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Calculation of Greenhouse Gas Inventory for German Forests under Convention and Kyoto Protocol using relational PostgreSQL-Database

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Introduction

- Under the United Nations Framework on Climate Change (UNFCC) , Germany has been obliged to prepare, publish and annually submit national emission inventories of greenhouse gases (GHG) in form of an Inventory Report since 1994

- Additionally in 2005, the Kyoto Protocol went into force requiring every participating nation to implement binding action objectives and instruments for global climate protection

  - As a result, extended standards and content in reporting, as well as in reviewing became legally binding for Germany in 2004

- The National Inventory Report reports on emissions occurring in sectors such as energy, industrial processes, waste and waste water, agriculture and land use, land-use changes and forestry (AFOLU)

Introduction

Institute of Forest Ecosystems Eberswalde

- Preparation and calculation of GHG-Inventory for land use, land-use change and forestry (LULUCF) and their respective Chapters in the National Inventory Report

Federal Environment Agency Dessau

- National Co-ordination Agency for emission inventories (Merging of all Contributions/Chapters)
- Preparation of Chapters related to Industry etc.
- Publication and Submission of National Inventory Report

United Nations Framework Convention on Climate Change Bonn

- International Entity of all participating Nations
- Collection and Reviewing of National Inventory Reports (Submissions)
- Publication of National Inventory Reports

Preparation- and Submission Co-ordination of German National Inventory Report

Introduction

- Thünen Institute of Forest Ecosystems provides reporting and inventories on land use, land-use changes and forestry as well as activities in forestry under the Kyoto Protocol

  - ➢ current process of GHG-inventory calculation involves derivation of data from two different databases and contributions by several staff, and is finalized in an Excel-file

Occurrence of

Problems:
- simultaneous work on the same Excel-file not possible
- each year a new Excel-file with different framework
- intense work-load
- human error

Need for

Centralized solution which:
- enables concurrent workflows
- combines and archives all data
- also conducts all calculations (second-level validation and comparison of results)
- decreases work-load

- UNFCC provides guidelines for report preparation in form of a Common Reporting Framework (CRF)
  - ➢ Land use, land-use change and forestry (LULUCF) is reported in CRF Sector 4 under Chapter 6 in the National Inventory Reports

IPCC Category	German LULUCF Categories
4.A Forest land	Forest land
4.B Cropland	Cropland
4.C Grassland	Grassland (in a strict sense) (i.s.s.)
	Woody grassland
4.D Wetlands	Flooded lands
	Peat extraction
	Waters
4.E Settlements	Settlements
4.F Other land	Other land
4.G Harvested Wood Products	Harvested Wood Products

German LULUCF-categories and their associated IPPC-counterparts

CRF Sector	LULUCF Categories
4.A.1	Forest Land remaining Forest Land
4.A.2.1	Cropland converted to Forest Land
4.A.2.2	Grassland (i.s.s.) converted to Forest Land
4.A.2.2	Woody Grassland converted to Forest Land
4.A.2.3.3	Other Wetlands converted to Forest Land
4.A.2.3.2	Flooded Lands converted to Forest Land
4.A.2.4	Settlements converted to Forest Land
4.A.2.5	Other Land converted to Forest Land (NO)

Land use and land-use change categories in Sector 4.A forest land

Category for KP reporting	Category pursuant to UNFCCC	
Afforestation under Art. 3.3 KP	4.A.2.1 Cropland converted to forest land	
	4.A.2.2. Grassland converted to forest land	4.A.2.2.1 Grassland (in a strict sense) converted to forest land
		4.A.2.2.2 Woody grassland converted to forest land
	4.A.2.3. Wetlands converted to forest land	4.A.2.3.1 Flooded lands converted to forest land
		4.A.2.3.2 Waters converted to forest land
	4.A.2.4. Settlements converted to forest land	
	4.A.2.5. Other land converted to forest land	
Deforestation under Art. 3.3 KP	4.B.2.1. Forest land converted to cropland	
	4.C.2.1. Forest land converted to grassland	4.C.2.1.1 Forest land converted to grassland (i.s.s.)
		4.C.2.1.2 Forest land converted to woody grassland
	4.D.2.1. Forest land converted to wetlands	4.D.2.1.1 Forest land converted to terrestrial wetlands
		4.D.2.1.2 Forest land converted to waters
	4.E.2.1. Forest land converted to settlements	
	4.F.2.1. Forest land converted to other land (NO)	
Forest management pursuant to Art. 3.4 KP	4.A.1 Forest land remaining forest land	

