in the column H takes into account the unit of the corresponding mitigation option indicated in the column D. For example, if the number of LEDs bulbs expected under implementation by 2025 is 200,000 bulbs, then the number to include in the column H for this mitigation option (*Efficient domestic lighting with LEDs* - line 20) will be 200, as 200 x 1000 (which is unit value in D) equal 200,000. The same reasoning between column D and H has to be made for each number inserted by the user in the column H.

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

4) Finding and understanding the results of the calculations made by GACMO

Once the steps described above have been taken by the user, GACMO will make the calculations and projections for baseline/reference and mitigation scenarios to 2025, 2030, and/or 2050. The results of the calculations, as well as graphical representations of the results, can be found in the different sheets already mentioned above.

4.1 Results found in the Main sheets

Once the user has introduced the numbers of units which are expected to be under implementation in the column H, GACMO calculates different parameters which are found in the same table.

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[9] Note that if a mitigation option relevant for your country is not included yet into GACMO, the user can contact UDP at jqfe@dtu.dk or ddes@dtu.dk. We will then consider if it is possible to include such an option in the GACMO tool.
[10] Note that for the mitigation options that the user does not want to choose, the corresponding cells of the column H are left in blank.

- **The emission reduction achieved by one specific mitigation option** (column I): For each mitigation option chosen by the user, GACMO calculates the annual emission reduction achieved *in* 2025 (2030 and/or 2050) by the corresponding mitigation option. These results can be found in the column I.
- **The cumulative emission reduction by all the mitigation options** (column J): For all the mitigation options chosen by the user, GACMO calculates the cumulative emission reduction achieved *in* 2025 (2030 and/or 2050). The results can be found in the column J. The values add up from top to bottom in the column; the emission reduction of an option is added to the value of the previous option in the column.
- **The total emission reduction by all the mitigation options** (J119): GACMO calculates the total emission reduction by all the mitigation options (corresponding to the total of the cumulative emission reduction) achieved *in* 2025 (2030 and/or 2050). The results can be found in the cell J119.
- **The total emissions produced in the baseline/reference scenario** (J120): GACMO calculates the total emissions produced in the baseline/reference scenario *in* 2025 (2030 and/or 2050). The results can be found in the cell J120.
- **The fraction of the total emission reduction for each option and the cumulative fraction** (column K): GACMO calculates the contribution of each mitigation option to the total emission reduction achieved through the mitigation scenario compared to the emissions of the baseline/reference scenario *in* 2025 (2030 and/or 2050). The results can be found in the column K. The values add up from top to bottom in the column. The contribution relative to an option is added to the value of the previous option in the column. The result found in the cell K119 corresponds thus to the total emission reduction achieved through the mitigation scenario expressed as a percentage of the total emissions of the baseline/reference scenario.
- **The investment cost of each mitigation option** (column F): GACMO calculates the investment cost of each mitigation option. The results can be found in the column F. The user has to note that these investments costs are the *additional* investment costs in comparison to a reference option. All the reference options are also described in the tables found in the Technology sheets. The total investment cost (compared to reference options) for all the mitigation options chosen by a user is found in the cell F120.
- **The annual cost of each mitigation option** (column G): GACMO calculates the annual cost of each mitigation option corresponding to the cost for operation and to the cost for maintenance of the mitigation option. The user has to note that these annual costs are the *additional* annual costs in comparison to a reference option. All the reference options are also described in the tables found in the Technology sheets. The total annual cost (compared to reference options) for all the mitigation options chosen by a user is found in the cell G120. It has to be noted that a negative number in the column G indicates that the implementation of a mitigation option (or of all mitigation options if the user refers to the cell G120) will allow a savings compared to the implementation of the reference option). This savings can be the consequence of a lower maintenance cost for the mitigation option and/or a reduced energy use for the mitigation option resulting in a lower operation cost for this option compared to the reference option.
- **The total emission reduction and the investment costs subdivided by category of activities** (table B127 to E137): From the emission and cost calculations made in the Main sheet, GACMO adds the results by category of activities. The table allows the user to have a quick overview on the contributions of the different categories of activities to the emission reduction, as well as the *additional* costs related to each category of activity.

4.2 Results found in the Growth sheet

In addition to the results of the calculation, GACMO represents also the projections for baseline/reference and mitigation scenarios to 2025, 2030, and/or 2050 in a graphical manner. These graphs can be found at the bottom of the Growth sheet.

- **Summary of the total emissions produced in the baseline/reference scenario and mitigation scenario** (table D45 to H59): GACMO summarizes the total emissions produced in the baseline/reference scenario and mitigation scenario for the base year as well as for the years 2020, 2025, 2030 and/or 2050. These results can be found in the table at the bottom of the Growth sheet (D45 to H59).
- **Graphic representation of the projections in the baseline/reference scenario and mitigation scenario**: Based on the previous table (D45 to H59), GACMO draws a curve for the projections of the emissions in the baseline/reference scenario and for the mitigation scenario. In the case that a user would like to establish different baseline/reference scenarios or different mitigation scenarios (for example a conditional and an unconditional scenarios), each additional scenario has to be developed separately through a GACMO process in different files. However the user can copy the three lines corresponding to the additional scenario in the equivalent table of the Growth sheet (from column A to column H) and copy these three lines into the table of its original GACMO file. An additional curve corresponding to the additional scenario will then be added to the graph.
- **Summary of the sectoral split for the emissions produced in the baseline/reference scenario** (table B79 to G88): GACMO summarizes the split of the emissions produced in the baseline/reference scenario among the different sectors for the years 2020, 2025, 2030 and/or 2050. These results can be found in the last table at the bottom of the Growth sheet (B79 to G88).
- **Graphic representation of the sectoral split for the emissions produced in the baseline/reference scenario**: Based on the previous table (B79 to G88), GACMO draws different curves representing the projections for the emissions produced by the different sectors in the baseline/reference scenario.

