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Mitigation-Inventory Tool for Integrated Climate Action (MITICA)

User Manual Version v.6

User Manual of MITICA: a Mitigation-Inventory Tool for Integrated Climate Action

Report details

User Manual of MITICA: a Mitigation-Inventory Tool for Integrated Climate Action

Presented by

Gauss International Consulting S.L.

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Table of content

ACRONYMS

AFOLU	Agriculture, Forestry, and Other Land Use
CRT	Common Reporting Tables.
ETF	Enhanced Transparency Framework
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
MACC	Marginal Abatement Cost Curves
MPGs	Modalities, Procedures and Guidelines
NDC	Nationally Determined Contributions
PAMs	Policies and Measures
UNFCCC	United Nations Framework Convention on Climate Change
WAM	With Additional Measures scenario, encompassing implemented, adopted and planned policies and measures.
WEM or WM	With Measures scenario, encompassing currently implemented and adopted policies and measures.
WOM	Without Measures Scenario, excluding all policies and measures implemented, adopted and planned after the year chosen as the starting points for the projection.

BASIC DEFINITIONS

Definitions are provided by the authors based on the following sources:

- IPCC Glossary, available at: https://www.ipcc.ch/sr15/chapter/glossary/
- Modalities, Procedures and Guidelines (MPGs) of the Enhanced Transparency Framework (ETF) of the Paris Agreement, available at: https://unfccc.int/documents/184700

Mitigation (of climate change): A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

Model: A model is a structured representation of a system, designed to abstract and simulate the essential features, relationships, and dynamics of the real-world system. It can be expressed through mathematical equations, computational algorithms, conceptual frameworks, or a combination thereof. Models can be used to project future values of any variable, including GHG emissions and other indicators (energy demand, energy supply, forest growth, etc.).

Projections: Estimation of future GHG emission levels under different GHG policy scenarios. In the MPGs, projections are referred to as "*indicative of the impact of mitigation policies and measures in future trends in GHG emissions and removals*".

Policy scenarios or Mitigation scenarios: This term encompasses the Without Measures Scenario (WoM), the With Measures Scenario (WeM) and the With Additional Measures Scenario (WaM). In the MPGs the following definitions are provided "*A 'with measures' scenario encompasses currently implemented and adopted policies and measures. If provided, a 'with additional measures' scenario encompasses implemented, adopted and planned policies and measures. If provided, a 'without measures' projection excludes all policies and measures implemented, adopted and planned after the year chosen as the starting points for the projection*.".

Mitigation Policies and Measures (PAMs): This term includes all types of actions, measures and policies that reduce GHG measures. The MPGs provide the following definition "*Each Party shall provide information on actions, policies and measures that support the implementation and achievement of its NDC under Article 4 of the Paris Agreement, focusing on those that have the most significant impact on GHG emissions or removals and those impacting key categories in the national GHG inventory*."

Mitigation targets: This term refers to specific objectives related to reductions in GHG emissions in a given emission source(s), sink(s) or sector(s), for one or several gases for a given geographical scope and a reference period. When these targets encompass all sectors of the economy, they are named as economy-wide targets. Different metrics and references can be used to define targets. In article 4 of the Paris Agreement, specifies that "Developed country Parties should continue taking the lead by undertaking economy-wide absolute emission reduction targets. Developing country Parties should continue enhancing their mitigation efforts, and are encouraged to move over time towards economy-wide emission reduction or limitation targets in the light of different national circumstances.". Furthermore, article 64 of the MPGs specify that "*Each Party shall provide a description of its NDC under Article 4, against which progress will be tracked. The information provided shall include the following, as applicable, including any updates to information previously provided: (…) (a) Target(s) and description, including target type(s) (e.g. economy-wide absolute emissions reduction, emissions intensity reduction, emissions reductions below a projected baseline (…) (b) Target year(s) or period(s), and whether they are single-year or multi-year target(s); (c) Reference point(s), level(s), baseline(s), base year(s) or starting point(s), and their respective value(s); (d) Time frame(s) and/or periods for implementation; (e) Scope and coverage, including, as relevant, sectors, categories, activities, sources and sinks, pools and gases; (…)*"

Proxy: a variable that is believed to be correlated with the variable of interest (i.e. GHG emissions). Changes in the proxy variable are expected to reflect changes in the variable of interest, implying causality. Causality refers to the theoretical relationship between variables and the direction of influence between them. Spurious relationships refer to cases where there is correlation but not causality.

National modelers: in this manual, the term national modelers is used to refer to practitioners aiming to use MITICA to develop mitigation scenarios.

Ex-post and Ex-ante assessment: PAMs can be assessed before implementation (ex-ante) or after implementation (ex-post). While the assessment methodologies are the same, the data used is different (observed versus expected data).

1. Background and purpose

The Mitigation-Inventory Tool for Integrated Climate Action (MITICA) is designed to assist Parties to the Paris Agreement in developing greenhouse gas (GHG) emission projections in different mitigation scenarios, based on their national GHG emission inventories. MITICA recognizes the crucial role of a comprehensive national GHG inventory as the cornerstone for evaluating national mitigation efforts. By utilizing a robust national GHG inventory, MITICA empowers policymakers with consistent emissions projections, informing the definition and tracking of national mitigation targets, including those outlined in Nationally Determined Contributions (NDCs).

One of MITICA's key objectives is to enhance the capacity of developing countries to develop GHG emission projections in different mitigation scenarios. MITICA builds upon existing knowledge, methodologies, and approaches for inventory compilation, leveraging the IPCC software to augment existing emission compilation capabilities. By synergizing the national inventory and the IPCC software, MITICA provides a solid foundation for developing GHG emissions projections.

The development of MITICA was spearheaded by a team of highly specialized experts in GHG emission inventories, modelling, and climate change mitigation. This team also created an accompanying manual to guide users in effectively utilizing the tool. Additionally, a peer-reviewed publication was developed, offering comprehensive insights into the methods and approaches employed in developing the tool.

From a common methodological framework for all IPCC sectors, MITICA design nationally specific models by IPCC category considering the data inputted into the software, which consist in the national GHG inventory and a set of socioeconomic and sectoral drivers. Through machine learning ensemble approaches, the model with highest accuracy by IPCC category is used to project GHG emissions by IPCC category in a baseline emission scenario known as the Without Measures (WoM) Scenario. Building upon this baseline, users have the flexibility to define a set of Policies and Measures (PAMs) and incorporate them into the tool to create mitigation scenarios to assess GHG emission levels considering the impact of these PAMs. This approach enables the creation of With Measures (WeM) and With Additional Measures (WaM) scenarios, facilitating reporting under the Paris Agreement. These scenarios play a crucial role in tracking the progress of NDCs and determining the level of ambition within them.

To ensure consistency in GHG emissions calculation across both historical and projected periods, MITICA employs the same methodology utilized in the national inventory, as defined by the reference national inventory, and estimated using the IPCC software. Furthermore, the tool offers users the flexibility to project emissions using various state-of-the-art econometric techniques, enhancing the robustness of the emission projections.

MITICA provides users with the capability to calculate diverse mitigation scenarios by allowing customization of the list of PAMs integrated in each scenario. This feature enables the assessment of individual and combined impacts of different PAMs, empowering users to tailor the scenarios to their specific context and requirements. All inventory sectors outlined by the IPCC Guidelines, including Energy, Industrial Processes and Product Use (IPPU), Waste, and Agriculture, Forestry and Land Use Change (AFOLU), are considered within these scenarios. MITICA offers a set of generic PAMs applicable to these sectors, while also accommodating the inclusion of national-specific PAMs, expanding the tool's versatility. Figure 1 shows the simplified data flow for creating GHG mitigation scenarios within MITICA.

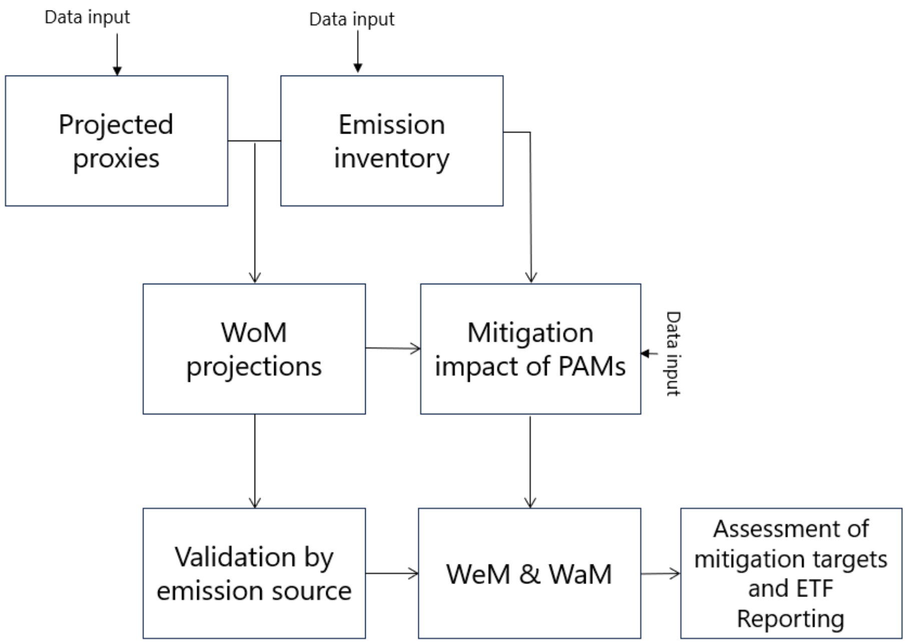


Figure 1. Simplified data flow for creating projected GHG emission scenarios in MITICA

In alignment with the Enhanced Transparency Framework of the Paris Agreement and its Modalities, Procedures, and Guidelines, MITICA adheres to the highest standards of transparency and accountability.

Overall, MITICA is a comprehensive and user-friendly tool that equips Parties to the Paris Agreement with the necessary resources to develop mitigation scenarios, evaluate mitigation strategies, and contribute effectively to global climate action.

2. Getting started with MITICA.

Obtaining the MITICA software requires the submission of an application form to the United Nations Framework Convention on Climate Change (UNFCCC) for review and approval. The application form will require the following information:

Name: The name of the individual who will be using the application
Country: The country where the tool will be used.
Organization: The name of the organization for which the individual is employed
Type of Organization: Government, Public institution, NGO, Private sector, Research institution.
Position: The individual's position within the organization
Purpose and objective: A detailed explanation of the reasons for using the MITICA tool, including the specific IPCC database that will be used. A minimum of 300 words is required.
Expected date of use: the date in which the tool will be put into use.
Expected outcomes: the expected outcome from the use of the tool.
Previous experience with IPCC software: if the applicant already has access to IPCC software, what has been their experience with it.
Previous experience and capacity in GHG emission inventories: A description of the applicant's previous experience in developing national GHG emission inventories.
E-mail: The corporate e-mail that will be used to receive the MITICA tool.
Phone: The individual's phone number. Please note that this may be used for verification purposes.

The application form and further details on MITICA are provided at the following web page: https://gauss-int.com/MITICA

Once the application has been approved, the applicant will receive a zip file containing the following three files: "MITICA_vX.X_CONSOLE[1]", "UUID_Finder" and "Password_Creator".

The first step will be to run the file "UUID_Finder" and send the UUID to mitica@gauss-int.com. The applicant will receive an e-mail within five working days, granting permission to install MITICA in your computer. Once permissions are granted, the file

[1] The file of the name will include the number of the latest version of the software.

"Password_Creator" needs to be used to create a password that will be used in the MITICA tool. Now, the file "MITICA_vX.X_CONSOLE" can be opened. In the user desktop, this file will be shown as an application icon, as illustrated in Figure 2.

Figure 2. Desktop icon of the application

The password should be entered on the first page of the application, and to proceed to the home page, click on 'GO!

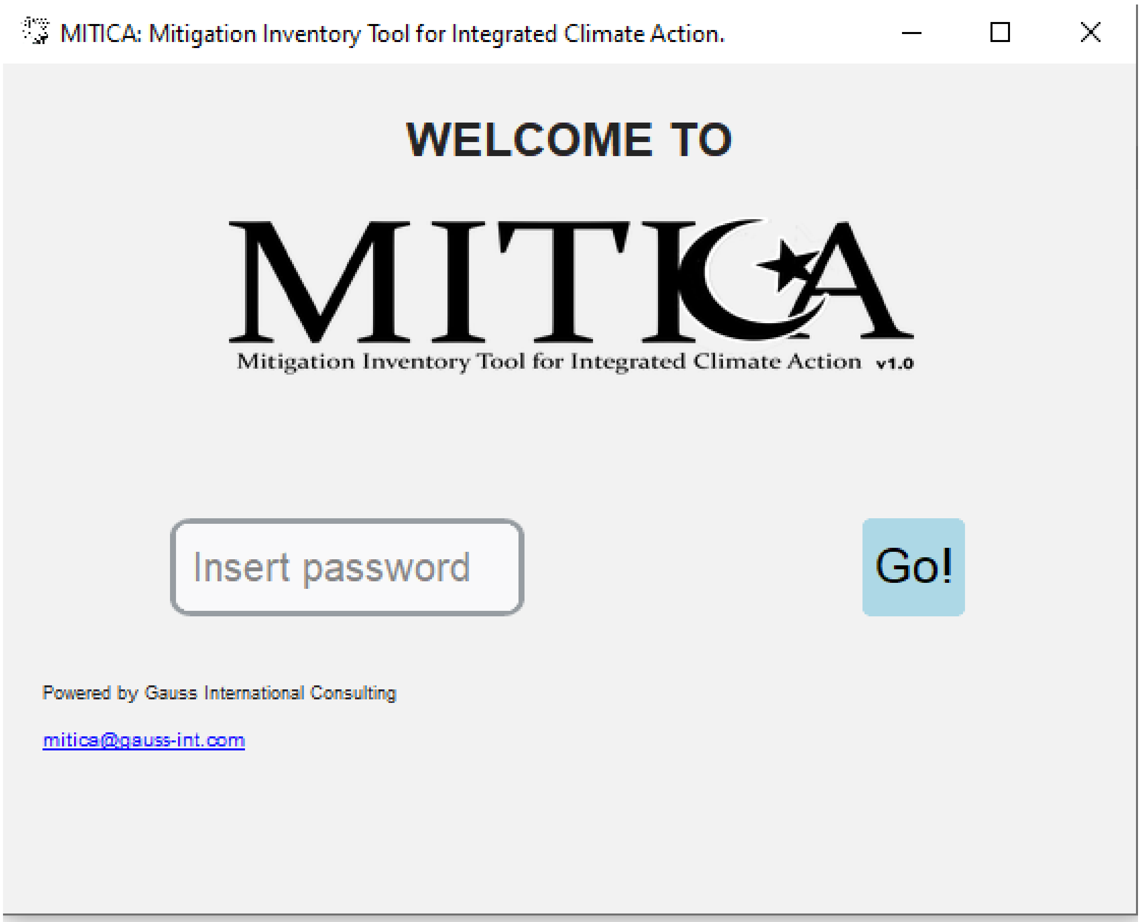


Figure 3. Password page of the application

The application will display the home page of the tool, featuring a list of steps and icons used for creating mitigation scenarios. No installation is required. This manual provides guidance on using every function of the application to produce mitigation scenarios, including a list of Policies and Measures (PAMs). The IPCC inventory software's database (.mdb file or .accdb) is required as input to create mitigation scenarios in MITICA. MITICA is compatible with version 2.85 of the IPCC Software[2]. Previous versions of the IPCC inventory software need to be upgraded in order to use MITICA. Please refer to the User Manual of the IPCC Software for additional information.

2.1. Handling data in MITICA

The 'MITICA Results' folder will be created in the same location where MITICA is stored. For example, if you store the file on your desktop, the 'MITICA Results' folder will be created and displayed on your desktop. All information added to MITICA will be stored within this folder, utilizing files with the ".pickle" extension to store information from different steps of the process.

When opening MITICA, the tool will prompt you to resume your work from where you left off, displaying a pop-up window on the homepage (figure 4).

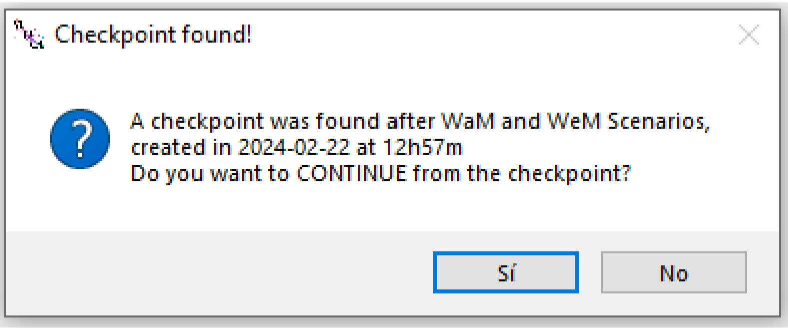


Figure 4. Checkpoints in MITICA

Collaborating with other MITICA users requires sharing the entire 'MITICA Results' folder, which needs to be stored in the same location as the file 'MITICA_vXX_CONSOLE' within the computer. See section "Collaborative work" for further information on how to share files among national modelers.

[2] https://www.ipcc-nggip.iges.or.jp/software/index.html

2.2. Home page

Figure 5 presents the tool's homepage, showcasing a comprehensive list of its components. This visual overview enables users to easily identify and access the various features and functionalities provided.

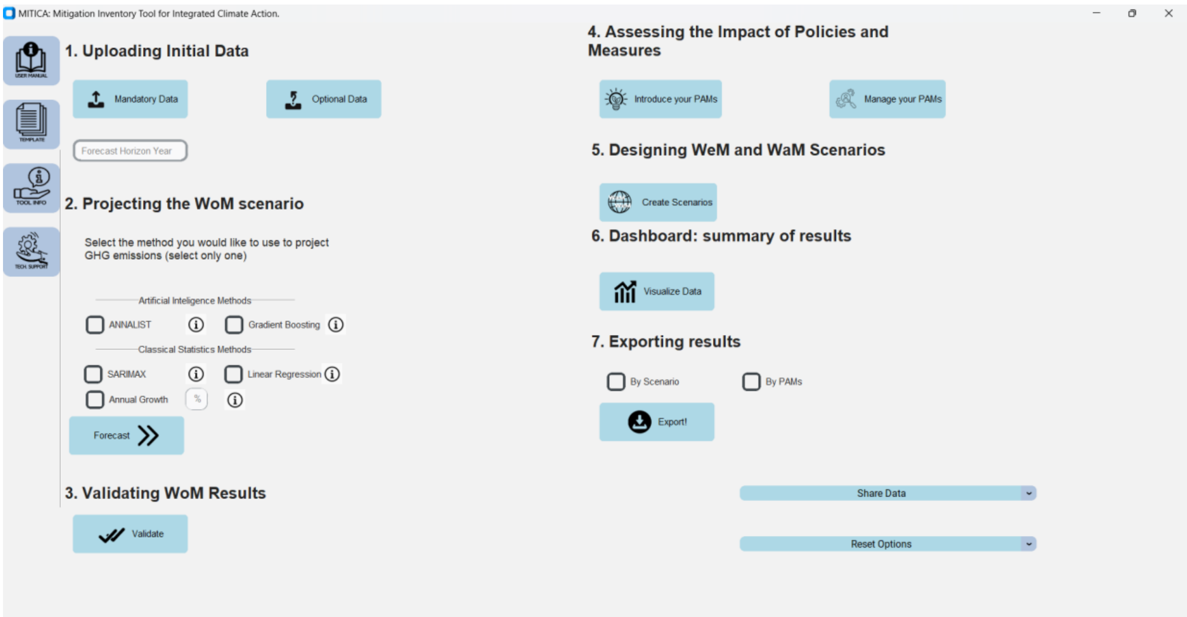
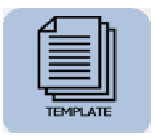


Figure 5. Home page

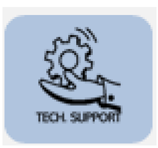
In the upper left side of the screen there are three buttons to:

Obtain the user Manual. Click on the icon to download.



Obtain the Excel templates for uploading inventory data (only in cases where the IPCC software is not used).

Check the tool information, including its version and other relevant information.



Obtain tech support. Click to display the contact information of support.

MITICA is designed following a step-by-step approach to facilitate the generation of mitigation scenarios. It encompasses a comprehensive set of steps that must be followed to obtain consistent results. As shown in Figure 5, these steps are prominently displayed in the central section of the home page, providing users with a clear overview. The following section presents a detailed description of each step included in the tool.

2.3. Step-by-step guide

2.3.1. Uploading initial data

To upload the information on the reference GHG emission inventory and existent proxies for generating mitigation scenarios. Two buttons are displayed:

- **Mandatory Data**. This requires information on the reference national GHG inventory, either from the IPCC software or excel template, and two main proxies: Gross Domestic Product (GDP) and population. Mitigation scenarios will not be created without this information.
- **Optional Data**. This requires additional proxies by IPCC sector. If proxies are available at national level, they can be uploaded into MITICA to support the GHG emission projections.

When clicking “Mandatory data”, a new window will be displayed for uploading inventory information, the GDP series and population as shown on Figure 6.

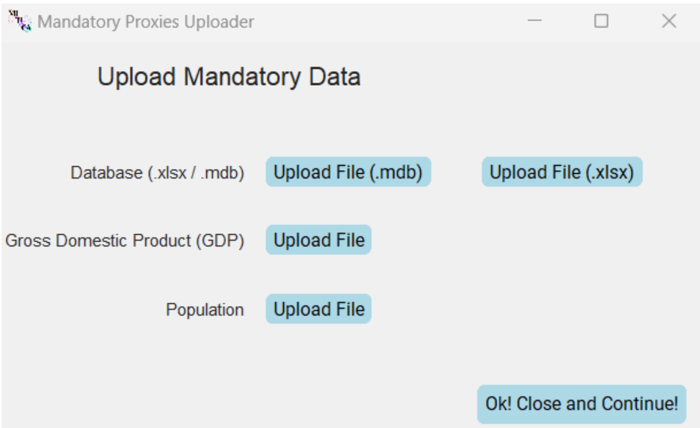


Figure 6. Mandatory data Uploader

Furthermore, together with mandatory data, information on the **Forecast Horizon year** is required. The user shall introduce in the box (figure 7) the desired last year of projections (for instance 2030 or 2050). The mitigation scenarios will be estimated from the latest inventory year[3] up to this year.

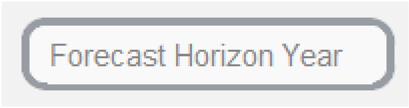


Figure 7. Forecast horizon year

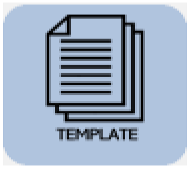
Uploading inventory data using the IPCC software

In this option, a national GHG inventory needs to be estimated in the IPCC software following the principles and methodologies outlined by relevant IPCC guidelines. Once the inventory is estimated, it is important to export the .accdb file from the IPCC software without a password, allowing MITICA to access the database information. Detailed instructions on exporting the .accdb file from the IPCC software without a password can be found in the IPCC User Manual, provided within the software. For assistance with difficulties downloading the IPCC Software Manual, please contact ipcc-software@iges.or.jp.

At the time of writing this manual, the IPCC Software was undergoing major revisions to ensure compatibility with ETF tables and reporting tools. Therefore, it is advisable at this moment to consider the second option: uploading the inventory data using the Excel template described herein.

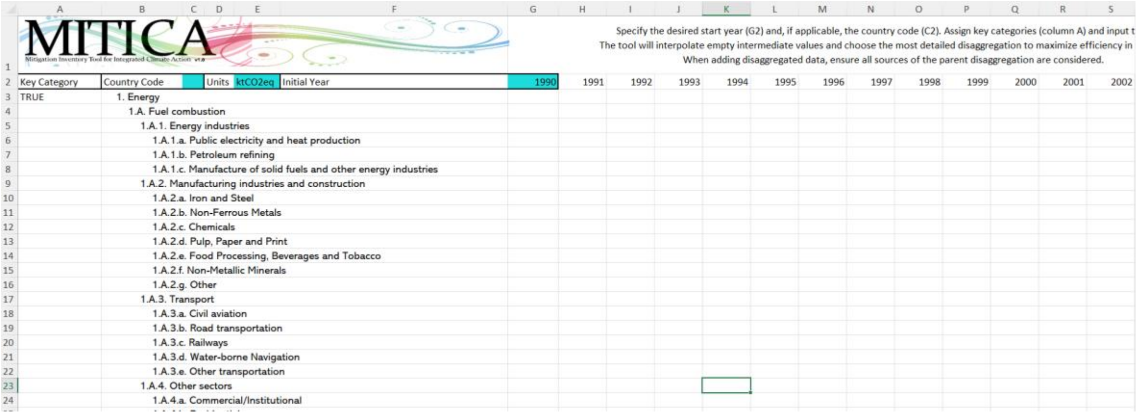
Uploading inventory data using the Excel template

An excel template for uploading inventory data is provided by the tool, in the icons displayed in the upper left part of the tool.