Kyoto Protocol-activities and their corresponding LULUCF-categories

Contents and necessary steps to prepare GHG-inventory

- **Under Convention and Kyoto Protocol Germany reports CO_2-emissions and -sequestrations from the following carbon pools:**

Above- and below- ground biomass	Dead organic matter	Organic- and mineral-soils

- **Also included in the GHG-inventory (as of Submission 2016) are:**

CO_2 emissions from:

- wood products
- industrial peat extraction

N_2O emissions from:

- drained organic soils
- humus mineralisation in mineral soils
- industrial peat extraction
- wildfires

CH_4 emissions from:

- organic soils
- drainage ditches in organic soils
- industrial peat extraction
- wildfires

Source: UBA, Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2016; Chapter 6

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Basic calculation-method for annual emissions:

Activity Data
(Land-use matrix):
- annual derivation of the total areas for the sub-categories in each of the categories with differentiation by mineral and organic soils

X

Emission Factors
- for various pools and differentiated by land-use categories

=

Emissions
- annual carbon stock change (under the assumption that, in each case, the entire carbon-stock change occurs in the year of the land-use change)

- additionally introduction of a twenty-year transition time:
  - ➢ land-use-matrix calculation is referenced to 1970, to make it possible to determine land-use-change areas for years prior to the period covered by the report
  - ➢ areas on which conversion occurs are assigned to the relevant land-use-change category, in the year in which the land-use change takes place, and remain in that transition category for 20 years (Implied Emission Factors for those areas derived via Annual Emission Factor/20 e.g. for mineral soils)

Source: UBA, Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2016; Chapter 6

Implementation of data and calculations into a PostgreSQL-Database

- Current database server featuring the greenhouse gas inventory for German forests is running under PostgreSQL and its administration-software pgAdmin III

PostgreSQL = Object-relational database (ORDBMS)

Features include:

