

The Quality System Assurance (QSA) in the German Emission Inventory Using the MESAP-CalQlator

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ABSTRACT

In the last years, the aspect of quality assurance QA has gained more and more importance. In Germany the procedures for quality assurance and quality control will be implemented in the context of the Quality System of Emissions (QSE) and the German National System of Emissions to ensure the application of the IPCC Good Practice Guidance or the EMEP/CORINAIR Emission Inventory Guidebook of the UNECE.

The MESAP information system has been developed during the last five years by the Federal Environmental Agency (UBA) as a standard software tool to support all aspects of setting up an integrated emission inventory – starting from data collection, database management, data processing, data analysis up to the final reporting. In the last year, several mechanisms to ensure quality control and assurance have been built into MESAP to support the Federal Environmental Agency (UBA) in improving transparency, consistency and comparability at all inventory levels.

The advances in the MESAP software development have been accompanied and backed by the future inventory improvement plan launched within the German National System of Emissions which will help to reduce the deviations from good practice. By means of iterative procedures the uncertainties as well as the key sources will be determined again according to the extended IPCC method (Tier 2). Thus UBA will continuously reduce the data gaps in order to improve accuracy and completeness of the German emission inventory.

INTRODUCTION

At the Third Conference of the Parties in Kyoto in 1997 for the first time obligatory delimitation and reduction obligations were specified for the industrialized countries. The obligation for the reduction of the greenhouse gas emissions, transferred by the European community in this framework, was divided in a burden sharing between the member states by the European Union. It is permitted to some European Union countries such as Spain and Portugal to increase their emissions, at the time it has to be compensated by clearly higher reductions in other countries such as Denmark and Germany. In the first obligation period (2008 to 2012) Germany has to make a substantial contribution within the European Union with 21 % emission reductions from the year 1990.

Since 1996 the countries which are designated in the annex I of the climate frame convention must annually convey an inventory of greenhouse gases to the secretariat of the climate frame convention. To fulfill this task the Federal Environmental Agency of Germany developed a national database - the Central System of Emissions (CSE), which complies with various requirements of the

emission calculation and reporting. The inventory planning (e.g. data collection), reporting (e.g. emission computation, recalculation and error analysis) as well as the inventory management (e.g. archiving, annual evaluation of the data) is facilitated by the CSE. The key requirements of the UNFCCC (transparency, consistency, completeness, comparability and accuracy) are implemented in this database system. A quality management and the administrative unit of the National System of Emission (NaSE) set the guidelines for the implementation of the CSE.

In accordance to the Kyoto Protocol (Article 5.1 KP) the National System Emission should combine all mechanisms of a government, to ensure a technically high-quality contribution for the emission inventories. It should establish a system between government mechanisms and other institutions to supply sufficient capacities for emission reporting. It is responsible for the organization and management of the data flow.

THE GERMAN EMISSION INVENTORY – CENTRAL SYSTEM OF EMISSIONS

Quality System Assurance (QSA)

Against the background of the reporting requirements on a comparable and complete emission inventory the application of extensive and methodologically specified procedures for quality assurance and quality control has to be considered in a quality management system. These procedures will be implemented in the context of the Quality System of Emissions (QSE) and the German National System of Emission. The QSE has to ensure the application of the IPCC Good Practice Guidance or of the EMEP/CORINAIR Emission Inventory Guidebook of the UNECE. In the context of an expert review and in accordance with the IPCC guidelines the uncertainties will be calculated, the quality condition of the inventory data will be documented and the deviation from the requirements will be determined. In future an inventory improvement plan will help to organize the reduction of deviations and to fill data gaps. By means of iterative procedures the uncertainties as well as the key sources will be determined again according to the extended IPCC method (Tier 2).

In the database system CSE various technical procedures are implemented to support these quality checks:

- Input of values in original (source) unit and automated unit conversion to the main unit which is stored in the database
- Plausibility control of input data according to predefined plausibility conditions
- Verification of Syntax during set up of calculation methods (equations)
- Consistency check for units in calculation methods
- Integrity checks of calculation results according to predefined technical integrity conditions

The Central System of Emissions (CSE)

The German Emission Inventory is filled with expert information for the main source categories energy, transport, agriculture, production processes etc. Further information is compiled by the Federal Statistical Office Germany, other relevant institutes and by owners of industrial plants. The Central System of Emissions (CSE) is the core database to store all data records, time series, calculation methods and additional information (e.g. documentation, quality etc.) of the main source categories.