The excel requires GHG emissions by CRT category (figure 8), for all years estimated by the inventory. Figure 8 shows the format of the excel template provided by MITICA.

[3] If users decide to start projections from a previous inventory year, the uploaded data on the national inventory shall include only up to the desired reference year. For instance, if the inventory available cover years 1990-2020, but the users require to start projections from 2015, data on inventory should cover only 1990-2015 years. Data on proxies should include 1990-2020 plus projected years.



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
MITICA Mitigation Inventory Tool for Integrated Climate Action v1.0							Specify the desired start year (G2) and, if applicable, the country code (C2). Assign key categories (column A) and input t The tool will interpolate empty intermediate values and choose the most detailed disaggregation to maximize efficiency in When adding disaggregated data, ensure all sources of the parent disaggregation are considered.											
Key Category	Country Code		Units	ktCO2eq	Initial Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
TRUE	1. Energy																	
	1.A. Fuel combustion																	
	1.A.1. Energy industries																	
	1.A.1.a. Public electricity and heat production																	
	1.A.1.b. Petroleum refining																	
	1.A.1.c. Manufacture of solid fuels and other energy industries																	
	1.A.2. Manufacturing industries and construction																	
	1.A.2.a. Iron and Steel																	
	1.A.2.b. Non-Ferrous Metals																	
	1.A.2.c. Chemicals																	
	1.A.2.d. Pulp, Paper and Print																	
	1.A.2.e. Food Processing, Beverages and Tobacco																	
	1.A.2.f. Non-Metallic Minerals																	
	1.A.2.g. Other																	
	1.A.3. Transport																	
	1.A.3.a. Civil aviation																	
	1.A.3.b. Road transportation																	
	1.A.3.c. Railways																	
	1.A.3.d. Water-borne Navigation																	
	1.A.3.e. Other transportation																	
	1.A.4. Other sectors																	
	1.A.4.a. Commercial/Institutional																	

Figure 8. Excel template for uploading inventory data

Column A requires specification of the key categories in the inventory. This allows MITICA to identify the more relevant emission sources and sinks for the country, as well as determine the PAMs affecting these key categories.

In Column B, the template displays the Common Reporting Tables (CTR) categories of the inventory, following the reporting templates available at https://unfccc.int/documents/311076. It is important to note that the 2006 IPCC categories differ slightly from the CRT categories. A mapping between the 2006 IPCC categories and CRT is provided by the UNFCCC at this link: https://unfccc.int/documents/634242 .

In cell G2 of the template, specify the first year of the reference inventory. Subsequently, provide GHG emissions (in kt CO2-eq) by CRT category. The selection of the disaggregation level is crucial for MITICA, as the projection models are specified at the most disaggregated level. When adding disaggregated data, ensure that all sources of the parent disaggregation are considered. For example, if the inventory allocates emissions for sub-categories 1A1a, 1A1b, and 1A1c that do not occur in the country, national modelers should provide data for categories 1A1a and 1A1b, and optionally, 1A1. If emissions are reported for either 1A1a or 1A1b, MITICA will calculate the emissions of 1A1 as the sum of these two categories. Therefore, if a certain level of disaggregation is provided, ensure that the disaggregated emissions add up to the parent category; in our example, category 1A1. If, for a given CRT category, the emissions for a given year are missing, MITICA will interpolate the emissions.

Uploading Mandatory proxies

Regarding the format for uploading the GDP and population series, one excel file by variable is needed, including in the first column the year and in the second column the value of the indicator, as shown in Figure 9. The first row should indicate "year" and the name of the indicator, to be defined by the user.

	A	B
1	Year	GDP
2	2010	100
3	2011	101
4	2012	102
5	2013	103
6	2014	104
7	2015	105
8	2016	106
9	2017	107
10	2018	108
11	2019	109
12	2020	110
13	2021	111
14	2022	112
15	2023	113
16	2024	114
17	2025	115
18	2026	116
19	2027	117
20	2028	118
21	2029	119
22	2030	120

Figure 9. Format to include information of proxies in Excel files

The following elements shall be considered for the GDP and population, as well as for other optional proxies:

- The time series shall contain, at least, the latest year estimated by the inventory, and all the projected years up to the projection horizon year (figure 7). Note that the projection horizon year must be introduced in step 1, and all proxies provided shall reach this year.
- It is recommended to provide the longest possible time series available (possibly starting in 1990, and up to the latest projection year) to improve the projection accuracy.
- The time series consistency of the indicator provided is essential. The user shall verify that the time series provided is estimated following the same methodology and has the same scope, without breaks in the time series. MITICA accepts any

type of unit[4]. The only requirement is that the values for all years have the same units and there are no breaks in the time series.

Once the information is entered a message in green will be displayed, the users can then click "Ok! Close and Continue" (see Figure 10).

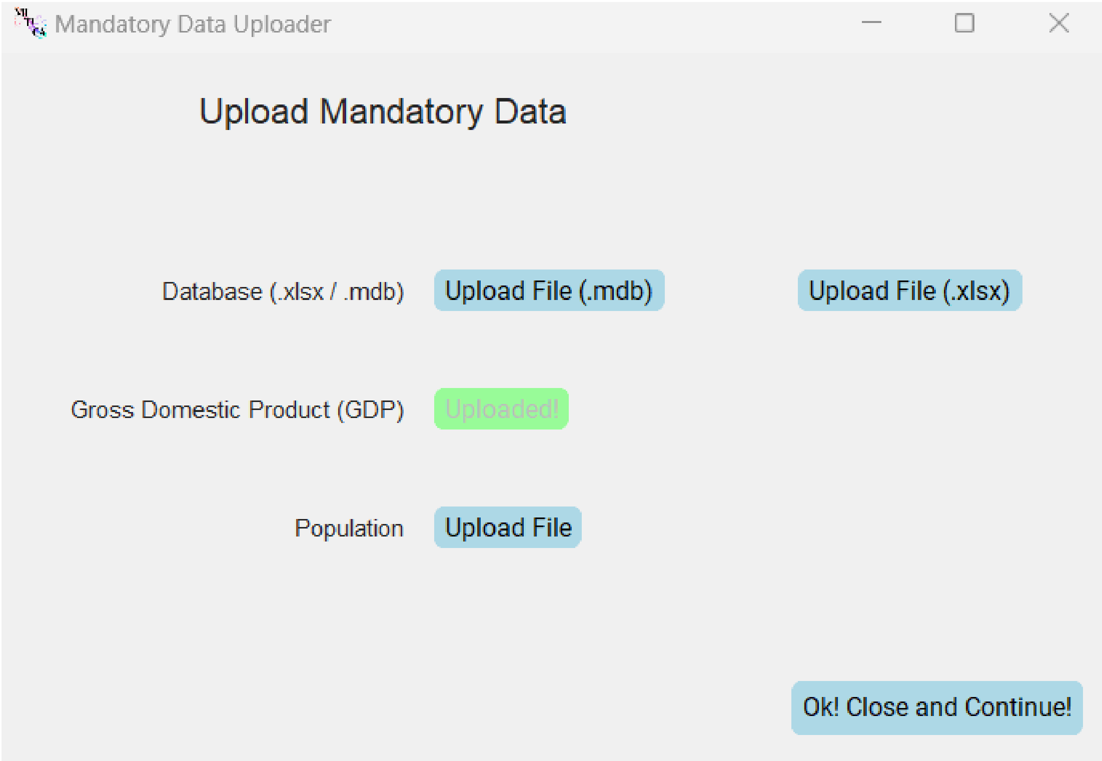


Figure 10. Close and Continue

The button "Optional Data" provides the possibility to upload sectoral proxies to be used by MITICA in the projection of sectoral GHG emissions (figure 11).

[4] The modelling approach of MITICA convert data into time series of growth rates, representing the interannual change of each variable.

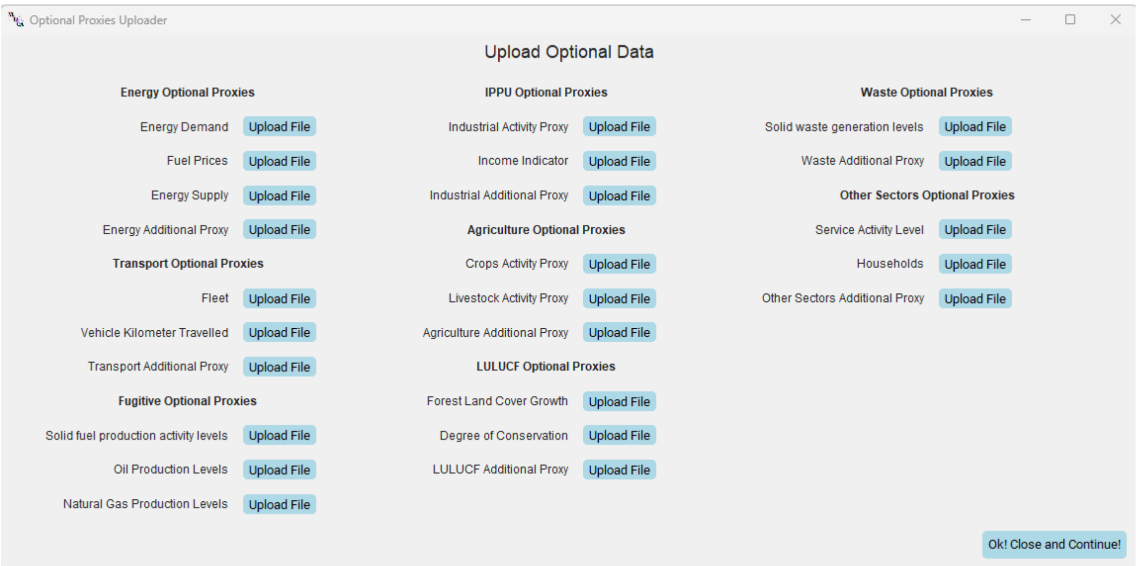


Figure 11. Upload Optional Data

MITICA is programmed to consider several proxies by CRT category in the estimation process. Following the general approach described in section 3 below, MITICA will design the best possible model for projecting the emissions of each category. It will take into account the characteristics of the uploaded data and its statistical results, ensuring that classical model specification problems[5] do not occur in the model. This includes addressing multicollinearity and heteroscedasticity issues in the category-specific models and their associated data. The following are the proxies allowed by sector:

Energy optional proxies:

- Energy demand: indicator of the overall demand for energy.
- Fuel prices: indicator on the price level of fuels.
- Energy supply: indicator on the overall supply of energy.
- Energy additional proxy: an additional proxy for energy that could be defined at the national level if considered relevant and not included in the list of optional sectoral proxies.

Transport optional proxies:

- Fleet: indicator of the total number of vehicles in use.

[5] For further information on these problems for classical regression models, see, for instance, this reference: https://es.scribd.com/document/482561862/Chapter-4-Violations-of-the-assumptions-of-Classical-Linear-Regression-models

- Vehicle kilometre traveled: measures the total distance traveled by vehicles.
- Transport additional proxy: an additional proxy for transport that could be defined at the national level if considered relevant and not included in the list of optional sectoral proxies.

Fugitive optional proxies:

- Solid fuel production activity levels: represents the activity levels related to solid fuel production.
- Oil production levels: describes the levels of oil production.
- Natural gas production levels: indicates the levels of natural gas production.

IPPU optional proxies:

- Industrial activity proxy: indicator of industrial activity.
- Income indicator: indicator on national average income levels.
- Industrial additional proxy: an additional proxy for industrial activities that could be defined at the national level if considered relevant.

Agriculture optional proxies:

- Crops activity proxy: Represents the activity levels related to crop production.
- Livestock activity proxy: describes the activity levels related to livestock population.
- Agriculture additional proxy: An additional proxy for agriculture that could be defined at the national level if considered relevant.

LULUCF optional proxies:

- Forest land cover growth: Indicator of changes in forest land cover.
- Degree of conservation: indicator on the degree of conservation efforts in land use.
- LULUCF additional proxy: an additional proxy for LULUCF that could be defined at the national level if considered relevant.

Waste optional proxies:

- Solid waste generation levels: proxy on the levels of solid waste generation.
- Waste additional proxy: an additional proxy for waste that could be defined at the national level if considered relevant.

Other sectors optional proxies:

- Service activity levels: any indicator of the average activity levels in the service sector.
- Households: indicator of the evolution of the household size.

Other sectors additional proxy: An additional proxy for other sectors that could be defined at the national level if considered relevant**.**

The provided proxies must respect the following three-fold criterion:

- ✓ For each proxy, the units of all years provided must be consistent. Indeed, the time series consistency of the indicator provided is essential. The user shall verify that the time series provided is estimated following the same methodology and has the same scope, without breaks in the time series. MITICA accepts any type of unit6. The only requirement is that the values for all years have the same units and there are no breaks in the time series.
- ✓ For each proxy, the time series provided must be annual, and must cover all years of the inventory and projections. For instance, if we use a GHG inventory covering years 2010-2020, and we want to project until 2030, the proxies provided must cover the period 2010-2030. The years for which statistics are available, in our example 2010-2020, shall use reliable statistics. For the projected years, official forecasts from sectoral planning exercises shall be prioritised. Central Banks and national agencies often perform specific modelling exercises for national accounts or other economic aggregates. Likewise, sectoral entities and agencies often perform sectoral planning exercises. Compiling all national forecasts available would benefit the modelling performed under MITICA.
- ✓ Proxies should depict the evolution of the economy and sectors without accounting for the influence of policies and measures. In cases where such projected forecasts are unavailable, national modelers can estimate a realistic business as usual macroeconomic framework for the modelling exercise. Conducting sensitivity analyses for this framework would be beneficial.

[6] The modelling approach of MITICA convert data into time series of growth rates, representing the interannual change of each variable.

Ensuring internal coherence among proxies

Proxies can be internally related. For example, if there is an increasing trend in GDP and a decreasing trend in population for the projected years, it suggests a potential inconsistency between proxies. While MITICA only selects proxies that statistically demonstrate an impact on the given CRT emissions, the overall quality of estimates would significantly improve if all provided proxies are consistent with each other.

This represents the finalisation of step 1. After this step, and every step thereafter, MITICA will automatically save the session to prevent data loss. When you resume your session, MITICA will detect the latest available version and display a message accordingly (figure 12).

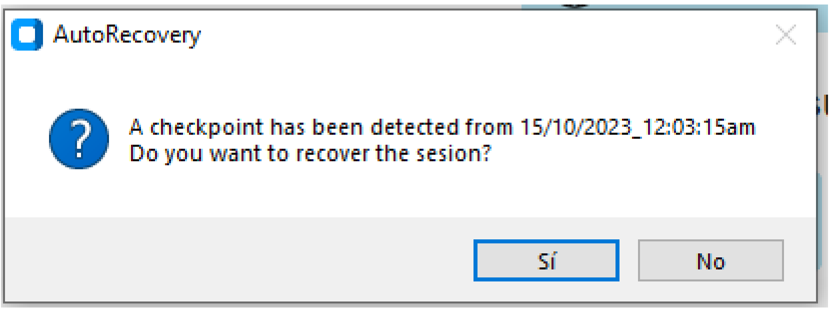


Figure 121. Resuming previous sessions

2.3.2. Projecting the WoM scenario.

The Without Measures (WoM) scenario represents the initial emission scenario developed in the tool. The WoM projects emissions of the national inventory using an Hybrid Model that integrates artificial intelligence method with classical econometric approaches named Artificial iNtelligeNce And cLassIcal STatistics (ANNALIST). Furthermore, alternative projection methods are provided for QA/QC, sensitivity analysis and research purposes. National modelers are therefore required to select between methods (figure 16). The information icon shown together the name provides a description of the method directly in the tool (figure 13).

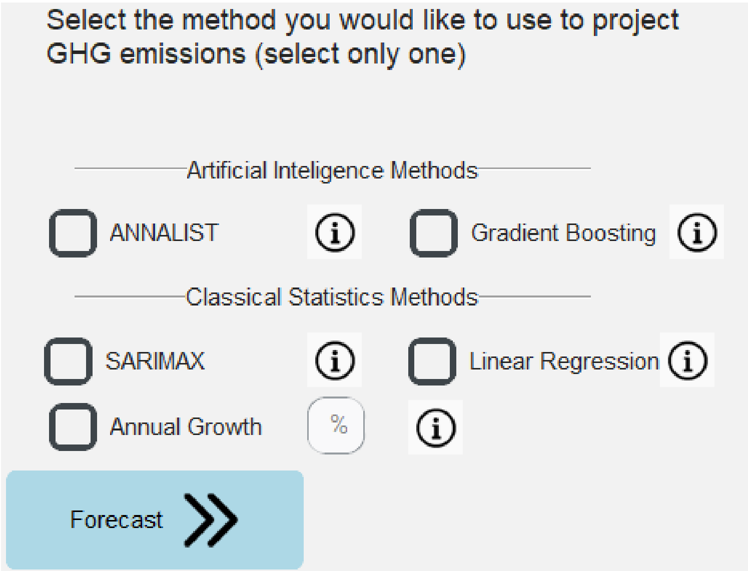


Figure 13. Projection Methods by MITICA

ANNALIST is recommended for more accurate results. The following table provides comments on the methodological choice for projecting the WoM scenario.

Table 1. *Methodological choice for projecting the WoM scenario.*

Method	Comment on methodological choice
ANNALIST	Annalist is a hybrid method that combines several machine learning techniques with classical approaches to define a best-fit model by source/sink category, define the hyperparameters of the models, calibre them and allow to train models specifically to the national data inputted into the software. It also ensures projection models meet classical requirements of regression models (such as heteroskedasticity, multicollinearity, non-stationarity, etc.). Computation speed is generally optimum.
Gradient Boosting	Gradient boosting is a well-recognised machine learning method widely used for forecasting GHG emissions. Computation speed is better than ANNALIST. This method is provided for comparative purposes (QA/QC), allowing to obtain a measure of the sensitivity of results to the method selected. The method included in MITICA is robust to the problems identified by classical regression models (such as heteroskedasticity, multicollinearity, non-stationarity, etc.).
Seasonal Autoregressive Integrated Moving Average with eXogenous factors (SARIMAX).	SARIMAX is probably the most advance classical method for estimating forecasts using exogenous factors. This method is provided for comparative purposes (QA/QC), allowing to obtain a measure of the sensitivity of results to the method selected. The method included in MITICA is robust to the problems identified by classical regression models (such as heteroskedasticity, multicollinearity, non-stationarity, etc.).
Linear regression	This alternative provides estimates made with the Generalised Least Square with Autoregressive Errors (GLSAR) algorithm. This method provides a more classical approach for developing projections. The method included in MITICA is robust to the problems identified by classical regression models (such as heteroskedasticity, multicollinearity, non-stationarity, etc.).
Annual growth	This allows to simply project GHG emissions by category using an annual growth rate applied since the latest inventory year. This method is not a model. Note that when selecting annual growth, an annual growth percentage must be indicated, or MITICA will obtain it from the GDP time series as an average annual growth.

Source: Martín-Ortega, J.L., Chornet, J., Sempos I., Akkermans, S., Lopez Blanco, M.J. (2024). Enhancing transparency of climate efforts: MITICA's Integrated Approach to greenhouse gas Mitigation. Pending to be published.

Only one approach can be selected at a time. Once one approach is selected, click on the button "Forecast" to obtain the WoM scenario. A pop-up will be displayed after that (figure 14).

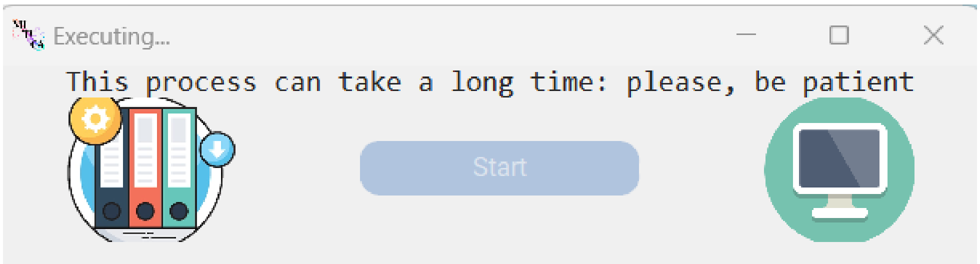


Figure 14. Forecasting in process pop-up

2.3.3. Validating the WoM scenario.

This section showcases the results of the WoM scenario across all the CRT categories of the national inventory. Users are asked to validate projections category by category and make any adjustments as necessary. The validation process stands as a pivotal phase in the development of the WoM scenario. The initial WoM is derived from the GHG emissions' time series for each CRT category and the sectoral proxies that have been uploaded. MITICA generates a best-fit model[7] for each category and then employs this model to project GHG emissions up to a chosen horizon year.

Nevertheless, it's crucial for users to verify the WoM results, making adjustments as needed. While MITICA's estimation is statistically grounded, it doesn't consider qualitative drivers that could influence the trajectory of each category. For example, it doesn't account for circumstances like the potential shutdown of all production plants within a category or the establishment of a certain activity level. Therefore, users should qualitatively evaluate if the projected emission levels seem feasible, given the current conditions surrounding a particular emission source or sink. For instance, MITICA might forecast a rising trend consistent with the historical progression of a specific emission source, even if present conditions, still not captured in the inventory, indicate a trend stabilization. In such cases, users are required to recalibrate their projections using the tools MITICA offers. On this note, MITICA furnishes users with several options to adjust

[7] The best-fit model is the one that is determined to be more effective in "explaining" the GHG emissions of the specified emission source/sink. It must also fulfil all the necessary statistical requirements for projection models.

projections. User would need to select an alternative projection method and save the results. MITICA requires users to navigate through all projected categories and validate the results to prevent spurious projections. Following good practice, MITICA instructs users to identify the driving forces behind the projections for each CRT category, pinpointing the primary reasons for the projected trends. To achieve this, users should utilize historical trends and the sectoral proxies uploaded in step 1.

It's essential to stress that any adjustments or interventions users implement must be meticulously documented, monitored and reported[8] to ensure complete transparency in the scenario results. Furthermore, users could reproduce the GHG emission results from other sectoral tools if this is considered relevant for the national circumstances.

MITICA's innovative approach designs one model for each CRT category using machine learning techniques, based on the information provided by national modelers for: i) GHG emissions and ii) sectoral proxies. Therefore, the model specification and the GHG projection of the WoM provided by MITICA builds from statistics and previous supervised training. It is therefore essential that **national modelers validate the results of the WoM scenario by source/sink category**.

To go to the validation, click on "Validate", after step 3 (figure 15).

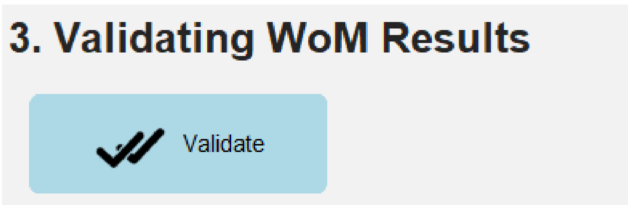


Figure 15. Validating WoM Results 1/4

In the validation screen, CRT categories can be explored by clicking in the right and left scroll signs (figure 16).

[8] The scenarios developed by MITICA aim at supporting countries to report under the UNFCCC. If that is the case, the transparency commitments under the UNFCCC advice a complete reporting of assumptions and, in the case, interventions done to calculate GHG emission projections.

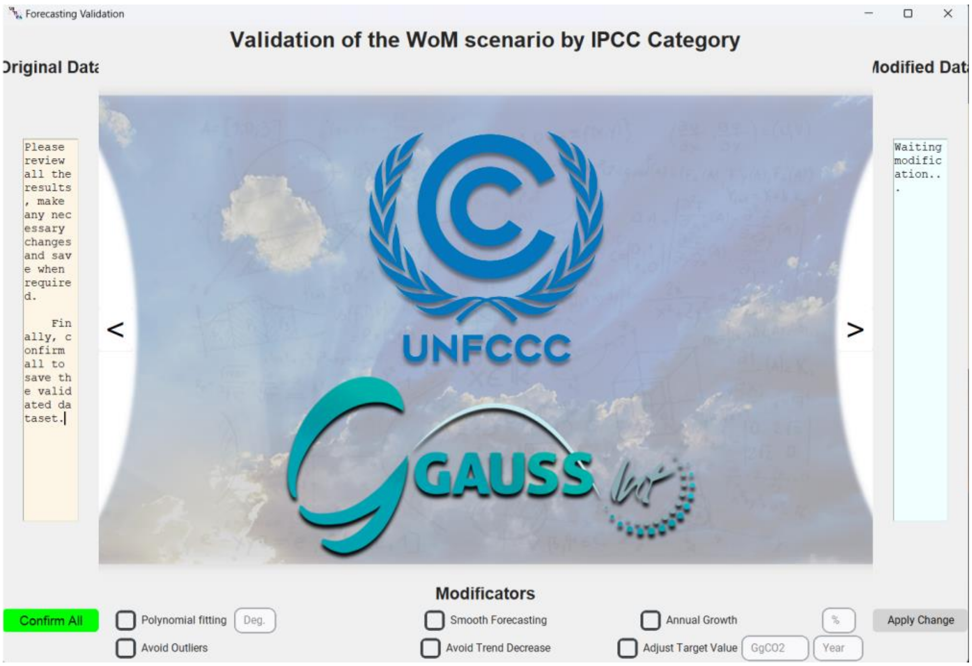


Figure 16. Validating WoM Results 2/4

The projected WoM will be displayed in the main validation screen. In the left menu, the original data can be consulted for easy reference (figure 17).