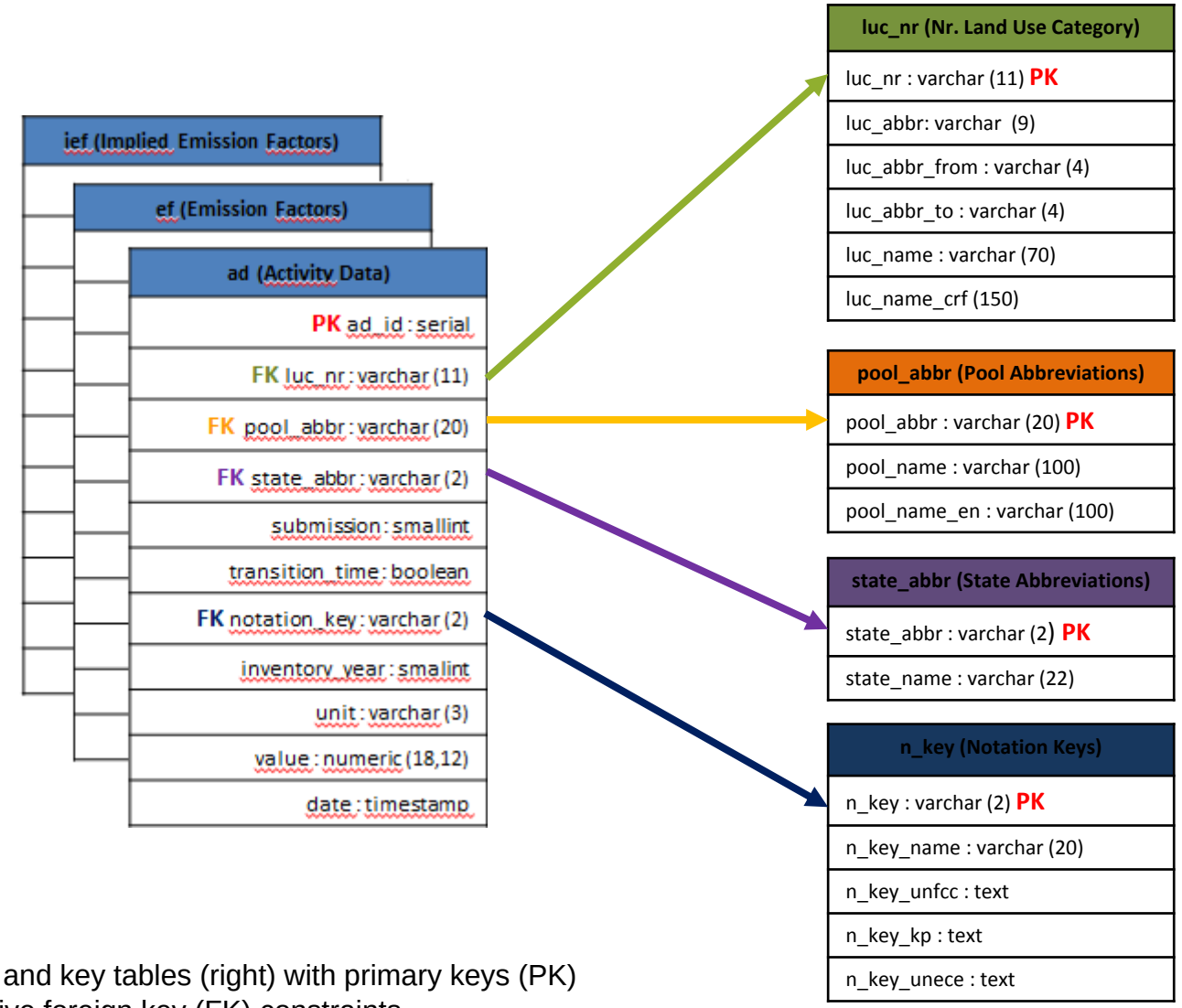
- ✓ Free and open-source under a permissive free-software license
- ✓ Updatable views, foreign keys and triggers
- ✓ Support of functions/stored procedures
- ✓ Enables the user to define new data types, functions and operators
- ✓ Multi-User support

- Greenhouse gas database *"thg"* consists of several schemas which are database clusters containing their own respective data, functions and views
  - ➢ main advantage of this architecture is the possibility for several users to concurrently work on their own projects