The CSE is an emission information system for data collection and processing. At the same time the CSE serves as reporting tool for preparing emission reports in accordance with the international (UNFCCC, UNECE/ EMEP) and national reporting requirements.

The following tasks are supported by the CSE system:

- Data collection of all relevant input data, documentation through manual input or automated import
- Definition of the relevant calculation methods
- Background information and documentation (literature) of the data material
- Calculation of composed activity rates and emission factors, of emissions and uncertainties
- Support of QA measures in the inventory
- Generation of reports for UNFCCC, UNECE, etc.
- Support of the expert review teams and of national experts during the review process

The MESAP-Software for the CSE

The MESAP software, which was developed according to the requirements of the Federal Environmental Agency, supports all phases and tasks of emission reporting, improves the quality of the results and reduces the time necessary to prepare the reports. The requirements for the software were

- to store any kind of time series with any time resolution,
- to flexibly define calculation methods for these time series,
- to support the review process, i.e. finding data quickly and visualizing it on the spot
- to easily create user defined views on the data for target oriented data entry
- to create reports based on MS Excel format with hotlink to the database
- to expand the database content without the need for programming.

The general objectives can be summarized as follows:

- to accelerate data processing by automation of data import, calculation and report generation,
- to improve data quality of reported data and to increase transparency in data processing by documentation of data sources and calculation methods
- to improve flexibility for making the system easily adaptable to new reporting requirements

The core of MESAP is a powerful relational database system that was optimized to store any kind of time series oriented data. It can be seen as a standardized multidimensional data warehouse for time series, which is highly customizable. Therefore MESAP can be easily adapted to new reporting requirements without modification of the underlying data tables and without programming.

Time series are stored using a customizable multidimensional key. Flexible retrieval functions based on this multidimensional key allow the user to create its own views on the data. Based on these views, MESAP offers a set of user friendly tools to facilitate data entry and to allow for extensive documentation of the origin and quality of the data. The central data management avoids data redundancy and offers a set of interfaces to link to other existing electronic data processing systems.

The MESAP-Module CalQlator is a core element for QA. It provides a high degree of flexibility concerning the mathematical formulation of the calculation methods. All calculation methods are stored and documented as objects within the database. In addition, integrity checks can be defined for each calculation method to check the consistency of calculated results. Together with the functionality of

plausibility checks, defined separately for each time series and executed during data entry, the whole process from data entry to result publication can be accompanied with QA procedures.

The MESAP information system separates data management, calculation methods and reporting. Calculation methods and reports contain only variables linked to the corresponding time series in the database. Only when the calculation is executed or the report is generated, the actual data from the database is inserted. Report generation is Microsoft-Excel based, which allows a high degree of flexibility to create user defined reports containing tabular evaluations and additional calculations for periodical publications. The special architecture of MESAP avoids the well known redundancy and quality control problem of storing data in the Excel-Sheets by establishing hotlinks to the central database management system. A special add-in function in Excel makes it easy to shift the reporting period for a whole sheet.