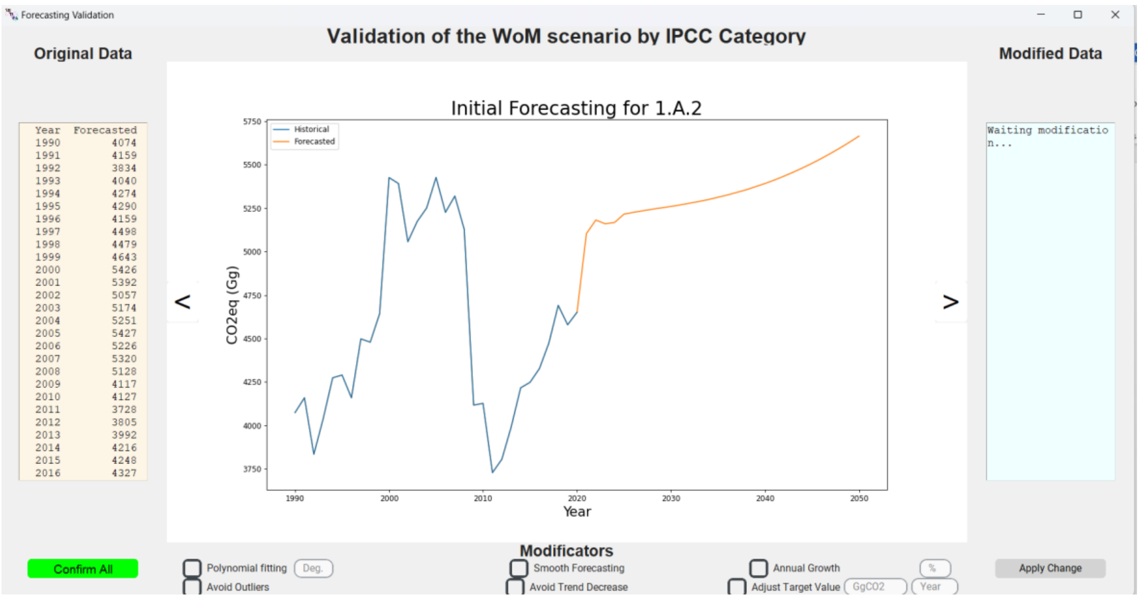


Figure 17. Validating WoM Results 3/4

In the bottom of the screen there are several methods to modify the initially projected WoM. To apply a change, users shall select the method and click in "apply change" to see the modified WoM. Once the WoM is validated, users shall click on "save change" (figure 18).

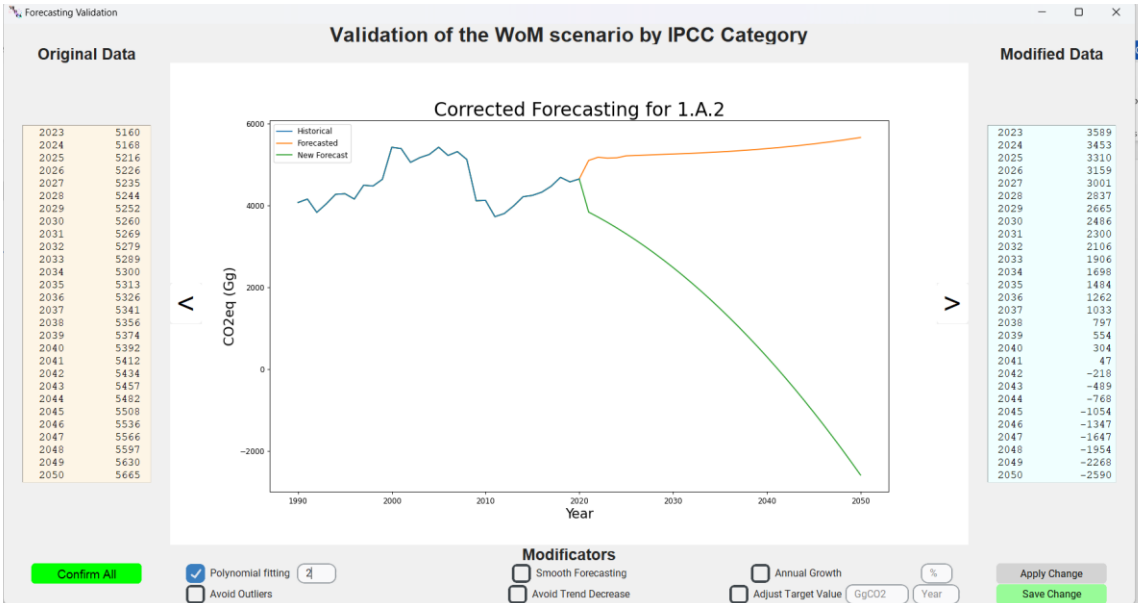


Figure 18. Validating WoM Results 4/4

Once all CRT categories are validated, click on "confirm all".

Why should WoM projections be validated?

The statistical validation is developed within MITICA[9], while the validation from national modelers shall carefully consider the following issues:

- **Identification of outliers.** Outliers or volatility in the historical period could derive in biased projections, specially when the time series provided is short (i.e. the inventory only have a few years). In this cases, national modelers shall identify outliers and remove them from the projected time series.
- **Identification of maximum/minimum values in the time series of GHG emissions**. The dynamics of certain emission sources or sinks include reaching maximum or minimum values, that are difficult to be surpassed due to the physical or technological boundaries of the source/sink. This can include limits in the land cover, or industrial processed that were recently decommissioned, while

[9] The model evaluation and the statistical robustness of the models is developed automatically within MITICA, ensuring that the models do not have statistical problems prior to forecasting.

the inventory does not yet reflect this issue. This type of situations requires qualitative interventions by national modelers to reflect reality.

- **Identification of structural changes in the historical time series that have not been adequately identified by the model**. Breaks in the time series are identified visually as the trend has sharp changes in the historical value, but the projection has not properly captured the break. National modelers shall pay special attention in detecting shifts between different regimes in the time series, where the model fails to capture transitions between distinct states or conditions.
- **Sudden Shifts:** Visualizing abrupt shifts in the forecast that do not align with historical trends or events. This may indicate the presence of unaccounted external factors affecting the time series.
- **Event Identification:** Spotting events or anomalies in the historical data that the model overlooks, leading to inaccuracies in the forecast. This could include sudden spikes, dips, or other irregularities.
- **Data Quality Issues:** Noticing unusual patterns that might be attributed to data quality problems, such as missing or erroneous data. Addressing these issues is crucial for maintaining the integrity of the model.

All below issues could involve the need to adjust the projected emissions for a given CRT category. A set of interventions are displayed below the main screen (figure 19):

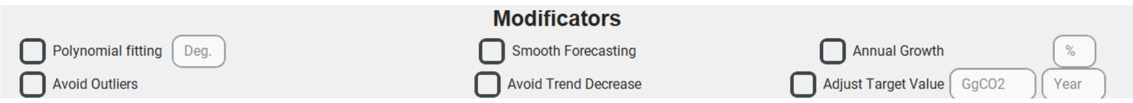


Figure 19. Recalculation of the WoM in MITICA

The following interventions are allowed within MITICA:

- **Polynomial Fitting**. Polynomial fitting in MITICA allows users to apply mathematical functions to represent data trends. National modelers have the flexibility to define the polynomial degree, providing a customizable approach to fit the model to the data.
- **Avoid Outliers**. This modifier helps in refining the model by excluding data outliers. It enhances the accuracy of the analysis by preventing unusual data points from unduly influencing the results.
- **Smooth Forecasting**. Smooth forecasting is a feature in MITICA that enables a more gradual and continuous prediction of future values. It helps to reduce the impact of short-term fluctuations, providing a more stable outlook.

- **Avoid Trend Decrease**. This modifier ensures that the forecasting model does not predict a decrease in trends, helping to maintain a positive trajectory over time. It is particularly useful for scenarios where a decline in values is undesirable.
- **Annual Growth**. Annual growth is a setting that allows users to incorporate a specified rate of growth into the model, reflecting a consistent increase in values over each year. This is beneficial for scenarios involving sustained growth patterns.
- **Adjust Target Value**. The adjust target value modifier allows users to fine-tune the desired outcome or goal. It provides a mechanism for national modelers to make necessary adjustments to target values based on specific considerations or requirements.

2.3.4. Assessing the impact of Policies and Measures.

Two main options are provided within step 4: "Introduce your PAM" or "Manage your PAMs", se figure 20.

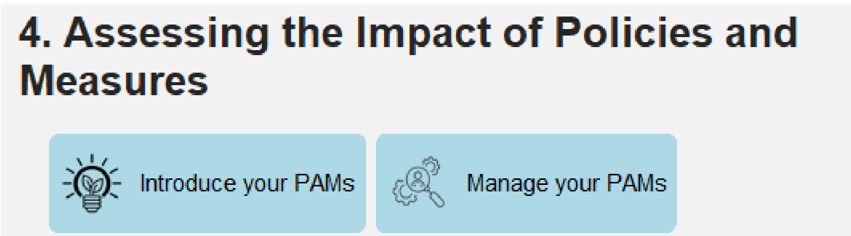


Figure 20. Assessing the impact of PAMs

The first action within this step consists of introducing the PAMs that national modelers require to consider within projections. It will be recommendable to define the list of PAMs and collect the required data before populating the data within MITICA. In line with MPGs, national modelers are recommended to prioritise the assessment of the main PAMs, affecting the key categories of the national GHG inventory. To obtain a full picture of the list of Policies and Measures available within MITICA, please consult Sections 4-7, 'PAMs'. It is important to note that MITICA provides default methodologies for more than 60 PAMs. Additionally, national modelers can add nationally specific PAMs within MITICA.

As a relevant note when inputting parameters in units of %, MITICA requires data to be entered as percentages and not as fractions (e.g., input 10% as 10, not as 0.1). Additionally, methodologies for all PAMs are related to inventory methodologies in the categories affected. For the full methodologies and background information, please consult [2006 IPCC Guidelines and its 2019 Refinement].

By clicking on “Introduce your PAM”, you will be redirected to the “PAM inserter screen” (figure 21).

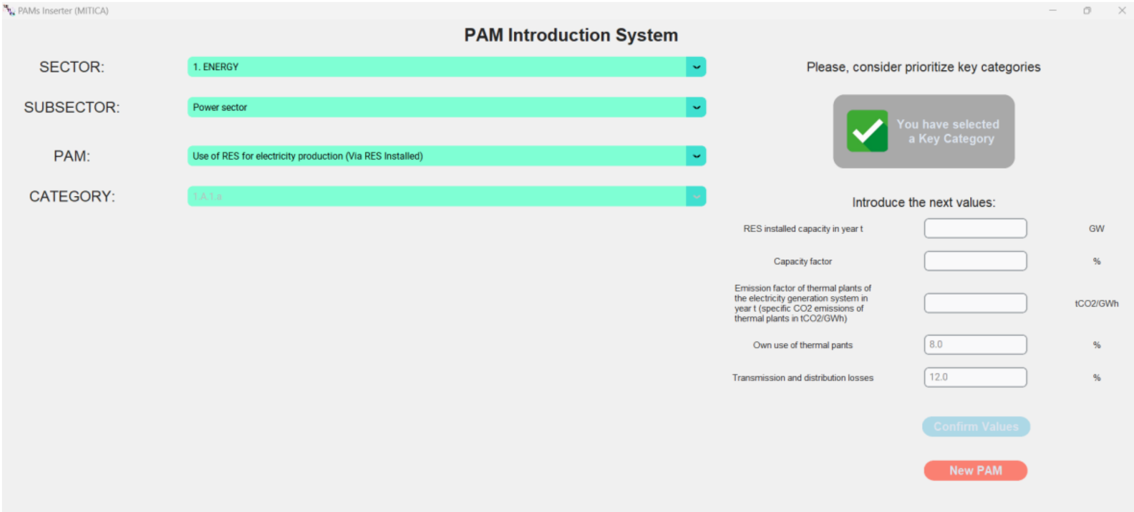


Figure 21. PAM inserter

PAMs are organized by sector, following the nomenclature of the IPCC Guidelines. Each subsector contains a list of PAMs, for which users need to define the magnitude and scope. National modelers shall select one PAM at a time, and introduce the data required for each PAM. Specific guidance for each PAM is provided in sections 4-7. Default parameters are provided in the relevant cells, but users are required to manually introduce the data to develop the estimations of the national policies and measures (figure 22). PAMs are nationally specific, so national modelers will need to collect the required data from national sources.

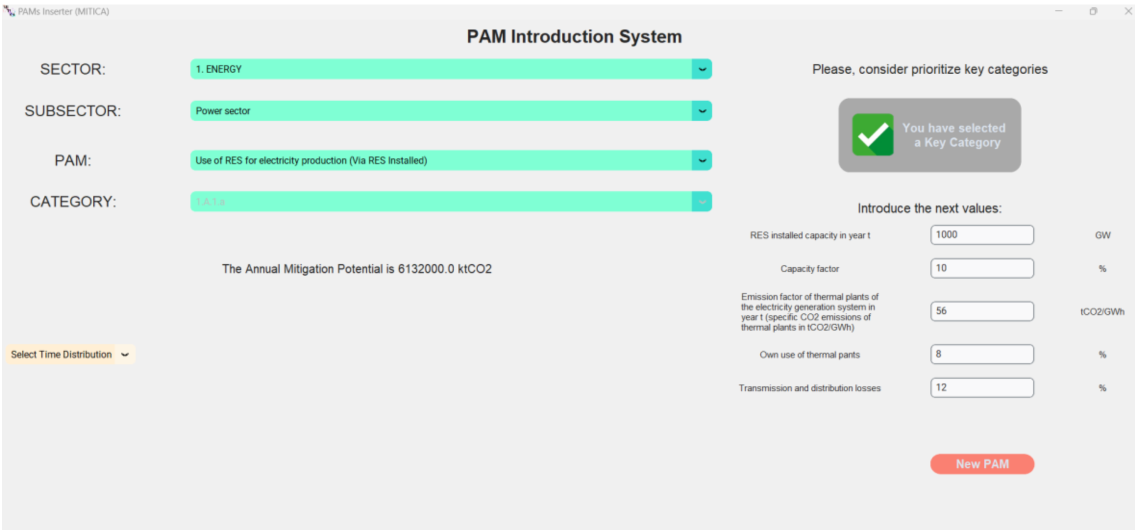


Figure 22. PAM inserter

Once the magnitude and parameters of a given PAM are populated within MITICA, the annual mitigation potential will be shown in the main screen, together a dropdown list to select the time distribution of the PAM. Selecting the option "variable", will allow us to introduce the starting year and the ending year (figure 23). If the information is available, national modelers could define an intermediate milestone year, by which 50% of the PAM should be implemented. Costs in USD per tonne reduced could be populated within MITICA to obtain Marginal Abatement Cost Curves (MACC).

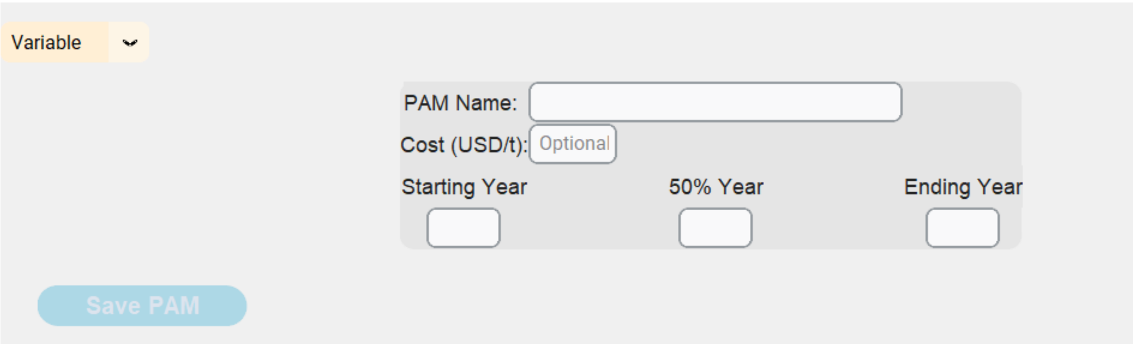


Figure 23. PAM inserter – Timeslots for PAM implementation 1/2

The PAM name is required before saving the PAM. If the option 'constant' is selected, the necessary information remains the same, with the exception of the intermediate milestone (figure 24). In this case, the annual mitigation impact will be constant, assumed to be fully realized from the year defined as the 'starting year.' National modelers should exercise caution when determining the starting years within this option, as most PAMs require some time before they begin to reduce emissions. National modelers are required to define the starting year when the intervention starts reducing emissions.

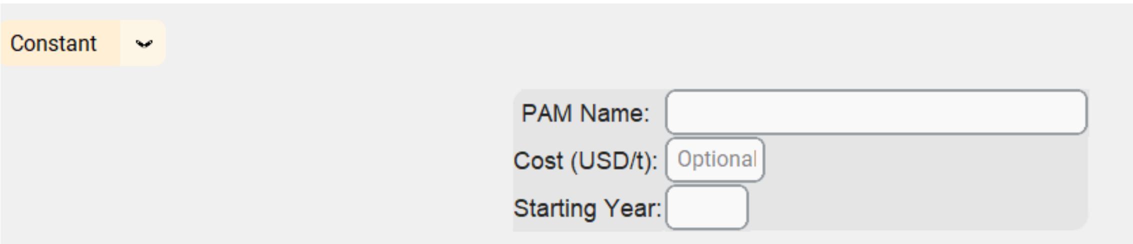


Figure 24. PAM inserter – Timeslots for PAM implementation 2/2

Once the time distribution is defined, PAMs should be "saved" in the left part of the screen. A new PAM can then be introduced by clinking on "New PAM" using the red button at the right part of the screen.

PAM introduced can be managed from the main menu of MITICA, using the right button named "Manage your PAMs" (figure 25).

PAMs Manager (MITICA)

PAM Name	Category Affected	Total Mitigation Potential	Cost (USD/t)	Total Cost (USD)
Installing RES	1.A.1.a	21900.0 ktCO2eq	11.3	247.47
Switch from Coal to Biomass	1.A.2	2327.35 ktCO2eq	31.6	73.54
Renewal diesel fleet	1.A.3.b	3.51 ktCO2eq	6.7	0.02
Diesel to NG	1.A.4.b	899.17 ktCO2eq	28.6	25.72
Reduction on coal mining	1.B	3.47 ktCO2eq	0.71	0.0
N2O abatement	2.B	936.51 ktCO2eq	3.1	2.9
Clinker replacement	2.A	14700.0 ktCO2eq	6.7	98.49
Imrpovenet feeding cows	3.A	9364.95 ktCO2eq	7.91	74.08
Using Cover Crops	3.D	1600.0 ktCO2eq	0.92	1.47
Reducing Tillage	4.B	426.3 ktCO2eq	2.1	0.9
Restoration of degraded forest	4.A	5074.64 ktCO2eq	27.2	138.03
Reducing Population Waste	5.A	-7076.7 ktCO2eq	1.1	-7.78
Improving Wastewater Treatment	5.D	414.54 ktCO2eq	3.8	1.58

Figure 25. PAM manager

2.3.5. Designining the WeM and WaM scenario.

This step is required to design the WeM and WaM scenarios, by selecting the PAMs to be considered under each. Click on "Create Scenarios" to start this step (figure 26).

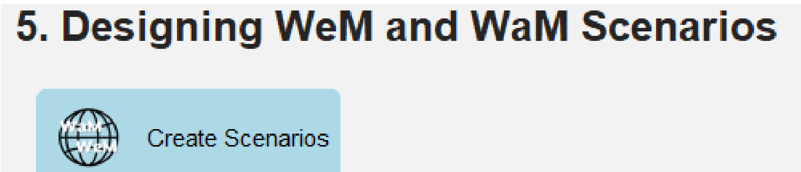


Figure 26. Scenario design within MITICA (1/2)

The WeM and WaM scenarios will be calculated from the WoM by subtracting the impact of PAMs. National modellers are required to design scenarios based on the objective of the analysis[10]. The only difference between scenarios is the consideration of different PAMs. To maintain consistency with the definition of scenarios provided in the MPGs, the

[10] The scope of the scenarios is defined by their objective. If the goal is to track the progress of mitigation targets, the created scenarios should align with the mitigation target, considering the same sectors defined in the target. It is the responsibility of national modelers to utilize this feature for assessing progress towards targets. Furthermore, it is important to note that the definition of scenarios can contribute to establishing new mitigation targets. Assessing potential emission levels after implementing a specific set of PAMs will facilitate the formulation of realistic mitigation targets.

WaM scenario should consider all PAMs encompassed within the WeM, plus additional PAMs. To design scenarios, click on the PAMs required under each (figure 27)

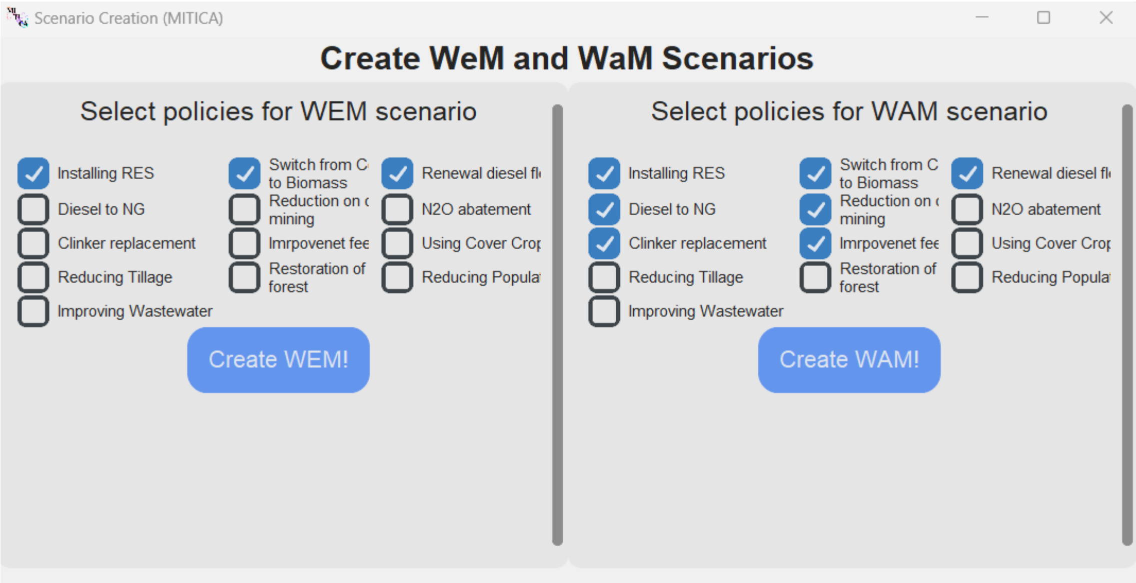


Figure 27. Scenario design within MITICA (2/2)

The definition of conditional and unconditional NDC targets is widespread under the Paris Agreement. To assess these type of targets, national modelers need to define unconditional PAMs within the WeM and conditional PAMs under the WaM, maintaining the consistency with the MPGs, while assessing the mitigation targets subject to receive international funding. This way of proceeding will determine specifically which PAMs require international funding, and their potential impact in national GHG emissions.

2.3.6. Dashboard: summary of results

Previous steps allow to estimate the WoM scenario, assess policies and measures by sector, and design the WeM and WaM scenarios. In the Dashboard, results can be visualised to assess future GHG emission profile under different mitigation scenarios and compare our main PAM by sector. Click on "Visualise data" to start this step (figure 28).

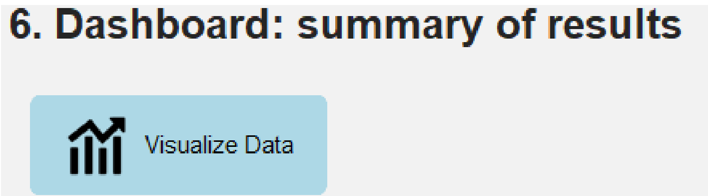


Figure 28. Dashboard

Two main options are displayed within the dashboard (figure 29): "Mitigation on time" and "Cost of mitigation".

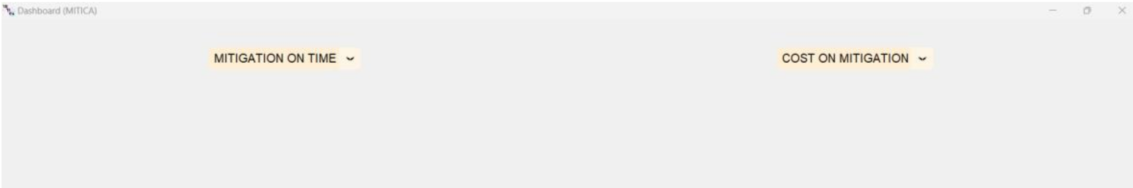


Figure 29. Alternatives to visualise results

Click on "Mitigation on time" to visualise GHG emissions created under the different mitigation scenarios. Within this option, the dropdown menu allows to select "By category" or "By PAM". In both cases, the sector needs to be defined (figure 30).