4.3 Results found in the Graph sheet: the Marginal Abatement Revenue curve

In order to easily compare the cost efficiency of the different mitigation options in regards to their respective greenhouse gas emissions reduction potential, GACMO establishes a Marginal Abatement Revenue curve (MAR). This curve is built on the cost of an option to reduce one ton of CO_2 equivalent (expressed in US\$ / tCO_2-eq) (y-axis), and the total greenhouse gas 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 Main sheets, in particular the column C which gives the cost of each option per ton of CO_2 (US\$/$tonCO_2$).

How to build the MAR curve?

First, the user has to select the year for which the scenario has to be built. Then, to build the MAR curve, the user has to press the "Create Abatement Revenue Curve" button in the Graph sheet.

Above the "Create Abatement Revenue Curve" button, the user will find some settings available to adjust the graph. They are used to ensure that the MAR curve created is readable and provides the necessary overview. If the user includes options that have a very small reduction impact (causing a very narrow expansion on the x-axis), or options that have a very low marginal cost (causing a very low expansion on the y-axis), the user can improve the graph appearance by changing the settings. By experimenting with the three values in the configuration chart (C22 to C24), the MAR curve can be modified to include only the most relevant options. If the "Include all options in graph with no thresholds" box is checked, then the MAR curve will be created with all the options included. In addition, to be able to read the names of all the options, the user can change the font size of the labels.

Two tables are shown below the graph of the MAR curve. The table on the left lists the mitigation options included in the chart. The table on the right lists the mitigation options excluded from the chart (due to the thresholds set up by the user).

How to read the MAR curve?

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 greenhouse gas emissions.

In the graph of the MAR curve made by GACMO, all the options which are located above the X-axis are "win-win" options. It means that their implementation would allow reducing the greenhouse gas emissions compare 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 also proportional to the total amount of greenhouse gas emissions reduced by the option.

4.4 Technology sheets

All the calculations made by GACMO in regards to the mitigation options and their references options are based on different default parameters already included in GACMO when a user download the GACMO tool from the UNEP DTU Partnership website. These default parameters are greenhouse gas emissions-related parameters as well as cost-related parameters.

All the default parameters included in GACMO are the results of average values for each parameter calculated from all the clean development mechanism (CDM) projects listed in the CDM pipeline (www.cdmpipeline.org).

A user can chose to run a GACMO process using these default parameters as they are good average representation of all the parameters. However a user may choose to modify some of these parameters by using country specific values for these parameters. By doing so, the user will increase the precision

of the calculations and thus the precision of the results and projections made by GACMO in regards to the specific context of the user´s country.

All the parameters related to the mitigation options and reference options are summarized in tables which are found in the "Technology" sheets.

GACMO includes 26 spreadsheets called the Technology sheets. There is one spreadsheet for each type of mitigation options as defined also in the CDM pipeline. The 26 spreadsheets are in alphabetical order. Each spreadsheet corresponds to a type of mitigation options (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 one below the other. It has to be noted that for one mitigation option, there may be different tables for 2020, 2025, 2030, and 2050 next to each other.[11]
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 entries 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 greenhouse gas emissions calculations with a column for the mitigation option, a column for the reference option and a column with the greenhouse gas reduction achieved by implementing the mitigation option compared to the reference option (that is, the difference between the mitigation scenario and the reference scenario).
• The last line in the left part of the table is the average abatement cost expressed in US$ / ton CO_2-eq.
• The right part of the table includes all the entries for the parameters needed to make the greenhouse gas emissions calculations and the costs calculations.

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[11] 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 DTU Partnership and we will try to include the missing option.

✓ 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 includes technical parameters and unit costs.

✓ The lower right part of the table shows all the entries for the reference option. These entries includes technical parameters and unit costs.

• At the bottom of each table, there are some notes providing some details about the option (if applicable), or giving some literature references where additional information about the option can be found and from where the entries of some parameters have been found. The user will see that a lot of time, the references are related to the CDM projects used to establish the default data.

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

4.5 MRV sheet - monitoring the effective implementation of the mitigation options

GACMO includes an "MRV" sheet. In this sheet, a user will be able to monitor the effective implementation of the different mitigation options and the resulting greenhouse gas emissions reduction. This sheet is thus used ex-post, that is, once the mitigation options have been implemented, to estimate and monitor the effective reductions of the GHG emissions.

For each mitigation option under implementation, the user will have to introduce the number of units which has been put in operation at the end of a specific year (column H to V). A user can thus follow the implementation of each mitigation option and monitor how many units have actually been installed. GACMO will then calculate the resulting greenhouse gas emissions reduction for each mitigation option and shows the accumulated greenhouse gas emissions reduction achieved through the implementation of the different option (column W).