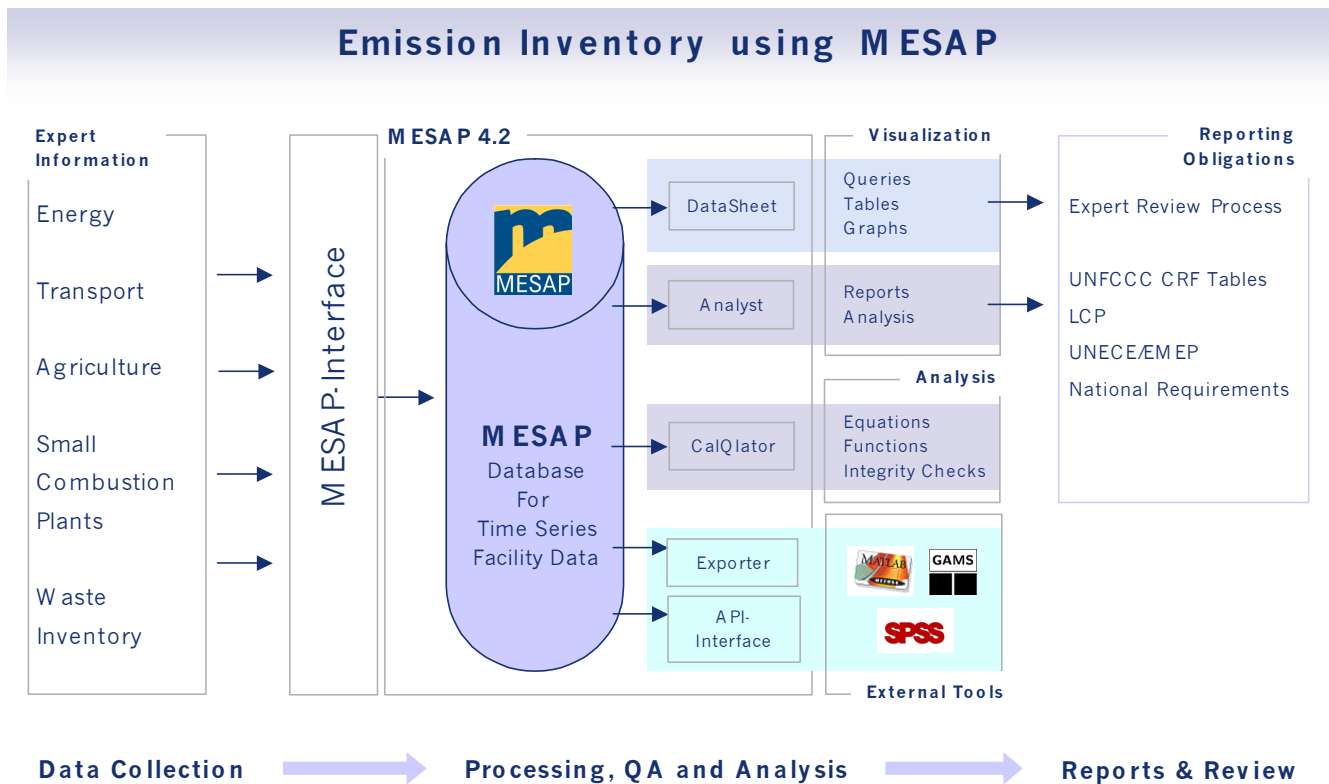


Figure 1. Data Flow in an Emission Inventory using MESAP

MESAP is a client/server based software running on Windows NT/2000/XP. It uses an object oriented 3-tier architecture and is .NET compatible. Three DBMS platforms are supported: MS Access 2000, MS SQL Server 7 and Oracle 8i. MESAP offers an API for the development of customized solutions. MESAP is multi user capable and offers a detailed access right management. A module to access the database and view the data via internet is available.

THE MESAP-CALQLATOR

Functionality of the CalQlator

The CalQlator allows specifying calculation methods which e.g. estimate the emissions from other indicators by some mathematical correlation using data stored in the database. The user establishes

the mathematical equation system and specifies which input variables for the calculation correspond to which time series in the database and which time series are to be used to store the results.

Calculation methods can be grouped together in a hierarchical structure. By this way complex calculations can be broken up transparently into smaller blocks that are easy to control. A status system indicates whether the results of a calculation are up-to-date or whether the calculation has to be re-launched. The execution of calculation jobs can also be scheduled.

Optional there is a possibility within a calculation method to define integrity conditions during the equation setup for input variables and results. The integrity is checked during the process of computation. In addition plausibility checks are available according to predefined rules during data entry.

Definition of Calculation Methods

The main object for the CalQlator is a calculation method. A complete defined calculation method consists of a declaration of all input variables and output variables (results), a specification of the periods of validity and the formulation of equations and integrity conditions using mathematical functions, aggregation functions and indexed (loop) functions.

The Editor is at the center for navigation and management of the calculation methods. The screenshot in Figure 2 shows on the left side the tree which allows navigation through the calculation methods. On the right side is the windows for the variable declaration and for the formulation of the equation syntax. Additionally the user has direct access to the time series data (inputs and outputs) related to a calculation method, by opening a correspondent MESAP DataSheet window.