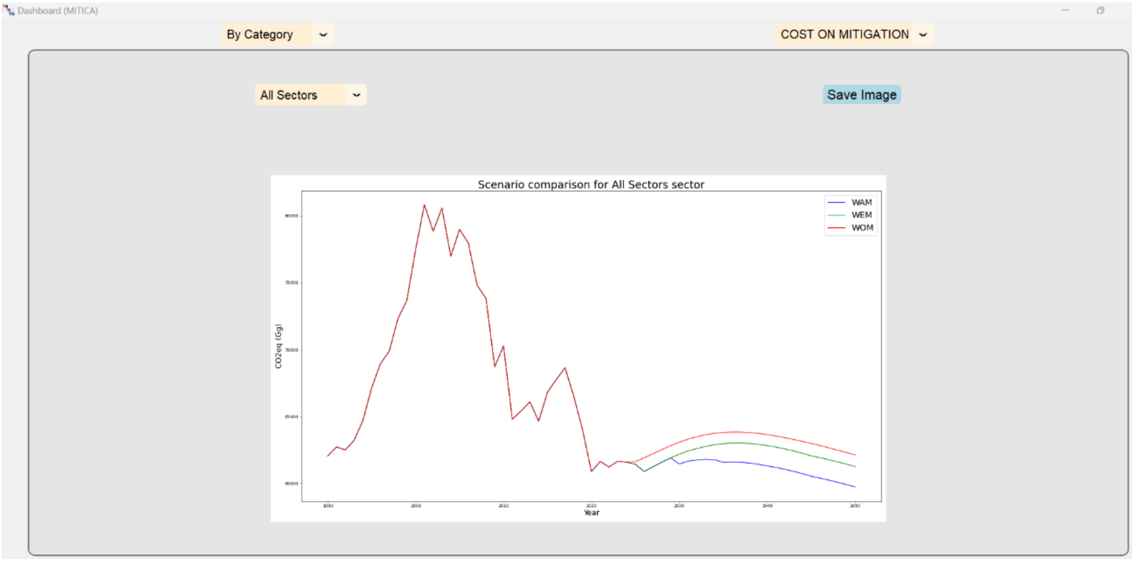


Figure 30. Alternatives to visualise results – scenarios by category

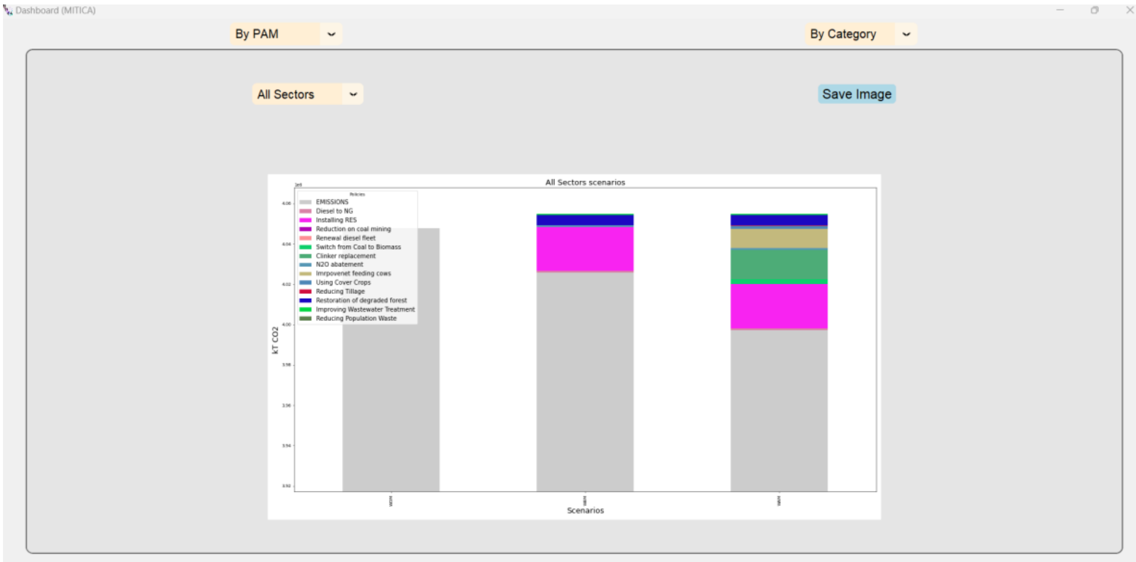


Figure 31. Alternatives to visualise results – PAMs by scenario

Click on "cost of mitigation" to analyse the MACC by scenario or sector (figure 32). MACC are built using the GHG mitigation impact estimated within MITICA, and the costs by PAM introduced by national modelers within PAM assessment. Analysing MACC by sector will enable sectoral assessment of main PAMs, while analysing MACC by scenario provides a view of most cost-efficient PAMs included under the WeM and WaM scenarios.

Figure 32. Alternatives to visualise results – MACC

All images created within the dashboard can be exported clicking on "Save image" for external use.

2.3.7. Export Results

In this step the user can export the results from MITICA on mitigation scenarios and policies and measures estimated. Click on "By Scenario" or "By PAM" to obtain an excel file with the results obtained in MITICA (figure 33).

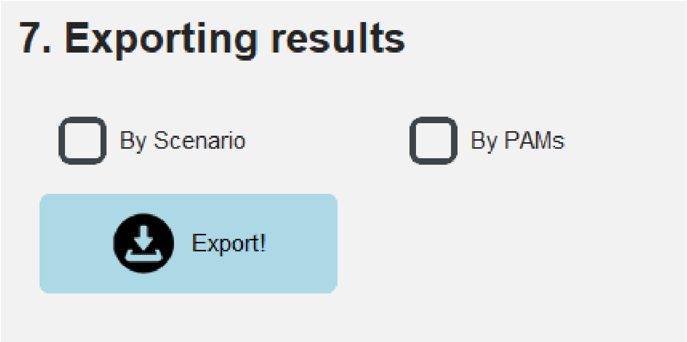


Figure 33. Exporting results in MITICA

2.3.8. Collaborative work within MITICA

At the bottom of the MITICA home screen, two additional options are displayed to enhance user experience and facilitate collaboration with other national modelers: 'Share data' and 'Reset options' (Figure 34).

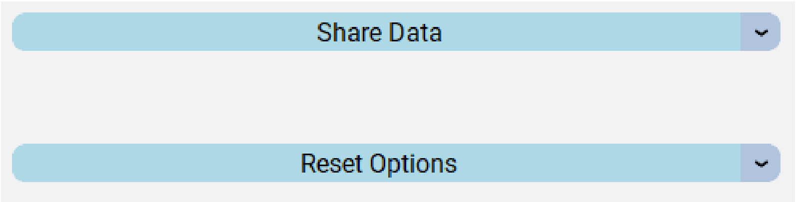


Figure 34. Additional features in MITICA

The 'Share data' option enables users to share work developed with other MITICA users, provided that their UUIDs have also been registered in MITICA. This feature facilitates the transfer of work among national modelers. Two options are available: one for exporting the database ('Export ZIP') and another for importing databases ('Import ZIP'). To share MITICA files, start by clicking on 'Export ZIP,' then send the file to a third person who will need to 'Import database' in their MITICA console.

Finally, the 'Reset options' button allows users to delete specific parts of the work developed within MITICA in the previous steps, including scenarios, PAMs, WoM validation, or everything.

3. Methodology

MITICA´s methodological approach is described extensively in the following peer reviewed paper, provided in open access:

Martín-Ortega, J.L., Chornet, J., Sempos I., Akkermans, S., Lopez Blanco, M.J. (2024). Enhancing transparency of climate efforts: MITICA's Integrated Approach to greenhouse gas Mitigation. Pending to be published.

MITICA develops GHG emission scenarios starting with the estimation of a WoM scenario, which represents projected national GHG emissions considering a set of projected proxies ceteris paribus; only the proxies change in the projected years, being the economic structure, technology mix, consumer behaviour as well as the GHG accounting methodologies the same of the latest historical year; these elements will only change as a result of the implementation of policies and measures. Indeed, MITICA uses the WoM as a benchmark for developing policy scenarios (WeM and WaM, in line with ETF definitions), in which the only difference between scenarios is the policies and measures implemented and their impact in GHG emissions.

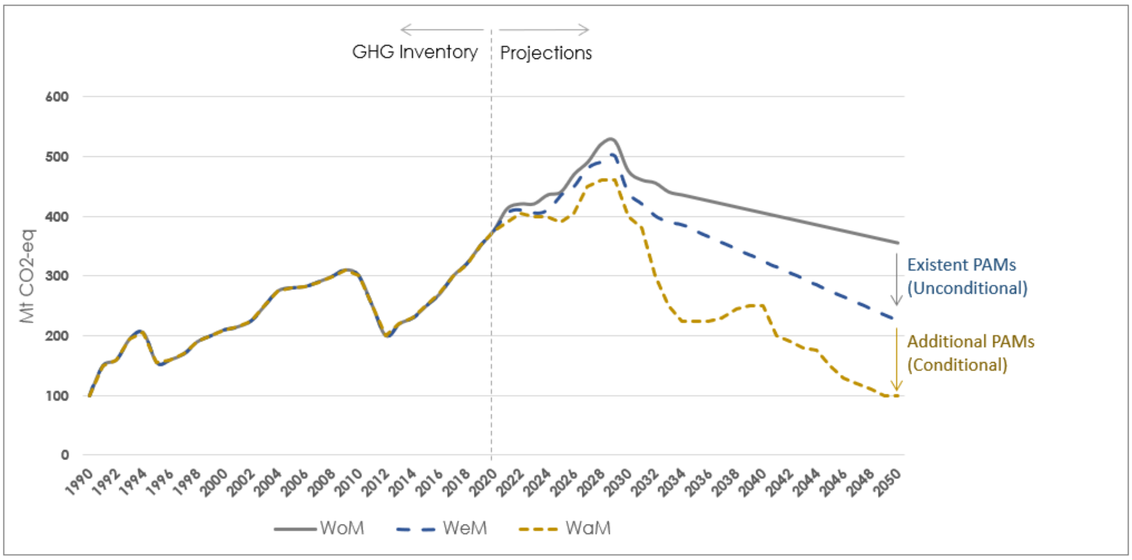


Figure 352. MITICA Concept to create policy scenarios.

From a practical point of view, MITICA´s methodology differentiates two main parts: the projection of the WoM and the assessment of policies and measures.

Projection of the WoM

The methodology applied by MITICA to project WoM GHG emissions can be simplified by a generalised multivariate time series model such as the Seasonal Autoregressive Integrated Moving Average with eXogenous variables (SARIMAX):

$$Y_t = \beta_0 + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \beta_3 X_{3,t} + \ldots + \beta_k X_{k,t} + \varepsilon_t \qquad \{1\}$$

where:

Y_t is $the\ endogenous\ time\ series (e.g., GHGemissions)$.
$X_{1,t}$, $X_{2,t}$,..., $X_{k,t}$, are exogenous variables (proxies).
$\beta_{1,t}$, $\beta_{2,t}$,..., $\beta_{k,t}$, are the coefficients associated with the exogenous variables.
ε_t is the error term, assumed to be normally distributed.

The time series Y_t is assumed to follow a SARIMA(p, d, q) × (P, D, Q) structure, where:

p is the autoregressive order.
d is the differencing order.
q is the moving average order.
P is the seasonal autoregressive order.
D is the seasonal differencing order.
Q is the seasonal moving average order.
s is the length of the seasonal period.

In the context of GHG emissions with multiple proxies, the equation becomes more specific. As MITICA deals with several proxies by CRT category, the general (simplified) equation would be:

$$Y_t = \beta_0 + \beta_1 X_{1,t} + \beta_2 X_{2,t} + \beta_3 X_{3,t} + \ldots + \beta_k X_{k,t} + \theta_1 Y_{t-1} + \theta_2 Y_{t-2} + \ldots + \theta_3 Y_{t-3} + \varepsilon_t \ \{2\}$$

Each parameter in the equation playing a specific role:

$\theta_1, \theta_2, \ldots, \theta_p$ $are\ the\ autoregressive\ parameters\ of\ the\ endogenous\ variable\ (GHG\ emissions)$
$\beta_{1,t}$, $\beta_{2,t}$,..., $\beta_{k,t}$, *are the coefficients associated with the exogenous variables.*
ε_t *is the error term representing unobserved influences on the endogenous variable*

From a general framework similar to {2}, MITICA design specific models by CRT category considering the data inputted in the software, creating robust models meeting the classical criteria for regression-based models (i.e. non-stationarity, heteroscedasticity, multicollinearity, etc.). Through machine learning ensemble approaches, the model with highest accuracy by category is used to project GHG emissions by CRT category in the WoM scenario.

The validation process from national modelers (step 4) is required to correct outliers, identify structural changes in the trend, and/or define ad hoc thresholds.

Assessment of impact of Policies and Measures (PAMs)

Policies and Measures accounting approach of MITICA extends the methodological framework described in Sebos at al. (2021) to all CRT sectors and main mitigation alternatives, in line with the principles and requirements described in section 3.1. The methodological framework has already been tested and its estimates have been included in the National Energy and Climate Plan of Greece (Ministry of the Environment and Energy, 2019). The basic estimation approach is depicted as:

$$ME_{t_i-t_f} = R \cdot M_{t_i-t_f} \cdot [REF_t - MEF_t] \qquad \{3\}$$

Where $ME_{t_i-t_f}$ represents the mitigation effect of the PAM for the entire projected period, $M_{t_i-t_f}$ is the magnitude of the PAM representing the affected activity levels, R represents the reduction factor in magnitude from PAM implementation, REF_t stands for the reference emission factor in the absence of the PAM at time t, and MEF_t is the mitigation emission factor, post implementation of the PAM at time t. From this generalization, PAM methodologies are specified case by case, and linked to the reference inventory through the REF, and linked to the WoM scenario through $M_{t_i-t_f}$.

4. PAMs – ENERGY

The following provides information by PAM for the sector. As a relevant note when inputting parameters in units of %, MITICA requires data to be entered as percentages and not as fractions (e.g., input 10% as 10, not as 0.1). Additionally, methodologies for all PAMs are related to inventory methodologies in the categories affected. For the full methodologies and background information, please consult 2006 IPCC Guidelines and its 2019 Refinement.

4.1 Power Sector

4.1.1 Use of RES for power production

The mitigation effect comes from the substitution of fossil fuels by Renewable Energy Sources (RES) for electricity production. Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us. Fossil fuels - coal, oil, and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, cause harmful greenhouse gas emissions, such as carbon dioxide. Generating renewable energy creates far lower emissions than burning fossil fuels. Transitioning from fossil fuels, which currently account for the lion’s share of emissions, to renewable energy is key to addressing the climate crisis. Renewables are now cheaper in most countries and generate three times more jobs than fossil fuels.

This mitigation action is related to GHG emissions that are reported under CRT category 1A1a (Main Activity Electricity and Heat Production). The following estimation methods (see tables 1 and 2) can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 2. Option 1 – based on electricity produced from RES

Variable	Value	Units	Comments
Electricity produced by RES as a result of the PAM	A	GWh	
Emission factor of thermal plants of the electricity generation system in latest inventory year (specific CO_2 emissions of thermal plants in t CO_2/GWh)	B	tCO_2/GWh	In the absence of national specific values, grid EF by country are provided by IGES
Own use of thermal plants	C	%	Own use of thermal plants is about 5-10%. If there is no country specific information about this parameter then use 8%. This is an author's estimation by comparing gross and net electricity production data from EU MS' energy balances.
Transmission and distribution losses	D	%	Losses could range from 2 up to more than 20%. Please refer to national statistics, IEA, OECD or https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS If there is no country specific information about this parameter, then use 12%.
Mitigation effect	=A*B/(1-C-D)/1000	kt CO_2	Annual Mitigation impact of the PAM.

Table 3. Option 2 – based on RES capacity

Variable	Value	Units	Comments
RES installed capacity as a result of the PAM	A	GW	

Variable	Value	Units	Comments
Capacity factor	B	%	The capacity factor (CF) basically measures how often a plant is running at maximum power. A plant with a capacity factor of 100% means it's producing power all the time. The CF depends on the type of the RES and the operation of the electricity grid. If there is no country specific information about this parameter use 25% for PV. 35% for wind, 40% for hydro and 70% for Geothermal.
Emission factor of thermal plants of the electricity generation system in in latest inventory year (specific CO_2 emissions of thermal plants in t CO_2/GWh)	C	t CO_2/GWh	In the absence of national specific values, grid EF by country are provided by IGES
Own use of thermal plants	D	%	Own use of thermal plants is about 5-10%. If there is no country specific information about this parameter use 8%. This is an author's estimation by comparing gross and net electricity production data from EU MS' energy balances.
Transmission and distribution losses	E	%	Losses could range from 2 up to more than 20%. Please refer to national statistics, IEA, OECD or https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS . If there is no country specific information about this parameter use 12%.
Mitigation effect	=A*365*24*B*C/(1-D-E)/1000	kt CO_2	Annual Mitigation impact of the PAM.

4.1.2. Commissioning of new efficient plants and /or fuel switch to less carbon intensive fuels

Power generation remains the largest greenhouse gas-emitting sector in many countries, e.g. being responsible for roughly one third of all energy-related greenhouse gas emissions and more than half of the verified emissions under the EU Emissions Trading Scheme (ETS) in Europe. This action is related to the improvement of the conventional power generation system through the replacement of ageing and end-of-life, mainly, coal-fired plants by new installed capacity, which is more energy efficient and/or uses less carbon intensive fuels (e.g. natural gas instead of lignite). It is a less ambitious mitigation action compared to the replacement of conventional power plants with RES, but it may be needed as a transitional action till the full deployment of RES capacity in a country.

This mitigation action is related to GHG emissions that are reported under CRT category 1A1a (Main Activity Electricity and Heat Production). The following estimation methods (see tables 3, 4and % ?) can be applied to estimate the mitigation effect for ex-ante analysis.

Table 4. Option 1 - Commissioning of new NG power plant (Combined Cycle) in place of lignite, hard coal, or fuel oil fired power plant

Variable	Value	Units	Comments
Installed capacity due to the PAM	A	GW	
Capacity factor	B	%	The capacity factor depends on national circumstances. If there is no country specific information about this parameter use 70% as a default (expert judgement from authors).

Variable	Value	Units	Comments
Power plant efficiency (new plant)	C	%	The efficiency of combined cycle NG-fired power plants could range from 45-60%. A default value is 55%.[11]
Specific EF of the fossil fuel power plant that would have produced the amount of electricity or replaced by the new plant	D	t CO_2/GWh	If there is no country specific information about this parameter use:[12] lignite old - 1221 g/kWh - eff 34% lignite modern - 966 g CO_2/kWh - eff 43% hard coal old - 1084 g CO_2/kWh - eff 36% hard coal modern - 849 g CO_2/kWh - eff 46% fuel oil - 796 g CO_2/kWh - eff 35%
EF of NG	E	t CO_2/TJ	Default is 56.1t/TJ
Conversion of GWh to TJ	3.6	TJ/GWh	
Mitigation effect	=A*365*24*B*(D-3.6*E/C)/1000	kt CO_2	Annual Mitigation impact of the PAM.

Table 5. Option 2 - Commissioning of new NG power plant (Combined Cycle) in place of lignite, hard coal, or fuel oil fired power plant

Variable	Value	Units	Comments
Installed capacity due to the PAM	A	GW	
Capacity factor	B	%	The capacity factor depends on national circumstances. If there is no

[11] Kenneth Storm, Chapter 6 - Combined cycle power plant (1×1) labor estimate, Editor(s): Kenneth Storm, Industrial Construction Estimating Manual, Gulf Professional Publishing, 2020, Pages 95-159, ISBN 9780128233627, https://doi.org/10.1016/B978-0-12-823362-7.00006-5.

http://needtoknow.nas.edu/energy/energy-sources/fossil-fuels/natural-gas/#:~:text=A%20gas%2Dfired%20plant%20was,as%20much%20as%2060%25%20efficient.

[12] https://www.volker-quaschning.de/datserv/CO2-spez/index_e.php

Variable	Value	Units	Comments
			country specific information about this parameter use 70%.
Power plant efficiency (new plant)	C	%	A default value is 48%.
Specific EF of the fossil fuel power plant that would have produced the amount of electricity or replaced by the new plant	D	tCO_2/GWh	If there is no country specific information about this parameter use: lignite old - 1221 g CO_2/kWh - eff 34% lignite modern - 966 g CO_2/kWh - eff 43% hard coal old - 1084 g CO_2/kWh - eff 36% hard coal modern - 849 g CO_2/kWh - eff 46% fuel oil - 796 g CO_2/kWh - eff 35%
EF of hard coal	E	t CO_2/TJ	Default is 98.3 t CO_2/TJ (2006 IPCC GLs)
Conversion of GWh to TJ	3.6	TJ/GWh	
Mitigation effect	=A*365*24*B*(D-3.6*E/C)/1000	kt CO_2	Annual Mitigation impact of the PAM.

This is a generalized mitigation action that covers the effect from multiple actions to improve the conventional power generation system, such as the decommissioning of old plants and the commissioning of new more efficient ones, the implementation of energy efficiency measures to existed plants, and fuel change to low carbon fuels (e.g., NG).

Table 6. Option 3 – generalized action - improvements in the conventional power generation system

Variable	Value	Units	Comments
Annual Electricity produced by fossil fuels	A	GWh	
Emission factor of thermal plants of	B	tCO_2/GWh	The EFs used in the model vary annually depending on the energy mixture and the energy efficiency level of the thermal plants for each year.

Variable	Value	Units	Comments
the electricity generation system in year t			
Emission factor of thermal plants of the electricity generation system in a reference base year (specific CO_2 emissions of thermal plants in t CO_2/GWh)	C	tCO_2/GWh	A reference / base year should be a year before the start of the implementation of policies related to energy efficiency measures, decommissioning of old plants and increase of NG share in electricity production.
Own use of thermal plants	D	%	Own use of thermal plants is about 5-10%. If there is no country specific information about this parameter use 8%. This is an author's estimation by comparing gross and net electricity production data from EU MS' energy balances.
Transmission and distribution losses	E	%	Losses could range from 2 up to more than 20%. Please refer to national statistics, IEA, OECD or https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS. If there is no country specific information about this parameter use 12%.
Mitigation effect	=A*(B-C)/(1-C-D)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.1.3. Production of electricity from biomass residues

Biomass is considered carbon neutral, regarding the direct CO_2 emissions associated with their combustion, on the grounds that the carbon dioxide absorbed by the plants through photosynthesis is equivalent to the CO_2 released during their combustion. The replacement of fossil fuels with biomass results in mitigation of the associated with fossil fuels CO_2 emissions.

This mitigation action is related to GHG emissions that are reported under CRT category 1A1a (Main Activity Electricity and Heat Production). The following estimation methods (see tablebelow) can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 7. Replacement of fossil fuels with biomass

Variable	Value	Units	Comments
Expected Biomass use due to the PAM	A	kt	
NCV of biomass	B	TJ/kt	If there is no country specific information about this parameter use 15.6 TJ/kt (2006 IPCC GLs)
Power plant efficiency	C	%	A default value is 20%.
Specific EF of the fossil fuel power plant that would have produced the amount of electricity or replaced by the new plant	D	tCO_2 /GWh	If there is no country specific information about this parameter use: lignite old - 1221 gCO_2/kWh - eff 34% lignite modern - 966 gCO_2/kWh - eff 43% hard coal old - 1084 gCO_2/kWh - eff 36% hard coal modern - 849 gCO_2/kWh - eff 46% fuel oil - 796 gCO_2/kWh - eff 35%
Conversion of GWh to TJ	3.6	TJ/GWh	
Mitigation effect	=A*B*C/3.6*D/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.1.4. Improvement of the energy efficiency of the electricity grid

Energy ranging from 2% up to more than 20% of the original primary energy is lost during the delivery of electricity through the Transmission & Distribution system. The energy becomes waste heat released in the air due to line losses and conversion losses in transformers and other line equipment. This mitigation action is related to the reduction of the transmission and distribution losses of electricity, so that this amount of electricity would be available for consumption.

This mitigation action is related to GHG emissions that are reported under CRT category 1A1a (Main Activity Electricity and Heat Production). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 8. Improvement of the energy efficiency of the electricity grid

Variable	Value	Units	Comments
Grid loss	A	%	This information is country specific. Losses could range from 2 up to more than 20%. Please refer to national statistics, IEA, OECD or https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS
Grid loss after mitigation action	B	%	The target depends on the extent of the mitigation action, the situation of the grid, the location between producers and consumers of electricity, etc. As default value, it is proposed to use 10%.
Grid CO_2 emission factor	C	tCO_2/GWh	This is the specific CO_2 emissions per GWh produced of the whole sector covering both thermal plants and RES. It depends on the country's energy mix.
Average annual electricity consumption	D	GWh	
Mitigation effect	=(A-B)*C*D/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.1.5. Development of advanced metering infrastructure in the electricity grid

Advanced metering infrastructure is an integrated system of smart meters, data management systems and communication networks that enable two-way communication between the utilities and the customers. It helps a customer to save monthly by providing detailed consumption information on electricity. The mitigation effect of the reduction in electricity consumption is estimated in this section.