Database structure

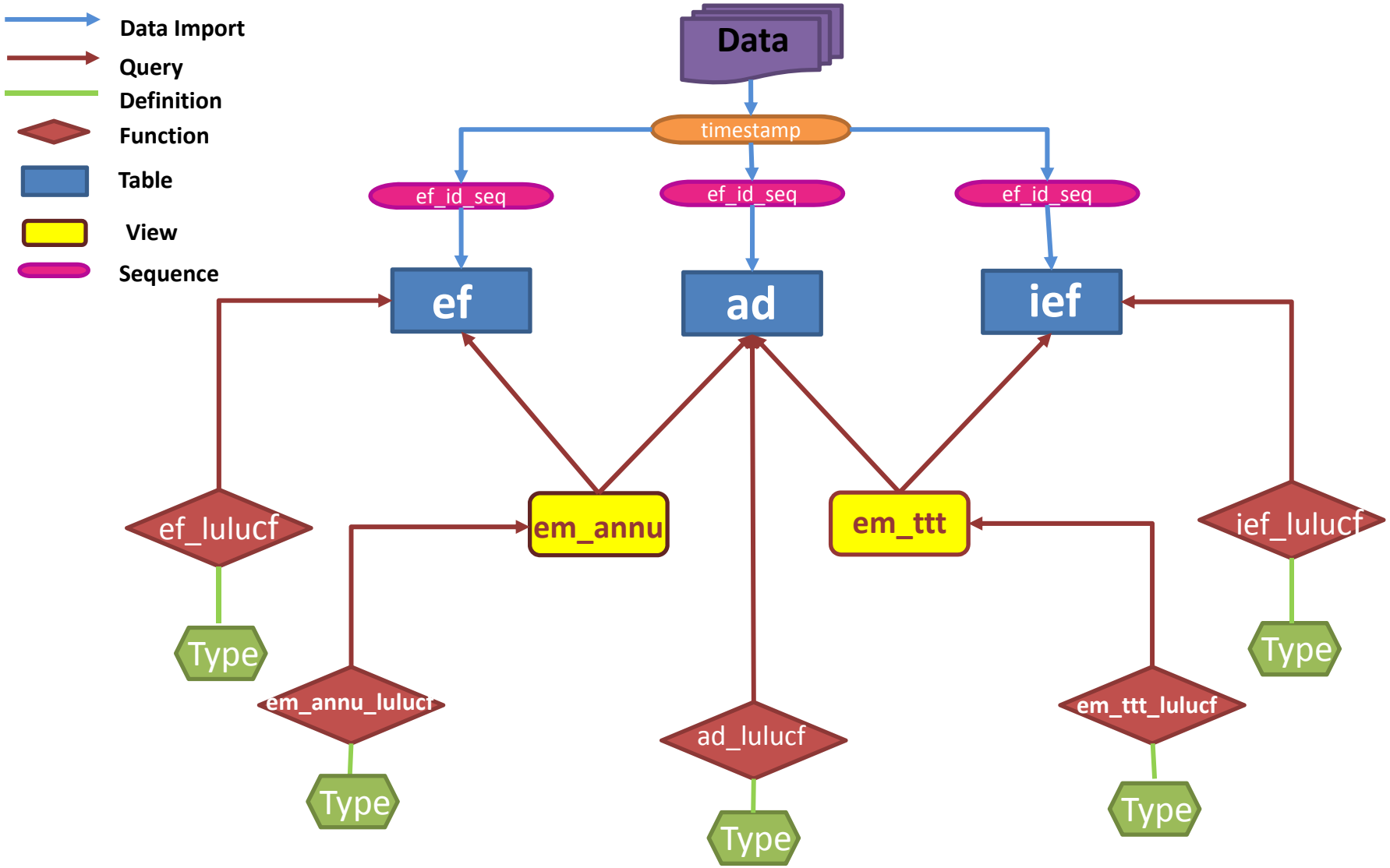
- **Data tables:** tables "*ad*", "*ef*" and "*ief*" containing the activity data (area), emission factors and implied emission factors
- **Key tables:** tables *"pool"*, *"luc_nr"*, *"n_key"* and *"state"* list all the data available and accepted used for key attributes in the data tables, and are constrained to their respective attributes in the data tables via foreign keys
- **Views:** *"em_annu"* and *"em_ttt";* pseudo-tables which fetch their data from existing tables via predefined SQL-queries and calculate the annual emissions and emissions for areas with transition time
- **Functions:** predefined stored procedures which would normally require multiple queries but can be easily executed via a function
- **Trigger function:** *"update_timestamp"* sets a timestamp to each data record when first created or edited
- **Sequences:** one for each data table; generate a unique number (within a predefined range) when first importing/creating a data record, also acts as Primary Key in the data tables
- **Types:** custom data types; transpose query results into horizontal alignment and defines limit of time series displayed which is much more convenient when comparing time series