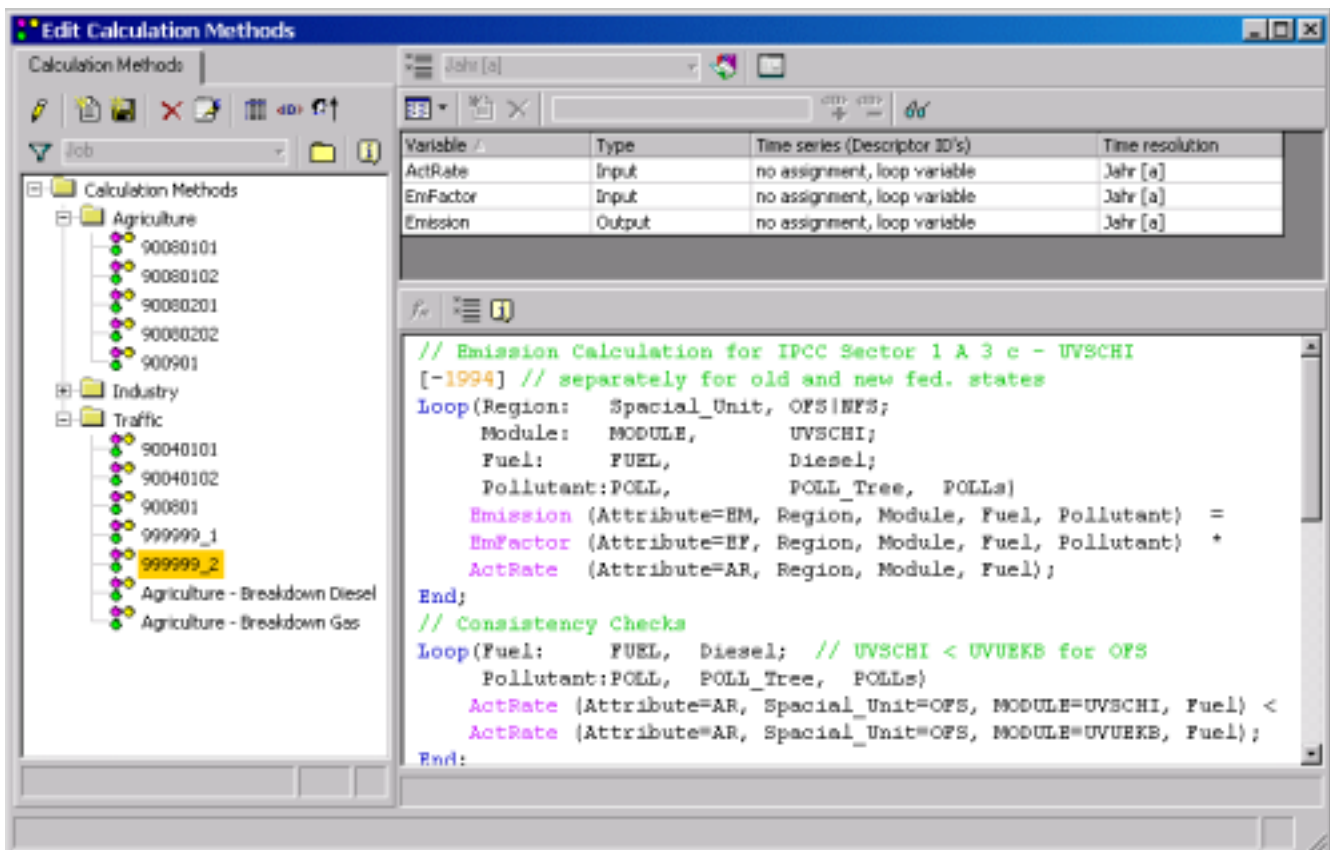


Figure 2. The Editor for Calculation Methods

The calculation method is managed in the database as general MESAP object. Thus it is fully integrated in the access rights management. As a MESAP object, customizable documentation objects may be assigned to it and finally it may be used as filter criteria to retrieve time series data, i.e. to find all time series associated with the calculation method.

Setup of Equations and Integrity Conditions

The mathematical equations of a calculation method consist of input variables and output variables (calculated results), constants and operators. For each variable the following characteristics need to be declared: name, type (input or output), assignment of an existing time series from the database, time resolution. Constants can either be treated as part of the mathematical expression or as a time series as well.

If a variable is used in an indexed equation (loop) no assignment of a time series is possible, since the variable is a placeholder for several different time series. For all variables the time index t is automatically used. But it is also possible to define time lags (e.g. $t-3$, $t+2$).