This mitigation action is related to GHG emissions that are reported under CRT category 1A1a (Main Activity Electricity and Heat Production). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 9. Development of advanced metering infrastructure in the electricity grid

Variable	Value	Units	Comments
Reduction of electricity consumption	A	%	The reduction could be of the range of 5% according to https://doi.org/10.1016/j.enpol.2017.05.002. There are studies that it could reach 15% (e.g. https://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf)
Grid CO_2 emission factor	B	tCO_2/GWh	This is the specific CO_2 emissions per GWh produced of the whole sector covering both thermal plants and RES. It depends on the country's energy mix.
Average annual electricity consumption	C	GWh	
Mitigation effect	=A*B*C/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.1.6. Improvements in the conventional power generation system

This PAM aims at capturing interventions in the power generation system which are not covered in the previous PAMs. This PAM affects category 1A1a and relates to overall improvements in technologies within the existent generation system.

Table 10. Improvements in the conventional power generation system

Variable	Value	Units	Comments
Average electricity produced by fossil fuels	A	GWh	
Emission factor of thermal plants of the electricity generation system after improvements	B	tCO2/GWh	A reduction in the grid emission factor would be expected.
Emission factor of thermal plants of the electricity generation system before PAM (specific CO2 emissions of thermal plants in tCO2/GWh)	C	tCO2/GWh	The grid emission factor could be used.
Own use of thermal pants	D	%	Proposed default value, from previous PAMs: 8,00
Transmission and distribution losses	E	%	Proposed defaul value, from previous PAMs 12,00
Mitigation effect	=0,1*A*(C-B)/(100-D-E)	ktCO2	Annual Mitigation impact

4.1.7. Generalised mitigation action for Power sector

This is a generalized mitigation action that reflects the mitigation of GHG emissions by reducing the electricity production associated with the consumption of fossil fuels. The reduction of fossil fuels use could be resulted from energy efficient measures and / or substitution by RES.

This mitigation action is related to GHG emissions that are reported under CRT category 1A1a (Main Activity Electricity and Heat Production). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 11. Option 1 – based on the reduction of electricity produced by fossil fuels

Variable	Value	Units	Comments
Reduction of GWh produced from solid fuels	A	GWh	
Specific CO_2 EF from solid-fuel fired thermal plants	B	tCO_2/GWh	If there is no country specific information about this parameter use:[13] lignite old - 1221 gCO_2/kWh - eff 34% lignite modern - 966 gCO_2/kWh - eff 43% hard coal old - 1084 gCO_2/kWh - eff 36% hard coal modern - 849 gCO_2/kWh -eff 46%
Reduction of GWh produced from liquid fuels	C	GWh	
Specific CO_2 EF from liquid-fuel fired thermal plants	D	tCO_2/GWh	If there is no country specific information about this parameter use: fuel oil - 796 gCO_2/kWh - eff 35%
Reduction of GWh produced from gaseous fuels	E	GWh	
Specific CO_2 EF from gaseous fuel fired thermal plants	F	tCO_2/GWh	If there is no country specific information about this parameter use: typical gas-fired power plant - 619 gCO_2/kWh - eff 39.2% CCGT - 411 gCO_2/kWh - eff 59%

[13] https://www.volker-quaschning.de/datserv/CO₂/-spez/index_e.php

Variable	Value	Units	Comments
Own use of thermal plants	G	%	Own use of thermal plants is about 5-10%. If there is no country specific information about this parameter use 8%. This is an author's estimation by comparing gross and net electricity production data from EU MS' energy balances.
Transmission and distribution losses	H	%	Losses could range from 2 up to more than 20%. Please refer to national statistics, IEA, OECD or https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS If there is no country specific information about this parameter use 12%.
Mitigation effect	=(A*B+C*D+E*F)/(1-G-H)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

Table 12. Option 2 – based on the reduction of fossil fuels activity data

Variable	Value	Units	Comments
Reduction of solid fuels consumed in power plants	A	TJ	
CO_2 EF of solid fuels	B	tCO_2/TJ	Default value is 98.3 t/TJ (anthracite) from 2006 IPCC GLs.
Reduction of liquid fuels consumed in power plants	C	TJ	
CO_2 EF of liquid fuels	D	tCO_2/TJ	Default value is 77.4 t/TJ (HFO) from 2006 IPCC GLs.
Reduction of gaseous fuels consumed in power plants	E	TJ	
CO_2 EF of gaseous fuels	F	tCO_2/TJ	Default value is 56.1 t/TJ (HFO) from 2006 IPCC GLs.

Variable	Value	Units	Comments
Mitigation effect	=(A*B+C*D+E*F)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.2. Industry

4.2.1. Fuel switch from coal to natural gas

The vast majority of industry's GHG emissions, 90 percent, consists of CO_2. Half of industry's CO_2 emissions result from the manufacture of the four industrial commodities—ammonia, cement, ethylene, and steel. This action is related to the mitigation of CO_2 emissions by the replacement of fossil fuels by a lower carbon fuel.

This mitigation action is related to GHG emissions that are reported under CRT category 1A2 (Manufacturing Industries and Construction). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 13. Fuel switch from coal to natural gas

Variable	Value	Units	Comments
Annual coal use	A	TJ	
CO_2 EF of coal	B	tCO_2/TJ	If country-specific information is not available, please use the following: Anthracite 98.3 tCO_2/TJ, Coking coal 94.6 tCO_2/TJ, Other bituminous coal 94.6 tCO_2/TJ, Sub-bituminous coal 96.1 tCO_2/TJ, Lignite 101 tCO_2/TJ (defaults from 2006 IPCC GLs).
CO_2 EF of NG	C	tCO_2/TJ	If country-specific information is not available, please use 56.1 tCO_2/TJ (default from 2006 IPCC GLs).
Mitigation effect	=A*(B-C)/1000	$ktCO_2$	In case of boilers, typical full load efficiency per fuel is as follows: 85% for coal, 80% for oil and 75% for NG. In the above calculation, it is considered that NG will replace coal boilers of the same efficiency (around 75% in full load).

4.2.2. Fuel switch from coal to biomass

Biomass is considered to be carbon neutral, regarding the direct CO_2 emissions associated with their combustion, on the grounds that the carbon dioxide absorbed by the plants through photosynthesis is equivalent to the CO_2 released during their combustion. The replacement of fossil fuels with biomass results in mitigation of the associated with fossil fuels CO_2 emissions.

This mitigation action is related to GHG emissions that are reported under CRT category 1A2 Manufacturing Industries and Construction). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 14. Fuel switch from coal to biomass

Variable	Value	Units	Comments
Annual coal use	A	TJ	
CO_2 EF of coal	B	tCO_2/TJ	If country-specific information is not available, please use the following: Anthracite 98.3 tCO_2/TJ, Coking coal 94.6 tCO_2/TJ, Other bituminous coal 94.6 tCO_2/TJ, Sub-bituminous coal 96.1 tCO_2/TJ, Lignite 101 tCO_2/TJ (defaults from 2006 IPCC GLs).
CO_2 EF of biomass	C	tCO_2/TJ	The direct CO_2 emissions of biomass, which is associated with their combustion, are considered to be carbon-neutral on the grounds that the carbon dioxide absorbed by the plants through photosynthesis is equivalent to the CO_2 released during their combustion. The direct emissions (combustion emissions) from unprocessed biomass (wood, wood waste, charcoal, pellets, etc) are considered to be zero. On the other hand, biodiesel (FAME) has a fossil carbon content, giving an CO_2 EF of 4tCO_2/TJ. (http://dx.doi.org/10.1080/17583004.2022.2046173)
Coal boiler efficiency	D	%	If the fuel is used in boilers, then it should be considered that the full load efficiency of old coal boilers is around 75%, while for new ones is 85%.
Biofuel boiler efficiency	E	%	If the fuel is used in boilers, then it should be considered that the full load efficiency of new biomass boilers is around 70%, less that the efficiency of coal ones.
Mitigation effect	=(A*B-A*C/E*D)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.2.3. Fuel switch from Heavy Fuel Oil (HF) to Natural Gas (NG)

This action is related to the mitigation of CO_2 emissions by the replacement of fossil fuels (coal) by a lower carbon fuel (NG).

This mitigation action is related to GHG emissions that are reported under CRT category 1A2 Manufacturing Industries and Construction). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 15. Fuel switch from Heavy Fuel Oil (HF) to Natural Gas (NG)

Variable	Value	Units	Comments
Annual HFO use	A	TJ	
CO_2 EF of HFO	B	tCO_2/TJ	If country-specific information is not available, please use the following: 77.4 tCO_2/TJ (defaults from 2006 IPCC GLs).
CO_2 EF of NG	C	tCO_2/TJ	If country-specific information is not available, please use 56.1 tCO_2/TJ (default from 2006 IPCC GLs).
Mitigation effect	=A*(B-C)/1000	$ktCO_2$	In case of boilers, typical full load efficiency per fuel is as follows: 85% for coal, 80% for oil and 75% for NG. In the above calculation, it is considered that NG will replace oil boilers of the same efficiency (around 75% in full load).

4.2.4. Replacement of clinker with other physical raw materials

The substitution of clinker by physical raw materials in cement reduces both combustion emissions (1A2) and the emissions originated from consumption of carbonates (2A1). The substitutes of clinker need to have hydraulic properties, which means the product hardens when water is added, such as pozzolan, fly ash, etc. The impact of this PAM is related to less energy consumption as a result of lower clinker production levels.

This mitigation action is related to GHG emissions that are reported under CRT category 1A2f (Non-Metallic Minerals). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 16. Replacement of clinker with other physical materials

Variable	Value	Units	Comments
Annual cement production	A	tons	
Share in clinker (reference)	B	%	If country specific information is not available use 70%
Share in clinker (reduction option)	C	%	If country specific information is not available use 50%
Thermal specific energy consumption per tonne of clinker	D	GJ/t	If country specific information is not available use 3.7GJ/t (https://www.iea.org/data-and-statistics/charts/thermal-specific-energy-consumption-per-tonne-of-clinker-in-selected-countries-and-regions-2018)
CO_2 EF of coal	E	tCO_2/TJ	If country specific information is not available use other bituminus coal 94.6 tCO_2/TJ (2006 IPCC GLs)
Mitigation effect	=A*(B-C)*D*E/1000000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.2.5. CHP in industry

Combined Heat and Power (CHP) requires less fuel to produce a given energy output and avoids transmission and distribution losses that occur when electricity travels over power lines. Because less fuel is burned to produce each unit of energy output and because transmission and distribution losses are avoided, CHP reduces emissions of

GHGs and other air pollutants.[14] The technology considered in this section is NG combustion turbine and heat recovery boiler.

This mitigation action is related to GHG emissions that are reported under CRT category 1A2 Manufacturing Industries and Construction). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 17. CHP in industry

Variable	Value	Units	Comments
CHP electricity output	A	GWh	In CHP 100 units of fuel are converted to 30 units electricity and 45 units heat (https://www.epa.gov/chp/chp-benefits)
CHP heat output	1.5*A	GWh	
Efficiency of CHP	B	%	If country specific information is not available use 75% (https://www.epa.gov/chp/chp-benefits)
CO_2 EF of NG	C	tCO_2/TJ	If country-specific information is not available, please use the following: NG 56.1 tCO_2/TJ (defaults from 2006 IPCC GLs)
Specific EF of the fossil fuel power plant that would have produced the amount of electricity	D	tCO_2/GWh	If there is no country specific information about this parameter use: lignite old - 1221 gCO_2/kWh - eff 34% lignite modern - 966 gCO_2/kWh - eff 43% hard coal old - 1084 gCO_2/kWh - eff 36% hard coal modern - 849 gCO_2/kWh -eff 46% fuel oil - 796 gCO_2/kWh - eff 35% typical gas-fired power plant - 619 gCO_2/kWh - eff 39.2% CCGT - 411 gCO_2/kWh - eff 59%
Efficiency of boiler that would have produced the	E	%	The proposed value to be used is 80%

[14] https://www.epa.gov/chp/chp-benefits#:~:text=Avoided%20Transmission%20and%20Distribution%20Losses&text=By%20avoiding%20losses%20associated%20with,demand%20for%20electricity%20is%20high.

Variable	Value	Units	Comments
amount of heat			
CO_2 EF of boiler fuel	F	tCO_2/TJ	If country-specific information is not available, please use the following: Anthracite 98.3 tCO_2/TJ, Coking coal 94.6 tCO_2/TJ, Other bituminous coal 94.6 tCO_2/TJ, Sub-bituminous coal 96.1 tCO_2/TJ, Lignite 101 tCO_2/TJ, HFO 77.4 tCO_2/TJ, NG 56.1 tCO_2/TJ (defaults from 2006 IPCC GLs)
Own use of thermal power plants	G	%	Own use of thermal plants is about 5-10%. If there is no country specific information about this parameter use 8%. This is an author's estimation by comparing gross and net electricity production data from EU MS' energy balances.
Transmission and distribution losses	H	%	Losses could range from 2 up to more than 20%. Please refer to national statistics, IEA, OECD or https://data.worldbank.org/indicator/EG.ELC.LOSS.ZS . If there is no country specific information about this parameter use 12%.
Conversion of GWh to TJ	3.6	TJ/GWh	
Mitigation effect	=(A*D/(1-G-H)+1.5*A*3.6/E*F-A/0.3*3.6*C)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.2.6. Generalised mitigation action for Industry

This is a generalised mitigation action that reflects the mitigation of GHG emissions due to the implementation of energy efficiency measures. The mitigation effect is associated with the reduction of fossil fuel consumption.

This mitigation action is related to GHG emissions that are reported under CRT category 1A2 (Manufacturing Industries and Construction). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 18. Generalized mitigation action for Industry

Variable	Value	Units	Comments
Reduction of annual fossil fuel consumption	A	TJ	
CO_2 EF of fuel	B	tCO_2/TJ	If country-specific information is not available, please use the following: Anthracite 98.3 tCO_2/TJ, Coking coal 94.6 tCO_2/TJ, Other bituminous coal 94.6 tCO_2/TJ, Sub-bituminous coal 96.1 tCO_2/TJ, Lignite 101 tCO_2/TJ, HFO 77.4 tCO_2/TJ, NG 56.1 tCO_2/TJ (defaults from 2006 IPCC GLs)
Mitigation effect	=(A*B)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3. Transport sector

4.3.1. Renewal of diesel vehicles

This mitigation action refers to the renewal of diesel passenger and light commercial vehicles fleet with more fuel-efficient diesel vehicles. The renewal with electrical cars is considered in another mitigation action. In many countries stricter standards are being adopted concerning fuel efficiency and CO_2 emissions. For example, in Europe according to EU Reg 2019/631 for 2020 the target is 85gCO_2/km for passenger cars and 147gCO_2/km for light commercial vehicles. Stricter targets were set for 2025 and 2030. Similar targets were set in other countries, too. E.g. the adoption of the EU Euro emissions standards for road vehicles in Asian countries is depicted at https://www.eea.europa.eu/data-and-maps/figures/number-of-international-environmental-agreements-adopted-1 .

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 19. Renewal of diesel vehicles

Variable	Value	Units	Comments
Number of cars	A	number	
Average Annual distance by car	B	km	If country-specific information is not available, please use 12000km/year
Fuel consumption of old cars	C	g/km	If country-specific information about the fuel consumption is not available, please use the following from 2019 EEA EMEP Guidebook: Diesel passenger cars conventional (medium-large) - 69g/km Diesel passenger cars Euro 1 (medium - large) - 69g/km Diesel light commercial conventional - 89g/km Diesel light commercial Euro 1 - 80g/km
Specific CO_2 emissions target for new cars	D	gCO_2/km	According to EU Reg 2019/631 for 2020 the target is $85gCO_2/km$ for passenger cars and $147gCO_2/km$ for light commercial vehicles. Stricter targets were set for 2025 and 2030. Similar targets were set in other countries, too.
NCV of diesel	E	TJ/kt	If country-specific information is not available, please use 43TJ/kt from 2006 IPCC GLs
CO_2 EF of diesel	F	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ from 2006 IPCC GLs
Fuel consumption of new cars	G=D/E/F*1000	g/km	
Mitigation effect	=A*B*(C-G)*E*F/10^12	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.2. Renewal of gasoline vehicles

This mitigation action refers to the renewal of gasoline passenger and light commercial vehicles fleet with more fuel-efficient gasoline vehicles. The renewal with electrical cars is considered in another mitigation action.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 20. Renewal of gasoline vehicles

Variable	Value	Units	Comments
Number of cars	A	number	
Average Annual distance by car	B	km	If country-specific information is not available, please use 12000km/year
Fuel consumption of old cars	C	g/km	If country-specific information about the fuel consumption is not available, please use the following from 2019 EEA EMEP Guidebook: Gasoline passenger cars open loop (small-medium-large) - 79g/km Gasoline passenger cars Euro 1 (small - medium - large) - 69g/km Gasoline light commercial conventional - 85g/km Gasoline light commercial Euro 1 - 70g/km
Specific CO_2 emissions target for new cars	D	gCO_2/km	According to EU Reg 2019/631 for 2020 the target is $85gCO_2/km$ for passenger cars and $147gCO_2/km$ for light commercial vehicles. Stricter targets were set for 2025 and 2030. Similar targets were set in other countries, too.
Net Calorific Value (NCV) of gasoline	E	TJ/kt	If country-specific information is not available, please use 44.3TJ/kt from 2006 IPCC GLs
CO_2 EF of gasoline	F	tCO_2/TJ	If country-specific information is not available, please use 69.3 tCO_2/TJ from 2006 IPCC GLs

Variable	Value	Units	Comments
Fuel consumption of new cars	G=D/E/F*1000	g/km	
Mitigation effect	=A*B*(C-G)*E*F/10^12	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.3. Fuel switch from fossil diesel to biodiesel

The reliance on petroleum derivatives and the increasing trend of fuel consumption in the transport sector have brought attention to biofuels as a measure to reduce greenhouse gas (GHG) emissions, enhance energy security and boost economic development. The incentive for utilizing biofuels is their potential to reduce carbon dioxide (CO_2) emissions compared to fossil fuels. Biofuels are considered to be carbon neutral, regarding the direct CO_2 emissions associated with their combustion, on the grounds that the carbon dioxide absorbed by the plants through photosynthesis is equivalent to the CO_2 released during their combustion. The mitigation effect comes from the replacement of fossil fuel by bio-origin fuel.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 21. Fuel switch from fossil diesel to biodiesel

Variable	Value	Units	Comments
Annual national biodiesel use	A	kt	
NCV of biodiesel	B	TJ/kt	The NCV of HVO is similar to that of petro-diesel (about 44 TJ/kt), while the NCV of FAME is 37-38.5 TJ/kt (http://dx.doi.org/10.1080/17583004.2022.2046173)
CO_2 EF of biodiesel	C	tCO_2/TJ	Biodiesel (FAME) has a fossil carbon content, giving an CO_2 EF of $4tCO_2/TJ$. Biodiesel (HVO) has not a fossil carbon content, so EF = 0.

Variable	Value	Units	Comments
			(http://dx.doi.org/10.1080/17583004.2022.2046173)
CO_2 EF of diesel	D	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ (default from 2006 IPCC GLs).
Mitigation effect	=A*B*(D-C)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.4. Fuel switch from fossil gasoline to bio-gasoline

Similar to the previous mitigation action, the mitigation effect comes from the replacement of fossil fuel by bio-origin fuel.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 22. Fuel switch from fossil gasoline to bio-gasoline

Variable	Value	Units	Comments
Annual bio gasoline use	A	kt	
NCV of bio gasoline	B	TJ/kt	The NCV of bioethanol is 27TJ/kt. The NCV of bio-ethers is as follows: MTBE 35.1, ETBE 36.2, and TAEE 38 TJ/kt. (http://dx.doi.org/10.1080/17583004.2022.2046173)
CO_2 EF of bio gasoline	C	tCO_2/TJ	The EF of bioethanol is 0. The EF of bio-ethers is as follows: MTBE 56.83, ETBE 47.63, and TAEE 49.81 tCO_2/TJ, given that isobutylene used for their production derives from fossil sources TJ/kt.(http://dx.doi.org/10.1080/17583004.2022.2046173)

Variable	Value	Units	Comments
CO_2 EF of gasoline	D	tCO_2/TJ	If country-specific information is not available, please use 69.3 tCO_2/TJ (default from 2006 IPCC GLs).
Mitigation effect	=A*B*(D-C)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.5. Electric cars

All forms of electric vehicles can help improve fuel economy, lower fuel costs, and reduce emissions. Electric and hybrid vehicles can have significant emissions benefits over conventional vehicles. All-electric vehicles produce zero tailpipe emissions, and Plug-in Hybrid Electric Vehicle (PHEVs) produce no tailpipe emissions when operating in all-electric mode. Hybrid electric vehicles (HEV)emissions benefits vary by vehicle model and type of hybrid power system.

This mitigation action is related to GHG emissions that are reported under IPCC category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 23. Electric cars

Variable	Value	Units	Comments
Number of cars	A	number	
Average Annual distance by car	B	km	If country-specific information is not available, please use 12000km/year
Gasoline consumption of cars	C	g/km	If country-specific information about the fuel consumption is not available, please use the following from 2019 EEA EMEP Guidebook: Gasoline passenger cars open loop (small-medium-large) - 79g/km Gasoline passenger cars Euro 1 (small - medium - large) - 69g/km Gasoline light commercial conventional - 85g/km

Variable	Value	Units	Comments
			Gasoline light commercial Euro 1 - 70g/km
Electric consumption of new cars	D	kWh/km	An average energy consumption of full electric vehicles is 0.202 kWh(km(https://ev-database.org/cheatsheet/energy-consumption-electric-car)
NCV of gasoline	E	TJ/kt	If country-specific information is not available, please use 44.3TJ/kt from 2006 IPCC GLs
CO_2 EF of gasoline	F	tCO_2/TJ	If country-specific information is not available, please use 69.3 tCO_2/TJ from 2006 IPCC GLs
Scecific CO_2 EF of the grid	G	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=A*B*(C*E*F/10^9 -D*G/10^6)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.6. Electric mopeds

All forms of electric vehicles can help improve fuel economy, lower fuel costs, and reduce emissions. Electric and hybrid vehicles can have significant emissions benefits over conventional vehicles. All-electric vehicles produce zero tailpipe emissions, and PHEVs produce no tailpipe emissions when operating in all-electric mode. HEV emissions benefits vary by vehicle model and type of hybrid power system.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 24. Electric mopeds

Variable	Value	Units	Comments
Number of mopeds	A	number	
Average Annual distance by moped	B	km	If country-specific information is not available, please use 5000km/year
Gasoline consumption of mopeds	C	g/km	If country-specific information about the fuel consumption is not available, please use the following from 2019 EEA EMEP Guidebook: Mopeds 4-stroke < 50 cm^3 - 20g/km Motorcycles 4-stroke < 250 cm^3 - 36g/km Motorcycles 4-stroke 250–750 cm^3 - 36g/km Motorcycles 4-stroke > 750 cm^3 - 46g/km
Electric consumption of new mopeds	D	kWh/km	An average energy consumption of full electric vehicles is 0.035kWh/km
NCV of gasoline	E	TJ/kt	If country-specific information is not available, please use 44.3TJ/kt from 2006 IPCC GLs
CO_2 EF of gasoline	F	tCO_2/TJ	If country-specific information is not available, please use 69.3 tCO_2/TJ from 2006 IPCC GLs
Specific CO_2 EF of the grid	G	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=A*B*(C*E*F/10^9-D*G/10^6)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.7. Battery Electric Buses

All forms of electric vehicles can help improve fuel economy, lower fuel costs, and reduce emissions. Electric and hybrid vehicles can have significant emissions benefits over conventional vehicles. All-electric vehicles produce zero tailpipe emissions, and PHEVs produce no tailpipe emissions when operating in all-electric mode. HEV emissions benefits vary by vehicle model and type of hybrid power system.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 25. Battery Electric Buses

Variable	Value	Units	Comments
Number of BEBs	A	number	
Average Annual distance by BEB	B	km	If country-specific information is not available, please use 40000km/year
Diesel consumption of buses	C	g/km	If country-specific information about the fuel consumption is not available, please use the following from 2019 EEA EMEP Guidebook: 301g/km
Electric consumption of BEBs	D	kWh/km	An average energy consumption of full electric vehicles is 1.35kWh/km
NCV of diesel	E	TJ/kt	If country-specific information is not available, please use 43TJ/kt from 2006 IPCC GLs
CO_2 EF of diesel	F	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ from 2006 IPCC GLs
Specific CO_2 EF of the grid	G	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=A*B*(C*E*F/10^9-D*G/10^6)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.8. Promotion of public means or transport and more energetic ways of transport

Active transport most commonly refers to walking and cycling, but other modes include skateboarding, and running. Research has repeatedly shown the health benefits attached to active transport, but other benefits include the potential for active travel to reduce car use, which would reduce congestion, air and noise pollution, as well as energy use and greenhouse gas emissions. Regional authorities have a range of policy options available to them to encourage active transport combined with public means of transport. One of the main objectives is to make active transport more convenient and safer for users, as these factors have a large impact on mobility choices made by citizens.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3b (Road Transportation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 26. Promotion of public means or transport and more energetic ways of transport

Variable	Value	Units	Comments
Number of drivers that reduce car use	A	number	
Annual usage of car avoided per person	B	km	If country-specific information is not available, please use 1000km/year
Gasoline consumption of cars	C	g/km	If country-specific information about the fuel consumption is not available, please use the following from 2019 EEA EMEP Guidebook: Gasoline passenger cars open loop (small-medium-large) - 79g/km Gasoline passenger cars Euro 1 (small - medium - large) - 69g/km Gasoline light commercial conventional - 85g/km Gasoline light commercial Euro 1 - 70g/km
NCV of gasoline	D	TJ/kt	If country-specific information is not available, please use 44.3TJ/kt from 2006 IPCC GLs
CO_2 EF of gasoline	E	tCO_2/TJ	If country-specific information is not available, please use 69.3 tCO_2/TJ from 2006 IPCC GLs
Mitigation effect	=A*B*C*D*E/10^12	$ktCO_2$	Annual Mitigation impact of the PAM.