Database structure



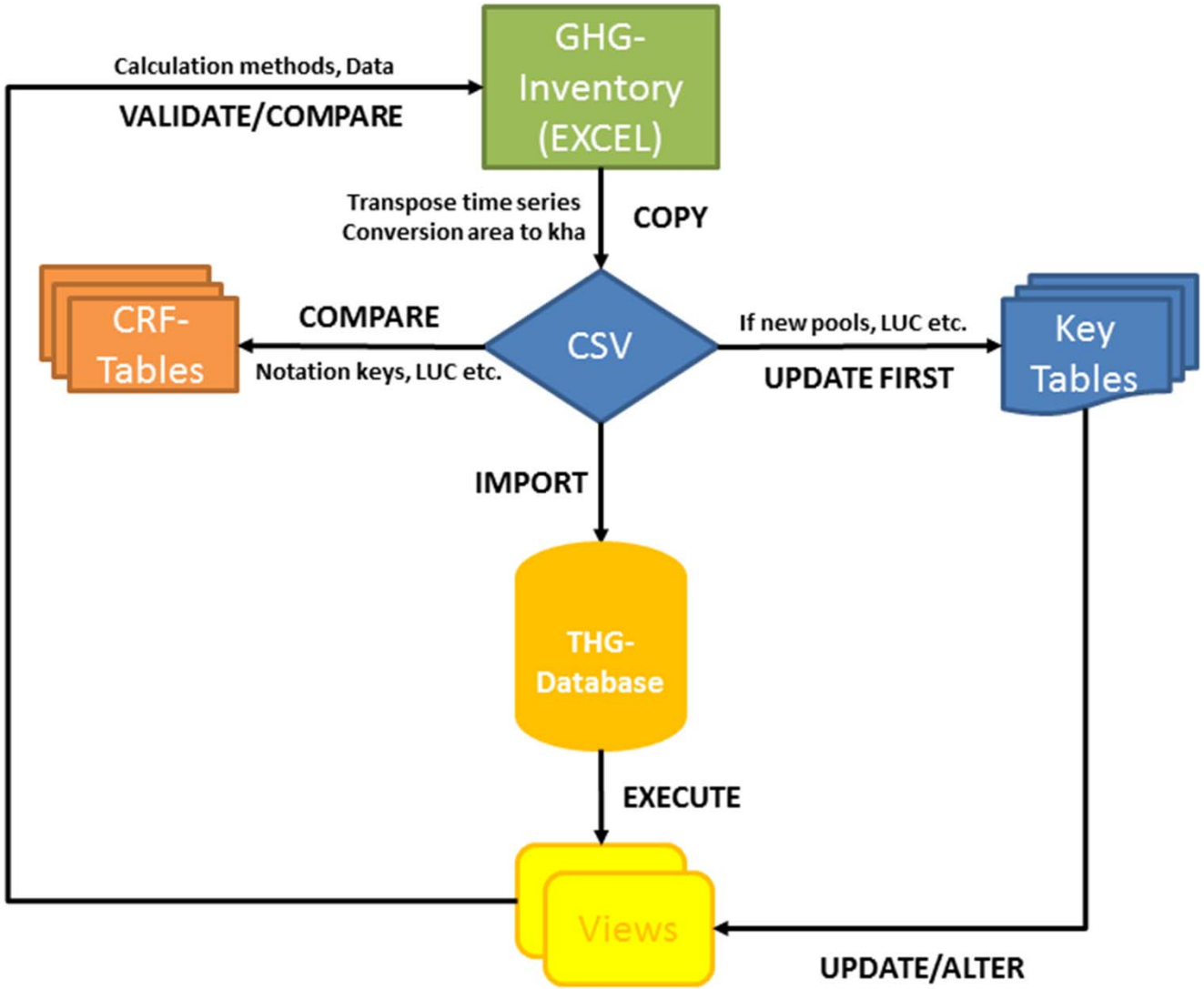
Data tables (left) and key tables (right) with primary keys (PK) and their respective foreign key (FK) constraints

Database structure



Data and query dependencies/relations

Data import & Query Programming



Annual workflow for importing activity data and emission factors from excel-file into database

GHG-inventory calculation

- calculation for positive (sources) and negative (sinks) emissions for LULUCF and Kyoto Protocol is conducted in the two pseudo-tables (views) *"em_annu"* and *"em_ttt"*; where:

  - *em_annu* calculates annual emissions by querying activity data from table *"ad"* and emission factors from table *"ef"*