Variable Δ	Type	Time series (Descriptor ID's)	Time resolution
ActRate	Input	no assignment, loop variable	Year [a]
EmFactor	Input	no assignment, loop variable	Year [a]
Emission	Output	no assignment, loop variable	Year [a]

Figure 3. Declaration of Variables and Assignment of Time Series to Variables

An equation contains variables, operators, functions and the equal sign. For the formulation of the equations a straightforward mathematical syntax is used. The variables are addressed using the variable name. The following functions are available:

- case differentiation (IF, then, else)
- statistical analysis (sum, average, minimum, maximum, standard deviation and variance)
- indexed equations (loops) using control variables to define the number of iterations

Integrity conditions use logical operators instead of the equal sign. If necessary, validity periods may be defined for single equations or group of equations. This is necessary, when a calculation method for a calculated result is changed at a certain point in time. In this case the equations apply only to their specified time window. This feature allows to document, how the equations used for calculation change over time. Comment lines may be added during equation formulation for structuring purposes or to provide additional information or documentation.

The equation editor (figure 4) offers a user friendly environment for entering equations. Different font colors for comments, time points, units, variables, functions key words and errors support the process of equation setup. Additionally a function-sensitive tool tip information helps to specify the arguments for the various functions.

```

fx
// Emission Calculation for IPCC Sector 1 A 3 c - UVSCHI
[-1994] // separately for old and new fed. states
Loop(Region: Spacial_Unit, OFS|NFS;
     Module:  MODULE,      UVSCHI;
     Fuel:    FUEL,        Diesel;
     Pollutant: POLL,      POLL_Tree,  POLLs)
Loop({<loop index>: <dimension>, ({<descriptors>} | <tree>, <node>);} {<equations>...} End; =
     EmFactor (Attribute=EF, Region, Module, Fuel, Pollutant) *
     ActRat  (Attribute=AR, Region, Module, Fuel);
End;
// Consistency Checks
Loop(Fuel:    FUEL, Diesel; // UVSCHI < UVUEKB for OFS
     Pollutant: POLL, POLL_Tree, POLLs)
     ActRate (Attribute=AR, Spacial_Unit=OFS, MODULE=UVSCHI, Fuel) <
     ActRate (Attribute=AR, Spacial_Unit=OFS, MODULE=UVUEKB, Fuel);
End.

```

Figure 4. The Equation Editor

During the variable declaration and the setup of equations the MESAP-DataSheet (figure 5), which is a time series browser, can be launched at any time to display the time series which are assigned to the variables of the calculation method. Thus the related input data as well as results can be accessed directly in the context of the management of calculation methods.