4.3.9. Generalised mitigation action for Transport sector

This is a generalised mitigation action that reflects the mitigation of GHG emissions due to the implementation of energy efficiency measures, fuel switching, and substituting fossil fuels with low carbon or neutral energy sources. The mitigation effect is associated with the reduction of fossil fuel consumption.

This mitigation action is related to GHG emissions that are reported under CRT category 1A3 (Transport). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 27. Generalised mitigation action for Transport sector

Variable	Value	Units	Comments
Reduction of gasoline consumption	A	TJ	
Reduction of diesel consumption	B	TJ	
Reduction of fuel oil consumption	C	TJ	
CO_2 EF of gasoline	D	tCO_2/TJ	If country-specific information is not available, please use 69.3 tCO_2/TJ (2006 IPCC default)
CO_2 EF of diesel	E	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ (2006 IPCC default)
CO_2 EF of fuel oil	F	tCO_2/TJ	If country-specific information is not available, please use 77.4 tCO_2/TJ (2006 IPCC default)
Mitigation effect	=(A*D+B*E+C*F)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4. Other sectors (Commercial, Residential and Agriculture)

4.4.1. Fuel switch from diesel to NG

This action is related to the mitigation of CO_2 emissions by the replacement of fossil fuels by a lower carbon fuel (replacement of diesel by natural gas). In addition, old diesel boilers are less efficient compared to modern condensing NG-fired ones.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional) and 1A4b (Residential). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 28. Fuel switch from diesel to NG

Variable	Value	Units	Comments
Annual diesel use	A	TJ	
CO_2 EF of diesel	B	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ)(default from 2006 IPCC GLs).
CO_2 EF of NG	C	tCO_2/TJ	If country-specific information is not available, please use 56.1 tCO_2/TJ (default from 2006 IPCC GLs).
Efficiency of old diesel boiler	D	%	If country-specific information is not available, consider that non-condensing heat-only boilers older than 20 years might typically have 60% efficiency
Efficiency of new NG boiler	E	%	If country-specific information is not available, consider that a modern condensing (made in the last 10 years) typically have >90% efficiency (around 95%).
Mitigation effect	=(A*B-A*D/E*C)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.2. Fuel switch from diesel to biomass efficient boilers

Biomass is considered to be carbon neutral, regarding the direct CO_2 emissions associated with their combustion, on the grounds that the carbon dioxide absorbed by the plants through photosynthesis is equivalent to the CO_2 released during their combustion. The replacement of fossil fuels with biomass results in mitigation of the associated with fossil fuels CO_2 emissions. In addition, old diesel boilers are less efficient compared to modern biomass boilers.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional), 1A4b (Residential) and 1A4c (Agriculture). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 29. Fuel switch from diesel to biomass efficient boilers

Variable	Value	Units	Comments
Annual diesel use	A	TJ	
CO_2 EF of diesel	B	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ)(default from 2006 IPCC GLs).
CH_4 EF of diesel	C	$kgCH_4/TJ$	If country-specific information is not available, please use 10kg/TJ (default from 2006 IPCC GLs).
CH_4 EF of biomass	D	$kgCH_4/TJ$	If country-specific information is not available, please use 300kg/TJ (default from 2006 IPCC GLs).
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon

Variable	Value	Units	Comments
Efficiency of old diesel boiler	F	%	If country-specific information is not available, consider that non-condensing heat-only boilers older than 20 years might typically have 60% efficiency
Efficiency of new biomass boiler	G	%	If country-specific information is not available, a modern biomass boiler typically have efficiency around 80% and above. The efficiency depends also on the type of fuel (pellets, wooden chips, logs etc).
Mitigation effect	=(A*B+A*C*E/1000-A*F/G*D*E/1000)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.3. Fuel switch from diesel to biomass high efficiency stoves

Biomass is considered to be carbon neutral, regarding the direct CO_2 emissions associated with their combustion, on the grounds that the carbon dioxide absorbed by the plants through photosynthesis is equivalent to the CO_2 released during their combustion. The replacement of fossil fuels with biomass results in mitigation of the associated with fossil fuels CO_2 emissions. In addition, old diesel boilers are less efficient compared to modern eco-designed stoves.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional) and 1A4b (Residential). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 30. Fuel switch from diesel to biomass high efficiency stoves

Variable	Value	Units	Comments
Annual diesel use	A	TJ	
CO_2 EF of diesel	B	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ)(default from 2006 IPCC GLs).
CH_4 EF of diesel	C	$kgCH_4/TJ$	If country-specific information is not available, please use 10 kg/TJ (default from 2006 IPCC GLs).
CH_4 EF of biomass	D	$kgCH_4/TJ$	If country-specific information is not available, please use 300 kg/TJ (default from 2006 IPCC GLs).
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Efficiency of old diesel boiler	F	%	If country-specific information is not available, consider that non-condensing heat-only boilers older than 20 years might typically have 60% efficiency
Efficiency of new biomass boiler	G	%	If country-specific information is not available, please consider that eco-design compliant wood stoves must have a minimum efficiency of 75% compared with the current CE requirement of 65%.
Mitigation effect	=(A*B+A*C*E/1000-A*F/G*D*E/1000)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.4. Retrofitting of buildings towards improving energy efficiency

Retrofitting a building involves changing its systems or structure after its initial construction and occupation. This work can improve amenities for the building's occupants and improve the energy efficiency of the building by interventions in the building shell, upgrading the heating systems, etc. The mitigation effect comes from the reduction of fossil fuels for heating and cooling needs.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional) and 1A4b (Residential). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 31. Retrofitting of buildings towards improving energy efficiency

Variable	Value	Units	Comments
No of households	A	number	
Average size of households	B	m2	
Average energy consumption of households (heating needs)	C	kWh/m2/year	This parameter needs to be provided by the country. Sources: national statistics agencies, regional and international databases, e.g. https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/heating-consumption-per-m2.html
CO_2 EF of fossil fuels used for heating	D	tCO_2/TJ	If country-specific information is not available, please use 74.1 tCO_2/TJ for diesel and 56.1tCO_2/TJ for NG (defaults from 2006 IPCC GLs).
Efficiency of boiler	E	%	If country-specific information is not available, consider that non-condensing diesel heat-only boilers older than 20 years might typically have 60%

Variable	Value	Units	Comments
			efficiency. NG old boilers may have 70% efficiency.
Energy efficiency improvements from retrofitting (building shell and heating system upgrade)	F	%	The energy savings could be in the range of 25-60%[15]. If country-specific information is not available, please use 30%.
kWh to TJ	3.6*10^(-6)		
Mitigation effect	=A*B*C*D*3.6*10(-6)*F/E/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.5. Switching to efficient residential air conditioners

Three-quarters of all homes in the United States have air conditioners. Air conditioners use about 6% of all the electricity produced in the United States, at an annual cost of about $29 billion to homeowners. As a result, roughly 117 million metric tons of carbon dioxide are released into the air each year. Switching to high-efficiency air conditioners and taking other actions to keep your home cool could reduce energy use for air conditioning by 20% to 50%.[16] The mitigation effect comes from the reduction of electricity use for cooling needs.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional) and 1A4b (Residential). The following estimation

[15] https://assets.sustainability.vic.gov.au/susvic/Report-Energy-Comprehensive-Energy-Efficiency-Retrofits-to-Existing-Victorian-Houses-PDF.pdf

https://doi.org/10.1007/s12053-019-09834-7

http://dx.doi.org/10.1016/j.scs.2017.02.017

[16] https://www.energy.gov/energysaver/air-conditioning

methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 32. Switching to efficient residential air conditioners

Variable	Value	Units	Comments
No of air conditioners	A	Number	
Daily usage	B	hours/day	
Annual usage	C	days/year	
Cooling capacity	D	BTU/h	Residential air-conditioners have a capacity of 9000, 12000, 18000 or 24000 BTU/h
Conversion of BTU/h to kW	1/3412		1kW = 3412 BTU/h
EER of old inefficient air-conditioners	E	(no units)	EER is the ratio of generated cooling per electricity input. Old inefficient air conditioners have an EER less than 3.
EER of new efficient air-conditioners	F	(no units)	New efficient air-conditioners have an EER more than 4, around 5.
Specific CO_2 EF of the grid	G	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=A*B*C*D*(1/E-1/F)/3412*G/10^9	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.6. Switching to efficient residential refrigerators

Fridges demand a lot of electricity to keep them running. Unlike many other appliances, they are left on and using energy all day, every day. Energy-efficient fridges simply use less electricity, enabling you to cut back on your power bills and reduce the associated CO_2 emissions.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional) and 1A4b (Residential). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 33. Switching to efficient residential refrigerators

Variable	Value	Units	Comments
No of refrigerators	A	Number	
Refrigerator wattage	B	Watt	The average home refrigerator uses 350-780 watts
Daily operation	C	Hours	Refrigerator power usage depends on different factors, such as the size and age, the kitchen's ambient temperature, the type of refrigerator, etc. Refrigerators run about 8-10 hours per day. Some old refrigerators may run more hours due to technical problems and / or inefficient type.
Annual electricity consumption of old (to be replaced) refrigerator	D=A*B*C*365/1000	kWh/year	The consumption depends on the size, operating conditions and energy efficiency class of the refrigerator. Annual consumption of old inefficient refrigerators may range from are 450kWh/year (class D), 550 kWh/year (class E), 650 kWh/year (class F) and >800 kWh/year (class F). 25 years old refrigerators may consume around 1400 kWh/year. The consumption depends also on the size and operating conditions.
Efficiency of the new refrigerator	E	%	Depending on the type, age and condition of the old fridge this could be from 15 to 60%. Default for calcs could be 35%.
Reduced electricity consumption of new refrigerators	F=D*(1-E)	kWh/year	
Specific CO_2 EF of the grid	G	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=F*G/10^9	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.7. Switching to efficient domestic lighting with LEDs

Although once known mainly for indicator and traffic lights, Light Emitting Diodes (LEDs) in white light, general illumination applications are today's most energy-efficient and rapidly-developing lighting technology. LEDs use up to 90% less energy and last up to 25 times longer than traditional incandescent bulbs.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional) and 1A4b (Residential). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 34. Switching to efficient domestic lighting with LEDs

Variable	Value	Units	Comments
Number of bulbs	A	number	
W of replaced bulbs	B	Watt	The average value is 60W
W of LED Bulbs	C	Watt	The equivalent to 60W incandescent light bulb is 6W
Daily operation	D	Hours	It depends on the country, as default use 7 hours
Specific CO_2 EF of the grid	E	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=A*(B-C)*D*E*365/10^12	$ktCO_2$	Annual Mitigation impact of the PAM.

4.4.8. Generalised mitigation action for Other sectors

This is a generalised mitigation action that reflects the mitigation of GHG emissions due to the implementation of energy efficiency measures, fuel switching and substituting fossil fuels with low carbon or neutral energy sources. The mitigation effect is associated with the reduction of fossil fuel and electricity consumption.

This mitigation action is related to GHG emissions that are reported under CRT category 1A4a (Commercial/Institutional), 1A4b (Residential) and 1A4c (Agriculture). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 35. Generalized mitigation action for Transport sector

Variable	Value	Units	Comments
Reduction of fossil fuel consumption	A	TJ	
CO_2 EF of fuel	B	tCO_2/TJ	If country-specific information is not available, please use the following: Anthracite 98.3 tCO_2/TJ, Coking coal 94.6 tCO_2/TJ, Other bituminous coal 94.6 tCO_2/TJ, Sub-bituminous coal 96.1 tCO_2/TJ, Lignite 101 tCO_2/TJ, HFO 77.4 tCO_2/TJ, NG 56.1 tCO_2/TJ (defaults from 2006 IPCC GLs)
Reduction of electricity use	C	GWh	
Specific CO_2 EF of the grid	D	tCO_2/GWh	This EF reflects both thermal and RES plants.
Mitigation effect	=(A*B+C*D)/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

4.5. Fugitives

4.5.1. Reduction of coal mining in surface mines

This action is related to the reduction of the use of solid fuels in power sector and industry. As a result, there is a decreasing trend of production of solid fuels from mines (anthracite, subbituminous coal, lignite, etc.). In addition, all intentional and unintentional emissions from the extraction, processing, storage and transport of solid fuels to the point of final use are decreased.

This mitigation action is related to GHG emissions that are reported under CRT category 1B1aii (Surface mines). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 36. Reduction of coal mining in surface mines

Variable	Value	Units	Comments
Reduction of coal extraction from surface mines	A	tonnes	
CH_4 EF	B	m3/tonne	If country-specific information is not available, please use the f2006 IPCC default: 1.2m3/tonne (extraction) + 0.1m3/tonne (post mining)
Density of CH_4	C	$ktCH_4$/m3	0.67*10^(-6) kt/m3
GWP of CH_4	D	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D	$ktCO_2$	Annual Mitigation impact of the PAM.

4.5.2. Reduction of coal mining in underground mines

This action is related to the reduction of the use of solid fuels in power sector and industry. As a result, there is a decreasing trend of production of solid fuels from mines (anthracite, subbituminous coal, lignite, etc.). In addition, all intentional and unintentional emissions from the extraction, processing, storage and transport of solid fuels to the point of final use are decreased.

This mitigation action is related to GHG emissions that are reported under CRT category 1B1ai (Underground mines). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 37. Reduction of coal mining in underground mines

Variable	Value	Units	Comments
Reduction of coal extraction from underground mines	A	tonnes	
CH_4 EF	B	m3/tonne	If country-specific information is not available, please use the f2006 IPCC default: 18m3/tonne (extraction) + 2.5m3/tonne (post mining)
Density of CH_4	C	kt CH_4 /m3	0.67*10^(-6) kt/m3
GWP of CH_4	D	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D	$ktCO_2$	Annual Mitigation impact of the PAM.

5. PAMS – Industrial Processes and Product Use (IPPU)

The following provides information by PAM for the sector. As a relevant note when inputting parameters in units of %, MITICA requires data to be entered as percentages and not as fractions (e.g., input 10% as 10, not as 0.1). Additionally, methodologies for all PAMs are related to inventory methodologies in the categories affected. For the full methodologies and background information, please consult 2006 IPCC Guidelines and its 2019 Refinement.

5.1. Replacement of clinker with other physical raw materials with hydraulic properties

The substitution of clinker by physical raw materials in cement reduces both combustion emissions (1A2) and the emissions originated from limestone (2A1). The substitutes of clinker need to have hydraulic properties, which means the product hardens when water is added, such as pozzolan, fly ash, etc.

This mitigation action is related to GHG emissions that are reported under CRT category 2A1 (Cement production). In this section, the mitigation effect associated with process-related emissions is estimated. The effect on combustion-related emissions is estimated and reported under 1A2f category.

The following estimation methods (see table 36 or table below) can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 38. Replacement of clinker with other physical raw materials with hydraulic properties

Variable	Value	Units	Comments
Cement production	A	tons	
Share in clinker (reference)	B	%	If country specific information is not available use 70%
Share in clinker	C	%	If country specific information is not available use 50%

Variable	Value	Units	Comments
(reduction option)			
EF of clinker production	D	tonnes CO_2 / ton clinker	If country specific information is not available use the default 2006 IPCC, which is 0.52
Mitigation effect	=A*(B-C)*D/1000	$ktCO_2$	Annual Mitigation impact of the PAM.

5.2. N2O abatement from nitric acid production

N_2O emissions in nitric acid plants can be abated by the installation of non-selective catalytic reduction (NSCR), (a NOX abatement technology that can also be managed to abate N_2O).

This mitigation action is related to GHG emissions that are reported under CRT category 2B2 (Nitric Acid Production). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 39. N2O abatement from nitric acid production

Variable	Value	Units	Comments
Nitric acid production	A	tons	
N_2O EF	B	kgN_2O/tonne nitric acid	If country specific information is not available, please refer to Table 3.3 of volume 3 / chapter 3 of the 2006 IPCC GLs: High pressure plants - 9 kgN_2O/tonne nitric acid Medium pressure combustion plants 7-9 kgN_2O/tonne nitric acid Atmospheric pressure plants (low pressure) 5-9 kgN_2O/tonne nitric acid
N_2O EF with NSCR abatement	C	kgN_2O/tonne nitric acid	2 kgN_2O/tonne nitric acid

Variable	Value	Units	Comments
GWP of N_2O	D	$ktCO_2eq/ktN_2O$	GWP (SAR) is 310 GWP (AR4) is 298 GWP (AR5) is 265 for 100-year time horizon
Mitigation effect	=A*(B-C)*D/1000000	$ktCO_2$	Annual Mitigation impact of the PAM.

5.3. Substitution of high GWP F-gases with low GWP ones

Hydrofluorocarbons (HFCs) and, to a very limited extent, perfluorocarbons (PFCs), are serving as alternatives to ozone depleting substances (ODS) being phased out under the Montreal Protocol. HFCs and PFCs have high global warming potentials (GWPs) and, in the case of PFCs, long atmospheric residence times. A large number of blends containing HFCs and/or PFCs are being used in Refrigeration and Air Conditioning applications.

The mitigation effect comes from the ban of the use of high GWP F-gases and their replacement by other F-gases or chemicals with lower GWP.

This mitigation action is related to GHG emissions that are reported under CRT category 2F1 (Refrigeration and Air Conditioning). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 40. Substitution of high GWP F-gases with low GWP ones

Variable	Value	Units	Comments
Number of equipments which are filled with new low GWP f-gas	A	Numbers	
GWP of f-gas that is replaced	B	$ktCO_2/kt$ fgas	Please refer to https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Variable	Value	Units	Comments
GWP of f-gases that is being used	C	$ktCO_2/kt$ fgas	Please refer to https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf
Charge of f-gas	D	kg	If country specific information is not available, please refer to Table 7.9 of volume 3 / chapter 7 of the 2006 IPCC GLs
Emission Factor during operation (% of initial charge/year)	E	%	If country specific information is not available, please refer to Table 7.9 of volume 3 / chapter 7 of the 2006 IPCC GLs
Initial charge remaining during end of life	F	%	If country specific information is not available, please refer to Table 7.9 of volume 3 / chapter 7 of the 2006 IPCC GLs
Recovery efficiency	G	%	If country specific information is not available, please refer to Table 7.9 of volume 3 / chapter 7 of the 2006 IPCC GLs
Lifetime	H	Years	If country specific information is not available, please refer to Table 7.9 of volume 3 / chapter 7 of the 2006 IPCC GLs
Mitigation effect	=(A*D*E+A*D*F*G/H)*(B-C)/1000000	$ktCO_2$	Annual Mitigation impact of the PAM.

6. PAMS - AFOLU (Agriculture, Forestry and Other Land Use

The following provides information by PAM for the sector. As a relevant note when inputting parameters in units of %, MITICA requires data to be entered as percentages and not as fractions (e.g., input 10% as 10, not as 0.1). Additionally, methodologies for all PAMs are related to inventory methodologies in the categories affected. For the full methodologies and background information, please consult [2006 IPCC Guidelines and its 2019 Refinement].

6.1. Livestock and Manure Management

6.1.1. Improved feeding practices

Methane emissions from herbivores is a by-product of enteric fermentation (a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream). Ruminant animals (e.g., cattle, sheep) are major sources with moderate amounts produced from non-ruminant animals (e.g., pigs, horses).

Methane emissions can be reduced by feeding more concentrates, normally replacing forages. Although concentrates may increase daily methane emissions per animal, emissions per kg feed intake and per kg-product are almost invariably reduced. The magnitude of this reduction per kg-product decreases as production increases. The net benefit of concentrates, however, depends on reduced animal numbers or younger age at slaughter for beef animals, and on how the practice affects land use, the N content of manure and emissions from producing and transporting the concentrates.

This mitigation action is related to GHG emissions that are reported under CRT category 3A (Enteric Fermentation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Livestock category – Dairy cattle

Table 41. Improved feeding practices

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for daily cattle from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 4%, East Asia 10%, West Asia 6%, Southeast Asia 6%, Central Asia 6% Oceania 22% North America 16%, South America 6%, Central America 3% Africa 1% N/S/W Europe 18%, Eastern Europe 11%, RF 10%, Japan 17%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 42. Livestock category – Beef cattle

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for beef cattle from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 2%, East Asia 5%, West Asia 3%, Southeast Asia 3%, Central Asia 3% Oceania 14% North America 11%, South America 3%, Central America 2% Africa 1% N/S/W Europe 12%, Eastern Europe 6%, RF 5%, Japan 11%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 43. Livestock category – Dairy Buffalo

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for daily buffalo from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 4%, East Asia 10%, West Asia 6%, Southeast Asia 6%, Central Asia 6%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 44. Livestock category – Non-dairy Buffalo

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for Non-dairy Buffalo from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 2%, East Asia 5%, West Asia 3%, Southeast Asia 3%, Central Asia 3%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 45. Livestock category – Sheep

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for sheep from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.

Variable	Value	Units	Comments
Percentage of livestock that improved feeding practices are applied	B	%	
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 2%, East Asia 3%, West Asia 2%, Southeast Asia 2%, Central Asia 2% Oceania 6% North America 4%, South America 2%, Central America 2% Africa 1% N/S/W Europe 4%, Eastern Europe 3%, RF 3%, Japan 4%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.1.2. Feed additives for ruminant diets

This mitigation action is considered with respect to its potential for reducing emissions of CH_4 from enteric fermentation. There are a several materials which could be added to livestock feeds in order to reduce CH_4 emissions. Such additives may work directly, by reducing the conversion of carbohydrate to CH_4 or indirectly, by improving animal performance and thereby reducing emissions intensity.

Feed additives could be propionate precursors, fats, ionophores, etc. The mitigation potential is based on the estimation of the effect of fat supplementation, as the best validated of the additives.

This mitigation action is related to GHG emissions that are reported under CRT category 3A (Enteric Fermentation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 46. Feed additives for ruminant diets

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for ruminant from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that fat supplementation is applied	B	%	
Fat content before	C	%	Increasing the fat content of the diet proportionally reduces enteric CH_4 emissions from cattle by approximately 5% for each 1% increase. Nutritional and practical aspects impose a limit of 5 to 6% of dry matter as total fat content.[17]
Fat content after	D	%	
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*(D-C)*E*5	$ktCO_2eq$	Annual Mitigation impact of the PAM.

[17] Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V., and Longhitano, D. (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

6.1.3. Optimization of feeding strategies for livestock

This mitigation action aims to optimize dietary intake by balancing the feed intake with the requirements of the animals. Streamlining diets to the required amounts of N, limits the amounts excreted without any effects to the animal performance. GHG reductions are implemented via reductions in direct and indirect N_2O emissions from excreta and manure as a result of reducing N excretion.

This mitigation action is related to GHG emissions that are reported under CRT category 3B (Manure Management). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 47. Livestock category – Pigs

Variable	Value	Units	Comments
N_2O emissions from manure management of pigs	A	ktN_2O	N2O Emissions for pigs from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that feeding optimisation is applied	B	%	
N excretion reduction	C	%	Reductions could be of the range 5 to 60% for pigs, depending upon current feeding practice.[18]
GWP of N_2O	D	$ktCO_2eq/ktCH_4$	GWP (SAR) is 310 GWP (AR4) is 298 GWP (AR5) is 265 for 100-year time horizon
Mitigation effect	=A*B*C*D	$ktCO_2eq$	Annual Mitigation impact of the PAM.