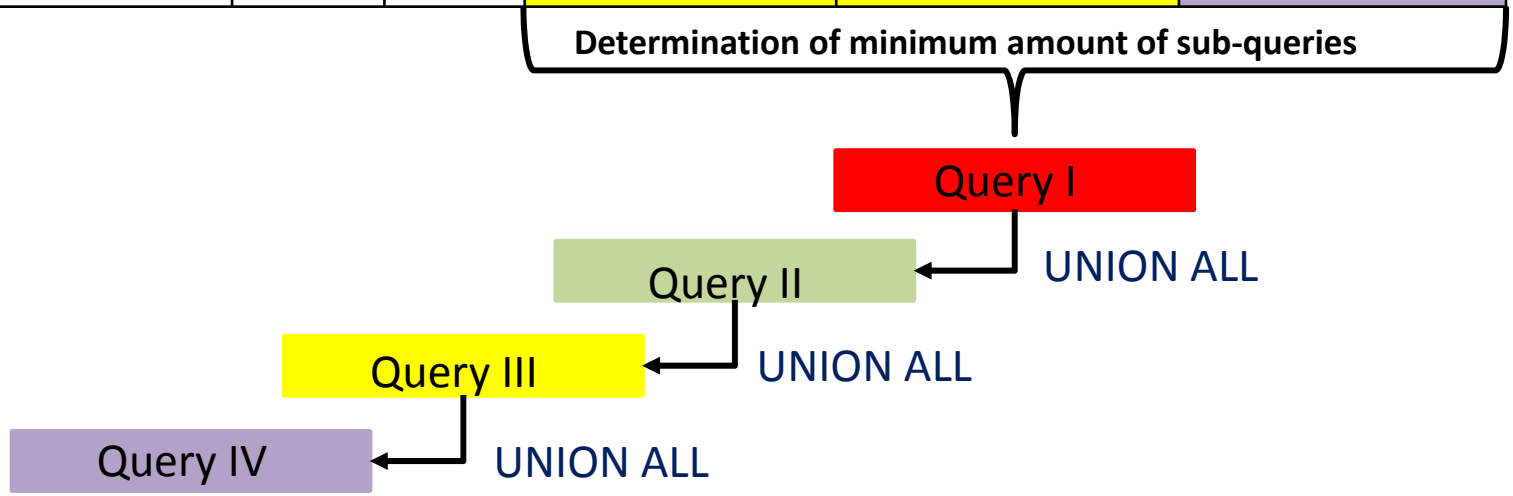
  - *em_ttt* calculates emissions for all land uses and land use-changes with transition time by querying only activity data with transition time (transition_time IS TRUE) from table *"ad"* and implied emission factors from table *"ief"*

- calculation-algorithms in both views consist of several sub-queries connected with the **UNION ALL**-operator

  - **UNION ALL** merges the result of the previous query with the result of the following one without distinction/exception/excluding redundant query

GHG-inventory calculation

Source Category	GHG	Pool	Submission 2012	Submission 2013	Submission 2014
A	1	I	equation_y	equation_y	equation_z
	2	III	equation_x	equation_x	equation_z
	3	VI	equation_xy	equation_xy	equation_z
B	1	I	equation_y	equation_y	equation_z
	2	III	equation_x	equation_x	equation_z
	3	VI	equation_xy	equation_xy	equation_z



Query-programming and -combination approach for creating views “em_annu” and “em_ttt” for emission calculation

GHG-inventory calculation

Since 2013 significant increase of query complexity and extension mainly due to:

2006 IPCC Guidelines (IPCC, 2006)

"2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol" (IPCC 2014a)

"2013 Supplement to the IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands" (IPCC 2014b)

"Revision of the UNFCCC reporting guidelines on Annual inventories for Parties included in Annex I to the Convention" (UNFCC 2013)

New selected activities under Kyoto Protocol for second Commitment Period

"*em_annu*"-view currently consists of 50 sub-queries

(25 queries for individual GHG and 25 queries for calculation into CO_2-equivalents, Submissions 2012 - 2017)

Conclusion/Outlook

- With progression and improvement of inventory methods, as well as implementation of revised reporting guidelines, query-programming became more and more challenging
  - Nevertheless, methodology and extent of reporting remains stable since Submission 2015
- Evaluations of methods to minimize amount of sub-queries and data-import:
  - Modification of existing queries
  - Splitting Views in several time periods with ongoing Submissions
  - Automated data-import to avoid human error (XML?)
- Planned in the future:
  - Execution of all derivations and calculations (land-use matrix and emission factors) inside PostgreSQL-databases to render the EXCEL-file obsolete.
  - Application of the GHG-database into a web-application with visualization and export of data

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Thank you

for your attention!