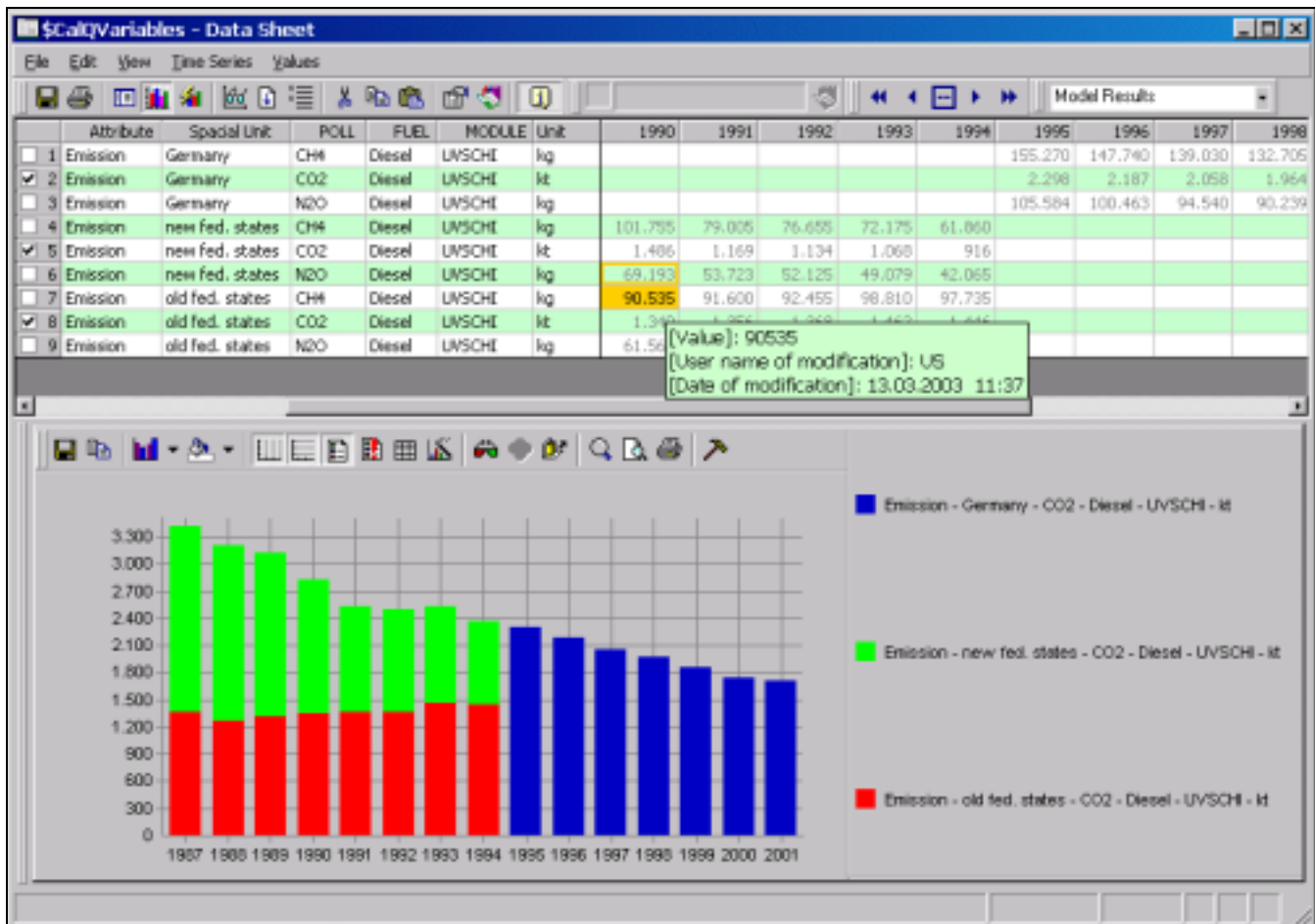


Figure 5. DataSheet – the MESAP Browser for Time Series

Perform Calculation

For the computation of calculation methods any number of calculation methods can be assigned to a calculation job. The MESAP-Solver processes a calculation job for a user defined period and with optional plausibility checks for input values and results. Calculation jobs are MESAP database objects and thus fully integrated in the access-right management. Only users with sufficient access right may start a calculation job. The calculation process consists of the following steps:

1. Parser
analysis if the equation syntax is correct for the equations of all calculation methods of the executed calculation job.
2. Equation System Builder
verifies if the assignments of time series to variables are complete and determines the involved time series in case of indexed equations or statistical functions. The number of equations is compared with the number of output variables. Finally the equation system is built based on hierarchical equation trees.
3. Mapping Routine
reads the data of all input time series and maps missing values according to predefined rules (interpolation, extrapolation and inheritance) for the period of computation.
4. Sequencer
determines the solving sequence for equations and integrity conditions.
5. Solver
processes the computation of equations and integrity conditions.
6. Activity Report
summarizes warnings, errors and violations of integrity or plausibility checks.
7. Save Results in Database
may be selected as automatically or launched manually by the user.

CONCLUSIONS

The development and management of an emission inventory is a very resource-intensive undertaking. The MESAP information system as a standard software tool supports all aspects of setting up an integrated emission inventory. This covers all tasks starting from data collection, database management, data processing, analysis and the final reporting.

In the last year, several mechanisms to ensure quality control and assurance have been built into the MESAP database and the MESAP CalQlator to support the Federal Environmental Agency UBA in improving transparency, consistency and comparability at all inventory levels:

- plausibility checks are available during data entry, they are customizable for each time series
- it is possible to document the uncertainties of input data and emissions for all source categories by specifying upper and lower margins
- each time series and each time series value are documented by specifying a source, a quality and a responsible person
- the calculation methods are documented even if they change over time - thus calculation results can be easily reproduced

- the execution of calculation methods can be automated in order to always guarantee up-to-date results
- consistency checks for data and calculated results are possible through direct comparisons between emission groups, order of magnitude checks, control totals and comparison of trends over time series
- checks for completeness are issued before a calculation and allow the identification of missing data
- reporting is automated even when based on Excel sheets

Since MESAP has been designed and implemented as a standardized software which is highly customizable by configuration, MESAP is also available to other countries with similar requirements.

The advances in the MESAP software development have been accompanied and backed by the inventory improvement plan launched within the German National System of Emissions which will continuously reduce the data gaps in order to improve accuracy and completeness of the German emission inventory.

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IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories;
iGES, OECD, IEA

KEYWORDS

Database Management System, Emission Inventories, Quality Assurance, Quality Management, Calculation, Information Systems, IPCC Reporting, Software