[18] Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V., and Longhitano, D. (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

Table 48. Livestock category – Poultry

Variable	Value	Units	Comments
N_2O emissions from manure management of poultry	A	ktN_2O	N2O Emissions for poultry from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that feeding optimisation is applied	B	%	
N excretion reduction	C	%	Reductions could be of the range 10 to 35% for pigs, depending upon current feeding practice.
GWP of N_2O	D	$ktCO_2eq/ktCH_4$	GWP (SAR) is 310 GWP (AR4) is 298 GWP (AR5) is 265 for 100-year time horizon
Mitigation effect	=A*B*C*D	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 49. Livestock category – Cattle

Variable	Value	Units	Comments
N_2O emissions from manure management of cattle	A	ktN_2O	N2O Emissions for cattle from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that feeding optimisation is applied	B	%	

Variable	Value	Units	Comments
N exertion reduction	C	%	Reductions could be of the range 25 to 50% for pigs, depending upon current feeding practice.
GWP of N_2O	D	$ktCO_2eq/ktCH_4$	GWP (SAR) is 310 GWP (AR4) is 298 GWP (AR5) is 265 for 100-year time horizon
Mitigation effect	=A*B*C*D	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.1.4. Longer-term management changes and animal breeding

This mitigation action is associated with the breeding of ruminants with reduced CH_4 emission intensity as concerns enteric fermentation. This is achieved by reducing the number of animals that are required to produce the same amount of products (meat, milk), by reducing the finishing period for meat animals, by having larger animals that produce less emissions per unit output compared to smaller breeds.

This mitigation action is related to GHG emissions that are reported under CRT category 3A (Enteric Fermentation). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 50. Livestock category – Dairy cattle

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for dairy cattle from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding	B	%	

Variable	Value	Units	Comments
practices are applied			
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: N/S/W Europe 4%, Eastern Europe 3%, RF 3%, Japan 3% South Asia 1%, East Asia 3%, West Asia 1%, Southeast Asia 1%, Central Asia 1% Oceania 5% North America 3%, South America 2%, Central America 1% Africa 0.4%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 51. Livestock category – Beef cattle

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for beef cattle from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	

Variable	Value	Units	Comments
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: N/S/W Europe 3%, Eastern Europe 7%, RF 6%, Japan 3% South Asia 1%, East Asia 6%, West Asia 2%, Southeast Asia 2%, Central Asia 2% Oceania 3% North America 3%, South America 3%, Central America 2% Africa 0.6%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 52. Livestock category – Dairy Buffalo

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for dairy buffalo from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	

Variable	Value	Units	Comments
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 1%, East Asia 3%, West Asia 2%, Southeast Asia 2%, Central Asia 2%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 53. Livestock category – Non-dairy Buffalo

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for non-dairy buffalo from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	

Variable	Value	Units	Comments
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: South Asia 2%, East Asia 7%, West Asia 3%, Southeast Asia 3%, Central Asia 3%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 54. Livestock category – Sheep

Variable	Value	Units	Comments
CH_4 emissions from enteric fermentation	A	$ktCH_4$	CH4 Emissions for sheep from latest inventory year. If available, emissions can be calculated with projected Activity Data using the Emission Factors from the latest inventory.
Percentage of livestock that improved feeding practices are applied	B	%	

Variable	Value	Units	Comments
Technical reduction potential enteric methane emissions	C	%	Default values from IPCC WGIII AR4: N/S/W Europe 0.3%, Eastern Europe 0.3%, RF 0.3%, Japan 0.3% South Asia 0.1%, East Asia 0.3%, West Asia 0.1%, Southeast Asia 0.1%, Central Asia 0.1% Oceania 0.4% North America 0.3%, South America 0.2%, Central America 0.2% Africa 0.04%
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*C*D*E	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.1.5. Improving animal health through better monitoring

Livestock diseases cause a reduction of animal performance and decreased output. Improvements in livestock disease management will improve efficiency of livestock production and reduce emissions.

This mitigation action is related to GHG emissions that are reported under CRT category 3A (Enteric Fermentation) and 3B (Manure Management). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 55. Improving animal health through better monitoring

Variable	Value	Units	Comments
CH_4 and N_2O emissions from enteric fermentation and manure management.	A	$ktCO_2eq$	Emissions from categories 3A and 3B from the WoM. This value is automatically selected by MITICA. There is no need to introduce it.
Percentage of livestock that improved feeding practices are applied	B	%	
Technical reduction potential enteric methane emissions	C	%	-According to a Spanish study GHG emission intensity was reduced by 2.5% by a preventive program for mastitis in dairy cows. - By increasing routine disease treatment in Scottish sheep, GHG emission intensity was decreased by 5-22%. -An eradication programme for BVD resulted in Dairy herd: 2% improvement in milk production per animal and a 3% reduction in replacement rate and Beef herd: 3% improvement in replacement rate leading to a 1.5% reduction in GHG emissions. -An implementation of disease mitigation measures for ten cattle diseases in UK resulted in reduction of emission intensity of cattle herd by 2-6%.
Efficiency of the application of the measure	D	%	It should be estimated according to national circumstances. As default value, please use 100%
Mitigation effect	=A*B*C*D	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.2. Forestry

6.2.1. Afforestation and reforestation

Afforestation and reforestation results in the enhancement of carbon sequestration in soils, biota, and long-lived products through increases in the area of carbon-rich ecosystems such as forests. According to IPCC definitions, afforestation describes forest planting activities on sites that have not been forested within the last 50 years, while reforestation refers to sites that have been stocked by forest plants within the last 50 years.

This mitigation action is related to GHG emissions that are reported under CRT category 4A (Forest land). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis. Option 1 is linked to the WoM scenario; while Option 2 reflects a more detailed estimation method. These two options are provided as different possibilities to estimate the effect of the PAM, each requiring different data.

Option 1 – simple approach directly linked to WoM

Table 56. Option 1 – simple approach directly linked to WoM

Variable	Value	Units	Comments
CO_2 Emissions from Category 'Land Converted to Forest Land'	A	$ktCO_2$/year	Source: National GHG Inventory
Area of 'Land Converted to Forest Land'	B	ha	Source: National GHG Inventory
Emissions from Land Converted to Forest	C=A/B	$ktCO_2$/year/ha	

Variable	Value	Units	Comments
Land per hectare			
Afforested land	D	ha	
Mitigation potential	E=C*D	$ktCO_2$/year	Annual Mitigation impact of the PAM.

Table 57. Option 2 – more detailed approach

Variable	Value	Units	Comments
Afforested land	A	ha	
Average annual above-ground biomass growth, Gw	B	t dm/(ha yr)	Country specific information or values from 2006 IPCC GLs, Table 4.10, Volume 4 / Chapter 4
Ratio of below-ground biomass to above-ground biomass, R	C		Country specific information or values from 2006 IPCC GLs, Table 4.4, Volume 4 / Chapter 4.
Average annual biomass growth above- and below-ground, Gtotal	D=B*(1+C)	t dm/(ha yr)	
Carbon fraction of dry matter, CF	E	tC / t dm	Country specific information or values from 2006 IPCC GLs, Table 4.3, Volume 4 / Chapter 4.

Variable	Value	Units	Comments
Annual increase in biomass carbon stocks due to biomass growth ΔCG	F=A*D*E	tC/yr	
Annual loss of carbon ΔCL	G	%	Country specific information. If information is not available use 10% - 20%
Carbon sequestered in soil	H	tCO_2eq/ha	1.47 to 1.83 t CO_2eq sequestered in soil per ha per year, assuming that arable land is afforested.
Mitigation effect	=F*(1-G)*44/12/1000+A*H/1000	$ktCO_2/year$	Annual Mitigation impact of the PAM.

6.2.2. Restoration of degraded forests

Protecting secondary forests and other degraded forests whose biomass and soil C densities are less than their maximum value and allowing them to sequester C by natural or artificial regeneration, rehabilitation of degraded lands, long-term fallows.

This mitigation action is related to GHG emissions that are reported under CRT category 4A (Forest land). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 58. Restoration of degraded forests

Variable	Value	Units	Comments
Degraded forest land protected	A	Ha	
Average annual above-ground	B	t dm/(ha yr)	Country specific information or values from 2006 IPCC GLs, Table 4.9, Volume 4 / Chapter 4. There is an assumption that

Variable	Value	Units	Comments
biomass growth, Gw			this annual growth of biomass will be restored to degraded forests.
Ratio of below-ground biomass to above-ground biomass, R	C		Country specific information or values from 2006 IPCC GLs, Table 4.4, Volume 4 / Chapter 4.
Average annual biomass growth above- and below-ground, Gtotal	D=B*(1+C)	t dm/(ha yr)	
Carbon fraction of dry matter, CF	E	tC / t dm	Country specific information or values from 2006 IPCC GLs, Table 4.3, Volume 4 / Chapter 4.
Annual increase in biomass carbon stocks due to biomass growth ΔCG	F=A*D*E	tC/yr	
Annual loss of carbon ΔCL	G	%	Country specific information. If information is not available use 10% - 20%
Mitigation effect	=F*(1-G)*44/12/1000	$ktCO_2$/year	Annual Mitigation impact of the PAM.

6.2.3.Reducing deforestation

Conservation of existing carbon (C) pools in forest vegetation and soil by controlling deforestation protecting forest in reserves and controlling other anthropogenic disturbances such as fire and pest outbreaks. Reducing slash and burn agriculture, reducing forest fires.

This mitigation action is related to GHG emissions that are reported under CRT category 4A (Forest land). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis. Option 1 is linked to the WoM scenario; while option 2 reflects a more detailed estimation method.

Table 59. Option 1 – simple approach directly linked to WoM

Variable	Value	Units	Comments
CO_2 emission from Forest Land Converted to Grassland	A	$ktCO_2$/year	CO_2 Emissions from the National GHG Inventory
CO_2 emission Forest Land Converted to Cropland	B	$ktCO_2$/year	CO_2 Emissions from the National GHG Inventory
CO_2 emission Forest Land Converted to Settlements	C	$ktCO_2$/year	CO_2 Emissions from the National GHG Inventory
Forest land converted to Grassland	D	Ha	Activity data from the National GHG Inventory
Forest land converted to Cropsland	E	Ha	Activity data from the National GHG Inventory
Forest land converted to Settlements	F	Ha	Activity data from the National GHG Inventory
Emissions from deforestation per hectare (Grassland)	G=A/D	$ktCO_2$/year/ha	
Emissions from deforestatio	H=B/E	$ktCO_2$/year/ha	

Variable	Value	Units	Comments
n per hectare (Cropland)			
Emissions from deforestation per hectare (Settlements)	I=C/F	$ktCO_2$/year/ha	
Forest land for which deforestation was prevented	J	Ha	
Mitigation effet	K=((G+H+I)/3)*J	$ktCO_2$/year	Annual Mitigation impact of the PAM.

Table 60. Option 2 – more detailed approach

Variable	Value	Units	Comments
Forest land for which deforestation was prevented	A	Ha	
Above-ground biomass in forests	B	t dm/ha	Country specific information or values from 2006 IPCC GLs, Table 4.7, Volume 4 / Chapter 4.
Ratio of below-ground biomass to above-ground biomass, R	C		Country specific information or values from 2006 IPCC GLs, Table 4.4, Volume 4 / Chapter 4.
Above- and below-ground biomass in forests	D=B*(1+C)	t dm/ha	
Carbon fraction of dry matter, CF	E	tC / t dm	Country specific information or values from 2006 IPCC GLs, Table 4.3, Volume 4 / Chapter 4.
Biomass carbon stock which was not deforested	F=A*D*E	tC	
Average carbon stock per hectare of post-deforestation land use	G	tC/ha	Country specific information or values from 2006 IPCC GLs, Table 4.4, Volume 4 / Chapter 4.
Post-deforestation carbon stock	H=G*A	tC	

Variable	Value	Units	Comments
Mitigation effect	=(F-H)*44/12/1000	$ktCO_2$/ year	Annual Mitigation impact of the PAM. Assuming instantaneous oxidation of deforested biomass.

6.3. Croplands and Grasslands

6.3.1. Reduced and Zero Tillage

Advances in weed control methods and farm machinery allow many crops to be grown with minimal tillage (reduced tillage) or without tillage. Zero tillage is best suited for semi-arid areas and is generally less compatible with crop systems in high rainfall areas where yields and crop residues are high. This mitigation action is better suited to self-structuring soils with significant clay content than sandy soils. This mitigation action is considered with respect to its potential for saving energy used for soil cultivation, and sequestering carbon (C) in the soil. Only where crop yields (or total production through avoidance of fallow) are increased by the introduction of zero tillage is C sequestration likely to occur.

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 61. Reduced and Zero Tillage

Variable	Value	Units	Comments
Area where the reduced / zero tillage practices are applied	A	ha	

Variable	Value	Units	Comments
Technical reduction potential from carbon sequestration and reduced CO_2 emissions from fuel consumption of agriculture machinery	B	tCO_2eq/ha	Reduced tillage 0.21 Zero tillage 0.29 tCO_2eq/ha[19]
Mitigation effect	=A*B/1000	$ktCO_2 eq$	Annual Mitigation impact of the PAM.

6.3.2. Agronomic practices: Residue management

Leaving crop residues in the soil after harvest will enable greater C retention in soils compared to removing them. However, the extent of C sequestration depends on the initial C soil and potential soil C capacity; the soil clay content (clay soils have greater potential for C retention); rainfalls during growing seasons and soil water-holding capacity; and the C:N ration of crop residues (smaller C:N rations favouring sequestration).

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 62. Agronomic practices: Residue management

Variable	Value	Units	Comments
Area with crop residue management	A	ha	

[19] McVittie, A (2014) Report on the cost-effectiveness of SOC measures (Deliverable 3.2 of SmartSOIL collaborative project KBBE-2001-5. Sustainable management of agricultural soils in Europe for enhancing food and feed production and contributing to climate change mitigation) http://smartsoil.eu/fileadmin/www.smartsoil.eu/Deliverables/D3_2_Final.pdf

Variable	Value	Units	Comments
Technical reduction potential from carbon sequestration	B	tCO_2eq/ha	0.11 to 2.2 t/ha CO_2eq [20]
Mitigation effect	=A*B/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.3. Agronomic practices: cease of field burning of vegetation and agricultural waste

Burning of agricultural residues and vegetation to clear the fields produces air emissions of PMs, CO, NOx etc. It also produces small amounts of CH_4 and N_2O. The gain from this mitigation action is the avoidance of removing crop residues from the field which may result in an increase of SOC levels.

This mitigation action is related to GHG emissions that are reported under CRT category 3F (Field burning of agricultural residues). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 63. Agronomic practices: cease of field burning of vegetation and agricultural waste

Variable	Value	Units	Comments
Area where field burning is avoided	A	ha	

[20] Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin.

Posthumus, H., Deeks, L.K., Rickson, R.J and Quinton, J.N (2013) Costs and benefits of erosion control measures in the UK. Soil Use and Management, DOI: 10.1111/sum.12057

Variable	Value	Units	Comments
Technical reduction potential from carbon sequestration	B	tCO_2eq/ha	0.11 to 2.2 t/ha CO_2eq [21]
Mitigation effect	=A*B/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.4. Agronomic practices: temporary vegetative cover

The group of agronomic practices that provide temporary vegetative cover between successive agricultural crops, reduce the duration of bare fallow, or between rows of tree or vine crops. These 'catch' or 'cover' crops add carbon to soils and may also extract plant available N unused by the preceding crop, thereby reducing N_2O emissions.

This mitigation action is related to GHG emissions that are reported under CRT category 3D (Agricultural soils). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 64. Agronomic practices: temporary vegetative cover

Variable	Value	Units	Comments
Area affected by vegetative cover	A	ha	
Technical reduction potential from cover crops	B	tCO_2eq/ha	0.88-1.47 $tCO_2eq/ha/yr$ [22]
Mitigation effect	=A*B/1000	$ktCO_2eq$	

[21] Ibid.

[22] Poeplau C and Don A (2015) Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis, Agriculture, Ecosystems and Environment, 200, 33-41.

6.3.5. Soil and nutrient management plan

A soil management plan provides a framework for the identification of soil erosion risks and their abatement through the implementation of multiple actions which in general are cost effective over a number of years. A Nutrient management plan aims at improving the nutrient (nitrogen) efficiency of a cropland, with the aim to reduce the total application of N fertilizers. Applying management practices from these plants contributes to increase or maintain of soil carbon levels and decrease of N_2O emissions.

This mitigation action is related to GHG emissions that are reported under CRT category 3D Agricultural soils. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 65. Soil and nutrient management plan

Variable	Value	Units	Comments
Direct and indirect N_2O emissions from managed soils	A	$ktCO_2eq$	Emissions based on projected AD and the Efs used in the latest year of inventory, without estimating any abatement due to improved practices from the implementation of soil and nutrient management plans
% of cropland area that soil and nutrient plans are applied	B	%	
Technical reduction potential from carbon sequestration	C	%	2-5% of baseline emissions (value A) [23]
Mitigation effect	=A*B*C	$ktCO_2eq$	Annual Mitigation impact of the PAM.

[23] DG Climate Action, 2016, Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming, Specific contract number 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A.4/FRA/2011/0027

6.3.6. Biological N fixation in rotations and in forages

Legumes can fix in excess of 300 kg N/ha/y making the N input comparable with N fertilizer applications. Legumes also provide N to subsequent crops and are a useful break crop in arable rotations. This mitigation action is related to a reduction of N_2O emissions from a decreased application of N fertilizers.

This mitigation action is related to GHG emissions that are reported under CRT category 3D Agricultural soils; this is considered under the Total for all land-use categories in CRT tables.. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 66. Biological N fixation in rotations and in forages

Variable	Value	Units	Comments
Area where grain legumes replace cereals or other arable crops in a rotation	A	ha	
Technical reduction potential from avoidance of N_2O emissions	B	tCO_2eq/ha	1.04 $tCO_2eq/ha/yr$ [24]
Areas of additional forage legumes	C	ha	
Technical reduction potential from avoidance of N_2O emissions	D	tCO_2eq/ha	0.17 $tCO_2eq/ha/yr$(0.6-2.7 $tCO_2eq/ha/yr$) [25]
Mitigation effect	=(A*B+C*D)/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

[24] Pellerin S., Bamière L., Angers D., Béline F., Benoît M., Butault J.P., Chenu C., Colnenne-David C., De Cara S., Delame N., Doreau M., Dupraz P., Faverdin P., Garcia-Launay F., Hassouna M., Hénault C., Jeuffroy M.H., Klumpp K., Metay A., Moran D., Recous S., Samson E., Savini I., Pardon L., 2013. How can French agriculture contribute to reducing greenhouse gas emissions? Abatement potential and cost of ten technical measures. Synopsis of the study report, INRA (France), 92 pgs.

[25] Ibid.

6.3.7. Water management

Expanding irrigated land or using more effective irrigation measures can enhance carbon storage in soils through enhanced yields and residue returns. According to the IPCC special report on Land Use, Land-Use Change and Forestry (2000), because most irrigation is located in arid and semi-arid regions, many irrigable soils are inherently low in soil organic carbon in their native state, therefore by converting dryland soils to irrigated agriculture may increase soil organic carbon content in the soil by 0.05-0.15 t C ha-1 yr-1, with a modal rate of 0.10 t C ha-1 yr-1.

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 67. Water management

Variable	Value	Units	Comments
Conversion of dryland soils to irrigated croplands	A	ha	
Increase of soil organic carbon content	B	tC/ha/yr	0.05-0.15 t C ha-1 yr-1, with a modal rate of 0.10 t C ha-1 yr-1. [26]
Mitigation effect	=A*B/1000*44/12	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.8. Development of new fruit orchards

Perennial woody vegetation in orchards and vineyards can store significant carbon in long-lived biomass, the amount depending on species type and cultivar, density, growth rates, and harvesting and pruning practices. To estimate the mitigation potential, it is assumed that these plantations accumulate biomass linearly until they reach maturity,

[26] IPCC, 2000 - Robert T. Watson, Ian R. Noble, Bert Bolin, N. H. Ravindranath, David J. Verardo and David J. Dokken (Eds.), Land Use, Land-Use Change and Forestry, Cambridge University Press, UK. pp 375

assumed to be at half the replacement cycle. During maturity biomass increases are offset by losses from pruning - in order for the tree to be retained to the desired form - and natural mortality, and hence changes in living biomass are assumed to be zero. The annual growth rate (GW), during the growth period, is derived thus by dividing biomass stock at maturity by the time from crop establishment to reach maturity.

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 68. Vineyards

Variable	Value	Units	Comments
Area of new vineyards	A	ha	It was assumed that these plantations accumulate biomass linearly until they reach maturity, assumed to be at half the replacement cycle. During maturity biomass increases are offset by losses from pruning - in order the tree to be retained to the desired form - and natural mortality, and hence changes in living biomass are assumed to be zero. The annual growth rate (GW), during the growth period, is derived thus by dividing biomass stock at maturity by the time from crop establishment to maturity reach.
Average Aboveground fresh biomass stock	B	t fresh b/ha	Default value is 20 t fresh b/ha
Biomass moisture	C	%	Default value is 40%
Average Aboveground biomass stock	D=B*(1-C)	t dm/ha	
Carbon fraction of dry matter	E	t C/t dm	Default value is 0.5
Average aboveground biomass C stock	F=D*E	t C/ha	

Variable	Value	Units	Comments
Harvest cycle	G	yr	Default value is 26yr
Annual C uptake from crop growth	H=F/(G/2)	t C/ha yr	
Mitigation effect	=A*H*44/12/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

Table 69. Fruit orchards

Variable	Value	Units	Comments
Area of new fruit plantations	A	ha	It was assumed that these plantations accumulate biomass linearly until they reach maturity, assumed to be at half the replacement cycle. During maturity biomass increases are offset by losses from pruning - in order the tree to be retained to the desired form - and natural mortality, and hence changes in living biomass are assumed to be zero. The annual growth rate (GW), during the growth period, is derived thus by dividing biomass stock at maturity by the time from crop establishment to maturity reach.
Average Aboveground fresh biomass stock	B	t fresh b/ha	Default value is 80 t fresh b/ha
Biomass moisture	C	%	Default value is 40%
Average Aboveground biomass stock	D=B*(1-C)	t dm/ha	
Carbon fraction of dry matter	E	t C/t dm	Default value is 0.5
Average aboveground biomass C stock	F=D*E	t C/ha	
Harvest cycle	G	yr	Default value is 26yr

Variable	Value	Units	Comments
Annual C uptake from crop growth	H=F/(G/2)	t C/ha yr	
Mitigation effect	=A*H*44/12/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.9. Rice management

Cultivated wetland rice soils emit significant quantities of methane. Emissions during the growing season can be reduced by various practices, such as draining wetland rice once or several times during the growing season reduces CH_4 emissions. Rice cultivars with low exudation rates could offer an important methane mitigation option. In the off-rice season, methane emissions can be reduced by improved water management, especially by keeping the soil as dry as possible and avoiding water logging. Increasing rice production can also enhance soil organic carbon stocks. Methane emissions can be reduced by adjusting the timing of organic residue additions (e.g., incorporating organic materials in the dry period rather than in flooded periods), by composting the residues before incorporation, or by producing biogas for use as fuel for energy production.

This mitigation action is related to GHG emissions that are reported under CRT category 3C (Rice Cultivations). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

The following estimation method corresponds to the practice of conversion of irrigated rice plantation from continuous flooding to intermittently flooded with a single aeration of more than 3 days during the cropping season.

Table 70. Rice management

Variable	Value	Units	Comments
Rice area where the management is changed	A	ha	
Cultivation period	B	days/year	
Daily CH_4 emission factor before change	C	$kgCH_4$/ha/day	1.3 (default $kgCH_4$/ha/day from 2006 IPCC GLs) Assumption: no flooding for

Variable	Value	Units	Comments
			less than 180 days prior to rice cultivation, and continuously flooded during rice cultivation without organic amendments
Scaling factor	D	-	0.60 (single aeration) 0.52 (multiple aeration)
Scaled daily CH_4 emission factor after change	E=C*D	$kgCH_4$/ha/day	
GWP of CH_4	F	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=A*B*(C-D)*F/1000000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.10. Agroforestry

Agro-forestry is the production of livestock or food crops on land that also grows trees for timber, firewood, or other tree products. It includes shelter belts and riparian zones/buffer strips with woody species. The standing stock of carbon above ground is usually higher than the equivalent land use without trees, and planting trees may also increase soil carbon sequestration.

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland) and 4C (Grassland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 71. Agroforestry

Variable	Value	Units	Comments
Area that agroforestry practices are applied	A	ha	

Variable	Value	Units	Comments
Carbon sequestration in soil	B	t CO_2eq/ha/yr	0.15 to 0.88 t CO_2eq sequestered in soil per ha per year [27]
Area of new plantation of trees that are integrated in croplands and grasslands (pastures)	C	ha	The estimation of the mitigation potential is based on poplar trees
C sequestration in above and below ground biomass	D	tC/ha/yr	Assumptions for estimating mitigation impact: poplars (140 trees/ha) of 13 years old have on average sequestered 540 kg C/tree in the trunk and 60 kg C/tree in the root system. The potential of sequestering C is 6.5 tonnes C/(ha year) in the trees (above and below ground biomass) [28]
Mitigation effect	=(A*B+ C*D*44/12)/1000	ktCO_2eq	Annual Mitigation impact of the PAM.

6.3.11. Grazing land management and pasture improvement

The following are examples of practices to reduce GHG emissions and to enhance removals:

[27] Frelih-Larsen, A., MacLeod, M., Osterburg, B., Eory, A. V., Dooley, E., Kätsch, S., Naumann, S., Rees, B., Tarsitano, D., Topp, K., Wolff, A., Metayer, N., Molnar, A., Povellato, A., Bochu, J.L., Lasorella, M.V. and Longhitano, D (2014) "Mainstreaming climate change into rural development policy post 2013." Final report. Ecologic Institute, Berlin

[28] Aertsens J, De Nocker L and Gobin A (2013) Valuing the carbon sequestration potential for European agriculture, Land Use Policy, 31, 584-594.

(a) Grazing intensity: The intensity and timing of grazing can influence the removal, growth, carbon allocation, and flora of grasslands, thereby affecting the amount of carbon accrual in soils

(b) Increase productivity: through irrigation and / or alleviating nutrient deficiencies.

(c) Nutrient management: practices aiming at improving nitrogen efficiency.

(d) Fire management: practices that reduce the frequency and extent of fires.

(e) Species introduction: Introducing grass species with higher productivity, or carbon allocation to deeper roots.

This mitigation action is related to GHG emissions that are reported under CRT category 4C (Grassland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 72. Grazing land management and pasture improvement

Variable	Value	Units	Comments
Area of pastureland improved	A	ha	
Transition period for soils	B	years	20 years (default value from 2006 IPCC GLs)
SOCref	C	tC/ha	This parameter is country specific and should be included in the national inventory. Default values per climate region and soil type are available at Table 2.3 / Volume 4 / Chapter 2 of 2006 IPCC GLs.
Stock change factor F (LU)	D	-	2006 IPCC default is 1
F (MG) before	E	-	2006 IPCC defaults (Table 6.2 Volume 4/ Chapter 6): 1 for Non degraded land 0.95-0.96 for moderately degraded grassland 0.7 for severely degraded

Variable	Value	Units	Comments
F (MG) after	F	-	2006 IPCC defaults (Table 6.2 Volume 4/ Chapter 6): 1.14-1.17 for improved grassland
F (I) input before	G	-	2006 IPCC defaults (Table 6.2 Volume 4/ Chapter 6): 1 for medium input and 1.11 for high input
F (I) input after	H		2006 IPCC defaults (Table 6.2 Volume 4/ Chapter 6)
SOC before	I=C*D*E*G		
SOC after	J=C*D*F*H		
Mitigation effect	=A*(J-I)/B/1000*44/12	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.12. Land cover (use) change: Conversion of arable land to grassland

One of the most effective methods of reducing emissions is often to allow or encourage the reversion of cropland to another land cover, typically one similar to the native vegetation. The conversion can occur over the entire land area ('set-asides'), or in localized spots, such as grassed waterways, field margins, or shelterbelts, marginal arable land that was historically kept as grazing land, such as steeply sloping land or shallow soils. Arable land converted to grassland must be maintained as grassland to maintain the climate benefit of sequestered carbon because reversion to annual cultivation will release the C sequestered under grass.

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland) and 4C (Grassland). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 73. Land cover (use) change: Conversion of arable land to grassland

Variable	Value	Units	Comments
Arable land converted to grassland	A	ha	

Variable	Value	Units	Comments
Increase of soil organic carbon content	B	$tCO_2eq/ha/yr$	2.2 to 7.3 t CO_2e sequestered in soil per ha per year [29]
Mitigation effect	=A*B/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.13. Land cover (use) change: Wetland conservation / restoration (drained croplands back to wetlands)

Restoration of wetlands help to reduce GHG emissions from decomposition of peat and restoring the natural water table of drained wetlands. With an increased water table in organic, carbon-rich soils, accumulation of organic substances is greater than the decomposition, which facilitates the conservation and accumulation of peat and reduces the carbon release from these soils.

This mitigation action is related to GHG emissions that are reported under CRT category 4B (Cropland) and 4D (Wetlands). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 74. Land cover (use) change: Wetland conservation / restoration (drained croplands back to wetlands)

Variable	Value	Units	Comments
Area of wetland conservation / restoration	A	ha	

[29] Ammann C, Flechard CR, Leifeld J, Neftel A and Fuhrer J (2007) The carbon budget of newly established temperate grassland depends on management intensity, Agriculture Ecosystems and Environment, 121: 5–20.

Lugato, E., Bampa, F., Panagos, P., Montanarella, L. and Jones, A (2014) Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices, Global Change Biology, 20, 3557-3567.

Variable	Value	Units	Comments
Increase of soil organic carbon content	B	$tCO_2eq/ha/yr$	1.3 to 8.2 t per ha per year [30]
Mitigation effect	=A*B/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.14. Management of organic/peaty soils

Organic or peaty soils contain high densities of carbon accumulated over many centuries because decomposition is suppressed by absence of oxygen under flooded conditions. To be used for agriculture, these soils are drained, which aerates the soil, favouring decomposition and therefore, high CO_2 and N_2O fluxes. Methane emissions are usually suppressed after draining, but this effect is far outweighed by pronounced increases in N_2O and CO_2. Emissions from drained organic soils can be reduced to some extent by practices such as avoiding row crops and tubers, avoiding deep ploughing, and maintaining a shallower water table. But the most important mitigation practice is avoiding the drainage of these soils in the first place or re-establishing a high-water table.

This mitigation action is related to GHG emissions that are reported under CRT category 4D (Wetlands). The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 75. Management of organic/peaty soils

Variable	Value	Units	Comments
Area of managed peat soils	A	ha	
Technical reduction potential from conservation of organic soils	B	tCO_2eq/ha	Annual mitigation potential in each climate region (source: IPCC AR4 WG3): 33.51 (cool-dry, cool-moist), 70.18 (warm-dry, warm-moist)

[30] DG Climate Action, 2016, Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming, Specific contract number 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A.4/FRA/2011/0027

Variable	Value	Units	Comments
Mitigation effect	=A*B/1000	$ktCO_2eq$	Annual Mitigation impact of the PAM.

6.3.15. Nitrification inhibitors (which slow the microbial processes leading to N_2O formation)

Nitrification inhibitors are chemical compounds that slow down nitrification process of the conversion of ammonium ions (NH4+) to NO3-. Inhibitors can potentially be applied, as part of mineral N fertilizer formulations, to manures in storage and when spread to land, be sprayed on grazed land periodically at critical times of enhanced nitrification or be dosed to animals via slow-release boluses.

This mitigation action is related to GHG emissions that are reported under CRT categories 3C4 (Direct N_2O Emissions from Managed Soils) and 3C5 (Indirect N_2O Emissions from Managed Soils) ; this is considered under the Total for all land-use categories in CRT tables. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 76. Nitrification inhibitors (which slow the microbial processes leading to N2O formation)

Variable	Value	Units	Comments
Direct and indirect N_2O emissions from managed soils	A	$ktCO_2eq$	Emissions based on projected AD and the Efs used in the latest year of inventory, without estimating any abatement due to improved practices from the implementation of soil and nutrient management plans
% of managed soils where inhibitors were applied	B	%	

Variable	Value	Units	Comments
Technical reduction potential	C	%	39% for AN and 69% for urea [31]
Mitigation effect	=A*B*C	$ktCO_2eq$	Annual Mitigation impact of the PAM.

[31] DG Climate Action, 2016, Effective performance of tools for climate action policy - meta-review of Common Agricultural Policy (CAP) mainstreaming, Specific contract number 340202/2014/688088/SER/CLIMA.A.2 implementing Framework Contract CLIMA.A.4/FRA/2011/0027

7.PAMS - Waste sector

The following provides information by PAM for the sector. As a relevant note when inputting parameters in units of %, MITICA requires data to be entered as percentages and not as fractions (e.g., input 10% as 10, not as 0.1). Additionally, methodologies for all PAMs are related to inventory methodologies in the categories affected. For the full methodologies and background information, please consult 2006 IPCC Guidelines and its 2019 Refinement.

7.1. Solid waste

7.1.1. Methane recovery in Solid Waste Disposal Sites (SWDS)

CH_4 is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites. It can be recovered and combusted in a flare or energy device. The mitigation effect comes from the recovery of methane (biogas) that is not released and recovered.

This mitigation action is related to GHG emissions that are reported under CRT category 5A Solid Waste Disposal. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis. Option 1 is linked to the WoM scenario; while option 2 reflects a more detailed estimation method.

Table 77. Option 1 – simple approach directly linked to WoM

Variable	Value	Units	Comments
GHG emissions from SWDS reported under WoM scenario	A	kt CO_2eq	These emissions have been estimated in the WoM scenario, under IPCC category 4 A Solid Waste Disposal. They correspond to CH_4 that is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites.
Population served by the new well managed solid	B	capita	-

Variable	Value	Units	Comments
waste disposal sites with methane recovery			
Total population served by solid waste disposal sites (SWDS) in the country	C	capita	This parameter was used to estimate A in the WoM scenario.
Methane recovery rates in existing SWDS used in calculations of WoM scenario.	D	%	This can be extracted from the methodology used in the latest inventory year.
Methane recovery rates in the well managed SWDS with new methane recovery systems	E	%	The default recovery efficiency of biogas is 20% of SWDS under operation.
Mitigation effect	=A*(B/C)*((E-D)/(1-D))	kt CO_2eq	Annual Mitigation impact of the PAM.

Table 78. Option 2 – more detailed approach

Variable	Value	Units	Comments
Population served by the new well managed solid waste disposal site (SWDS)	A	capita	
Municipal solid waste (MSW) generation rate	B	tonnes/capita/yr	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1. Please provide the generation rate in wet basis
Fraction disposed to SWDS	C	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1
Fraction of waste type - Food waste	D	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3

Variable	Value	Units	Comments
Fraction of waste type - Garden	E	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Paper	F	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Wood and straw	G	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Textiles	H	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Disposable nappies	I	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
DOC-Food waste	J	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Garden	K	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Paper	L	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Wood and straw	M	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Textiles	N	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Disposable nappies	O	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4.

Variable	Value	Units	Comments
			Please provide the DOC content in % of wet waste.
DOCf	P		If country-specific information is not available, please use the 2006 IPCC default, which is 0.5
Methane correction factor (MCF)	Q		1.0 for managed aerobic
Fraction of CH_4 in generated landfill gas (volume fraction)	0.5		
Methane recovery	R	%	The default recovery of biogas is 20% of SWDS under operation.
Average time taken to decay half of initial degradable content of waste (average half time)	S		If country-specific information is not available, please use 10 years (expert judgement based on Table 3.4 of 2006 IPCC GLs.
CH_4 generation potential before the improvement	T=A*B*C*(D*J+E*K+F*L+G*M+H*N+I*O)*P*0.5*Q*16/12/1000	$ktCH_4$	
CH_4 generation potential after the improvement	U=A*B*C*(D*J+E*K+F*L+G*M+H*N+I*O)*P*0.5*Q*(1-R)*16/12/1000	$ktCH_4$	
GWP of CH_4	V	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=(T-U)/(2*S)*V	kt CO_2eq	Annual Mitigation impact of the PAM.

7.1.2. Reduction of biodegradable material that is disposed in SWDS

Treatment and disposal of municipal, industrial and other solid waste produces significant amounts of methane (CH_4) from the decomposition of degradable organic material. The mitigation effect comes from the reduction of biodegradable material that is disposed in landfills. By this way CH_4 emissions are reduced.

This mitigation action is related to GHG emissions that are reported under CRT category 5A Solid Waste Disposal. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis. Option 1 is linked to the WoM scenario; while option 2 reflects a more detailed estimation method.

Table 79. Option 1 – simple approach directly linked to WoM

Variable	Value	Units	Comments
GHG emissions from SWDS reported under WoM scenario	A	kt CO_2eq	These emissions have been estimated in the WoM scenario, under IPCC category 4 A Solid Waste Disposal. They correspond to CH_4 that is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites.
Reduction of biodegradable material	B	%	It depends on the national policies targeting the reduction of biodegradable material that ends up to landfills. For example, according to landfill directive, EU set reduction targets of biodegradable municipal waste going to landfills of 35-75%.
Mitigation effect	=A*B	kt CO_2eq	Annual Mitigation impact of the PAM.

Table 80. Option 2 – more detailed approach

Variable	Value	Units	Comments
Population served by the new well managed solid waste disposal site (SWDS)	A	capita	
Municipal solid waste (MSW) generation rate	B	tonnes/capita/yr	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1. Please provide the generation rate in wet basis
Fraction disposed to SWDS	C	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1
Fraction of waste type - Food waste	D	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Garden	E	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Paper	F	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Wood and straw	G	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Textiles	H	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Disposable nappies	I	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3

Variable	Value	Units	Comments
DOC-Food waste	J	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Garden	K	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Paper	L	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Wood and straw	M	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Textiles	N	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Disposable nappies	O	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOCf	P		If country-specific information is not available, please use the 2006 IPCC default, which is 0.5
Methane correction factor (MCF)	Q		0.5 for managed semi-aerobic 1.0 for managed aerobic

Variable	Value	Units	Comments
Fraction of CH_4 in generated landfill gas (volume fraction)	0.5		
Methane recovery	R	%	The default recovery of biogas is 20% of SWDS under operation.
Average time taken to decay half of initial degradable content of waste (average half time)	S		If country-specific information is not available, please use 10 years (expert judgement based on Table 3.4 of 2006 IPCC GLs).
Reduction of biodegradable material	T	%	It depends on the national policies targeting the reduction of biodegradable material that ends up to landfills. For example, according to landfill directive, EU set reduction targets of biodegradable municipal waste going to landfills of 35-75%.
CH_4 generation potential before the improvement	U=A*B*C*(D*J+E*K+F*L+G*M+H*N+I*O)*P*0.5*Q*(1-R)*16/12/1000	ktCH_4	
CH_4 generation potential after the improvement	V=A*B*C*(D*J+E*K+F*L+G*M+H*N+I*O)*P*0.5*Q*(1-R)*16/12/1000*(1-T)	ktCH_4	
GWP of CH_4	W	ktCO_2eq/ktCH_4	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=(U-V)/(2*S)*W	kt CO_2eq	Annual Mitigation impact of the PAM.

7.1.3. Reduction of waste production per capita

The mitigation effect comes from the reduction of municipal solid waste generation rates per person, trough awareness campaigns and other policies such as "pay as you throw" taxes.

This mitigation action is related to GHG emissions that are reported under CRT category 5A Solid Waste Disposal. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 81. Reduction of waste production per capita

Variable	Value	Units	Comments
GHG emissions from SWDS reported under WoM scenario	A	kt CO_2eq	These emissions have been estimated in the WoM scenario, under IPCC category 4 A Solid Waste Disposal. They correspond to CH_4 that is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites.
Waste per capita generation rate used in WoM scenario	B	kg/cap/yr	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1.
Reduced waste per capita generation rate due to the effect of awareness campaigns and other policies (e.g. taxes, etc)	C	kg/cap/yr	
Mitigation effect	=A*C/B	kt CO_2eq	Annual Mitigation impact of the PAM.

7.1.4. Composting of organic municipal waste

The mitigation effect comes from the diversion of biodegradable material from SWDS to composting.

This mitigation action is related to GHG emissions that are reported under CRT category 5A Solid Waste Disposal. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis. Option 1 is linked to the WoM scenario; while option 2 reflects a more detailed estimation method.

Table 82. Option 1 – simple approach directly linked to WoM

Variable	Value	Units	Comments
GHG emissions from SWDS reported under WoM scenario	A	kt CO_2eq	These emissions have been estimated in the WoM scenario, under IPCC category 4 A Solid Waste Disposal. They correspond to CH_4 that is produced from anaerobic microbial decomposition of organic matter in solid waste disposal sites.
Total municipal solid waste disposed to managed and unmanaged disposal sites according to WoM scenario	B	kt	The total waste going to disposal sites has been estimated in the WoM scenario (waste per capita * population * % to SWDS)
Biodegradable part of MSW	C	%	The default IPCC value is 65%.
Amount of waste that is diverted from SWDS to composting facilities	D	kt	It depends on the national policies targeting the reduction of biodegradable material that ends up to landfills. For example, according to landfill directive, EU set reduction targets of biodegradable municipal waste going to landfills of 35-75%.

Variable	Value	Units	Comments
CH_4 EF of composting	4	gCH_4/kg waste wet basis	2006 IPCC default
N_2O EF of composting	0.24	gN_2O/kg waste wet basis	2006 IPCC default
GWP of CH_4	E	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
GWP of N_2O	F	$ktCO_2eq/ktN_2O$	GWP (SAR) is 310 GWP (AR4) is 298 GWP (AR5) is 265 for 100-year time horizon
Mitigation effect	=A*(D/(B*C))-D*(4*E+0.24*F)/1000	$ktCO_2$	It is considered that the amount of waste that is composted consists of 100% biodegradable material.

Table 83. Option 2 – more detailed approach

Variable	Value	Units	Comments
Population served by the new well managed solid waste disposal site (SWDS)	A	capita	
Municipal solid waste (MSW) generation rate	B	tonnes/capita/yr	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1. Please provide the generation rate in wet basis
Fraction disposed to SWDS	C	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.1 and Table 2A.1
Fraction of waste type - Food waste	D	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3

Variable	Value	Units	Comments
Fraction of waste type - Garden	E	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Paper	F	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Wood and straw	G	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Textiles	H	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
Fraction of waste type - Disposable nappies	I	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.3
DOC-Food waste	J	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Garden	K	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Paper	L	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Wood and straw	M	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOC-Textiles	N	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.

Variable	Value	Units	Comments
DOC-Disposable nappies	O	%	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 2 / Table 2.4. Please provide the DOC content in % of wet waste.
DOCf	P		If country-specific information is not available, please use the 2006 IPCC default, which is 0.5
Methane correction factor (MCF)	Q		1.0 for managed aerobic 0.5 for managed semi-aerobic 0.8 for unmanaged - deep 0.4 for unmanaged - shallow 0.6 for uncategorized SWDS
Fraction of CH_4 in generated landfill gas (volume fraction)	0.5		
Methane recovery	R	%	The default recovery of biogas is 20% of SWDS under operation.
Average time taken to decay half of initial degradable content of waste (average half time)	S		If country-specific information is not available, please use 10 years (expert judgement based on Table 3.4 of 2006 IPCC GLs.
Fraction of waste that is diverted from SWDS to composting facilities	T	%	It depends on the national policies targeting the reduction of biodegradable material that ends up to landfills. For example, according to landfill directive, EU set reduction targets of biodegradable municipal waste going to landfills of 35-75%.
CH_4 EF of composting	4	gCH_4/kg waste wet basis	2006 IPCC default
N_2O EF of composting	0.24	gN_2O/kg waste wet basis	2006 IPCC default

Variable	Value	Units	Comments
GWP of CH_4	U	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
GWP of N_2O	V	$ktCO_2eq/ktN_2O$	GWP (SAR) is 310 GWP (AR4) is 298 GWP (AR5) is 265 for 100-year time horizon
CH_4 generation potential	W=A*B*C*(D*J+E*K+F*L+G*M+H*N+I*O)*P*0.5*Q*(1-R)*16/12/1000	$ktCH_4$	
Mitigation effect	=W*T/(2*S)-A*B*C*(4*U+0.24*V)/1000000	kt CO_2eq	Annual Mitigation impact of the PAM.

7.1.5- Diversion of solid waste from unmanaged disposal sites to aerobic landfills

The mitigation effect comes from the reduction of methane emissions due to aerobic conditions. It is assessed through the MCF factor.

This mitigation action is related to GHG emissions that are reported under CRT category 5A Solid Waste Disposal. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 84. Diversion of solid waste from unmanaged disposal sites to aerobic landfills

Variable	Value	Units	Comments
GHG emissions from SWDS reported under WoM scenario	A	kt CO_2eq	These emissions have been estimated in the WoM scenario, under IPCC category 4 A Solid Waste Disposal. They correspond to CH_4 that is produced from anaerobic microbial

Variable	Value	Units	Comments
			decomposition of organic matter in solid waste disposal sites.
Total municipal solid waste disposed to SWDS according to WoM scenario	B	kt	The total waste going to disposal sites has been estimated in the WoM scenario (waste per capita * population * % to SWDS)
Amount of waste that is diverted from unmanaged SWDS to aerobic SWDS	C	kt	
MCF of unmanaged sites	D		For Unmanaged – deep (>5 m waste) and /or high water table use 0.8. For Unmanaged – shallow (<5 m waste) use 0.4 For Uncategorised SWDS use 0.6. Source: 2019 Refinement to 2006 IPCC GLs.
MCF of aerobic SWDS	E		For Managed well – semi-aerobic use 0.5. For Managed well – active-aeration use 0.4. Source: 2019 Refinement to 2006 IPCC GLs.
Mitigation effect	=A*(C/B)*(1-E/D)	kt CO_2eq	In case that E>=D, then there is no mitigation effect.

7.2. Wastewater

7.2.1. Improvement of the wastewater treatment infrastructure

The mitigation effect comes from the reduction of the percentage of wastewater that is treated under anaerobic system or conditions.

This mitigation action is related to GHG emissions that are reported under CRT category 5D1 Domestic Wastewater Treatment and Discharge. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 85. Improvement of the wastewater treatment infrastructure

Variable	Value	Units	Comments
Population served by the new aerobic system	A	capita	
BOD per capita in domestic wastewater	B	g/capita/yr	If country-specific information is not available, please refer to 2006 IPCC GLs volume 5 / chapter 6 / Table 6.4 or 2019 Refinement to 2006 IPCC GLs / Table 6.4
Correction factor for additional industrial BOD discharged into sewers (I)	C		Parameter I expresses the BOD from industries and establishments (e.g., restaurants, butchers or grocery stores) that is co-discharged with domestic wastewater. For co-discharged the default is 1.25, else the default is 1.00.
Total organics in wastewater in inventory year	D=A*B*C /1000	kg BOD/yr	
Maximum CH_4 producing capacity (Bo) for domestic wastewater	E	kg CH_4 / kg BOD	If country-specific information is not available, please use the 2006 IPCC default value 0.6 kg CH_4 / kg BOD

Variable	Value	Units	Comments
Methane correction factor (MCF) of previous used anaerobic system or poorly operated aerobic system	F		Please refer to 2019 Refinement of 2006 IPCC GLs Table 6.3: Not well managed aerobic plant MCF=0.3 Stagnant sewer (open and warm) MCF=0.5 Discharge to aquatic environments (Tier 1) MCF=0.11 Discharge to aquatic environments other than reservoirs, lakes, and estuaries (Tier 2) MCF=0.035 Discharge to reservoirs, lakes, and estuaries (Tier 2) MCF=0.19 Anaerobic shallow lagoon and facultative lagoons MCF=0.2 Anaerobic deep lagoon MCF=0.8 Latrine, dry climate (small family) MCF=0.1 Latrine, dry climate (many users) MCF=0.5 Latrine, wet climate MCF=0.7 Latrine with regular sediment removal for fertilizer MCF=0.1 Septic tank MCF=0.5
MCF of aerobic treatment plant	G		MCF is 0.03 for Centralised, aerobic treatment plant
GWP of CH_4	H	$ktCO_2eq/ktCH_4$	GWP (SAR) is 21 GWP (AR4) is 25 GWP (AR5) is 28 for 100-year time horizon
Mitigation effect	=D*E*(F-G)*H/1000000	$ktCO_2$	Annual Mitigation impact of the PAM.

7.2.2. Reduction of protein consumption

This mitigation action is related to GHG emissions that are reported under CRT category 5D Domestic Wastewater Treatment and Discharge. The following estimation methods can be applied to estimate the mitigation effect both for ex-post and ex-ante analysis.

Table 86. Improvement of the wastewater treatment infrastructure

Variable	Value	Units	Comments
GHG emissions (N_2O) from domestic wastewater under WoM scenario	A	kt CO_2eq	These emissions have been estimated in the WoM scenario, under IPCC category 4 D1 Domestic Wastewater Treatment and Discharge. They correspond to N_2O that is produced during wastewater treatment.
Annual per capita protein consumption according to WoM	B	kg protein/person/yr	If national statistics on protein consumed or protein supply are not available, Food Balance Sheets of FAOSTAT can be used as activity data on per capita "protein supply quantity." This information represents the total amount of protein available to the population but must be adjusted to reflect the fraction of protein consumed (FPC), according to the Table 6.10a of the 2019 Refinement of the 2006 IPCC GLs.
Reduced annual per capita protein consumption	C	kg protein/person/yr	The reduction of protein consumption is needed in cases that protein consumption per capita is more than 0.8 grams protein per kilogram of body weight for an average sedentary adult. It could be the result of e.g. awareness campaigns about the need for healthier diets.
Total population of the country	D	capita	
Population with healthier diet	E	capita	
Mitigation effect	=A*E/D*(1-C/B)	ktCO_2	Annual Mitigation impact of the PAM.

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