Climate MRV for Africa – Phase 2
Development of National GHG Inventory
Chemical Industry: Ammonia Production

NIRAS Lead partner GreenStream TÜVRheinland® Precisely Right. camco clean energy

Project of the European Commission DG Clima Action

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IPPU: Chemical Industry Ammonia Production

Ammonia Production

Source: BBC GCSE Bitesize

- **Ammonia** (NH_3) is manufactured applying the Haber Process which combines **nitrogen** and **hydrogen** (from natural gas).
- During the production, **CO_2** gas is emitted to the atmosphere.

Source: IPCC 2006 Vol. 3, Ch. 3, Fig. 3.1

Uses of Ammonia

Uses:

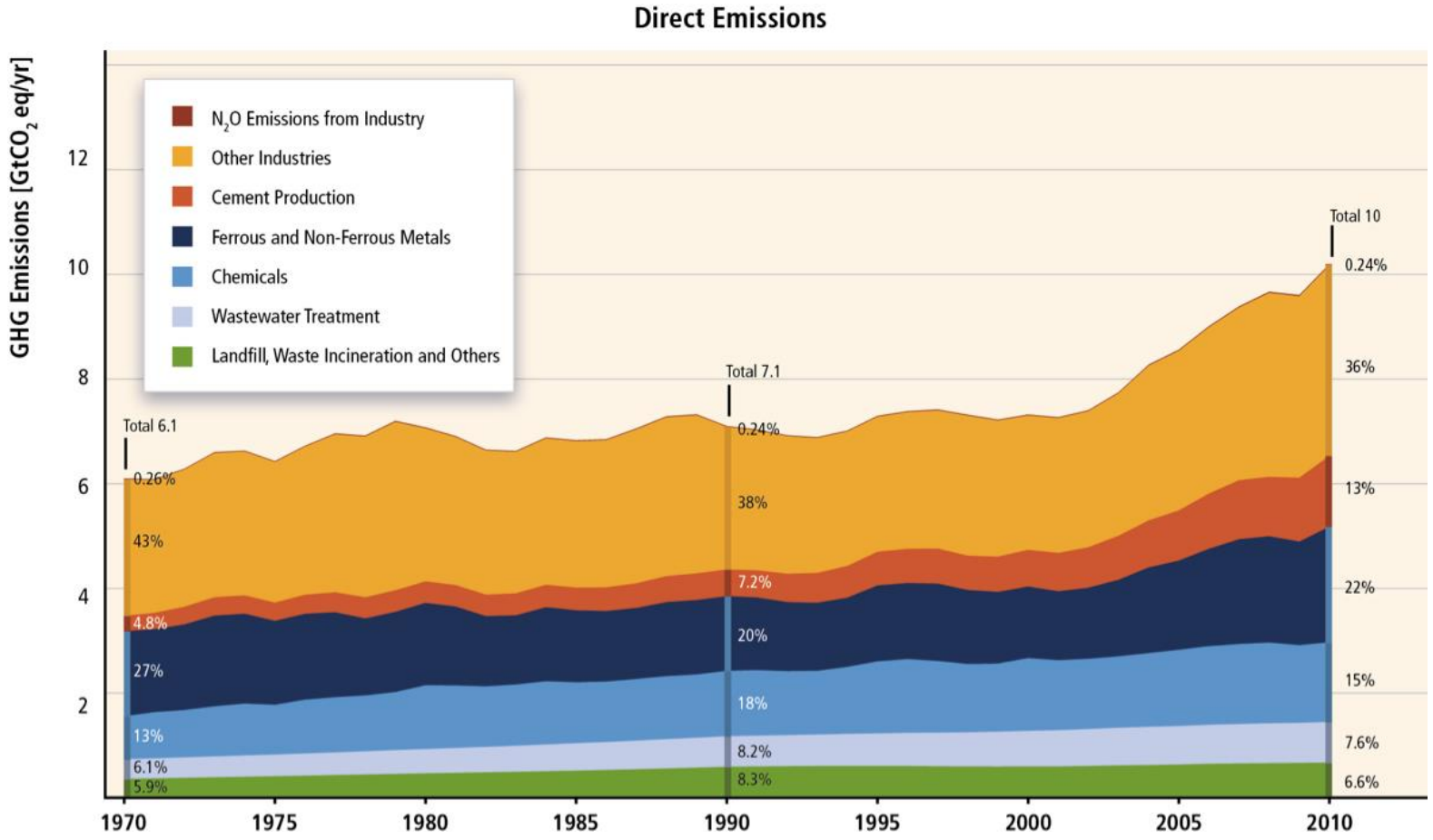
- Fertilizers
- Converted into nitric acid
- Cleaning fluids
- Refrigerant

Source: Cosale Projecto, Nitric Acid

Source: U.S. Bureabu of Labor Statistics, (2013), Growing demand for fertilizer keeps prices high

- Manufacture of synthetic polymers (nylon and acrylics)
- Extract gold from ore bodies

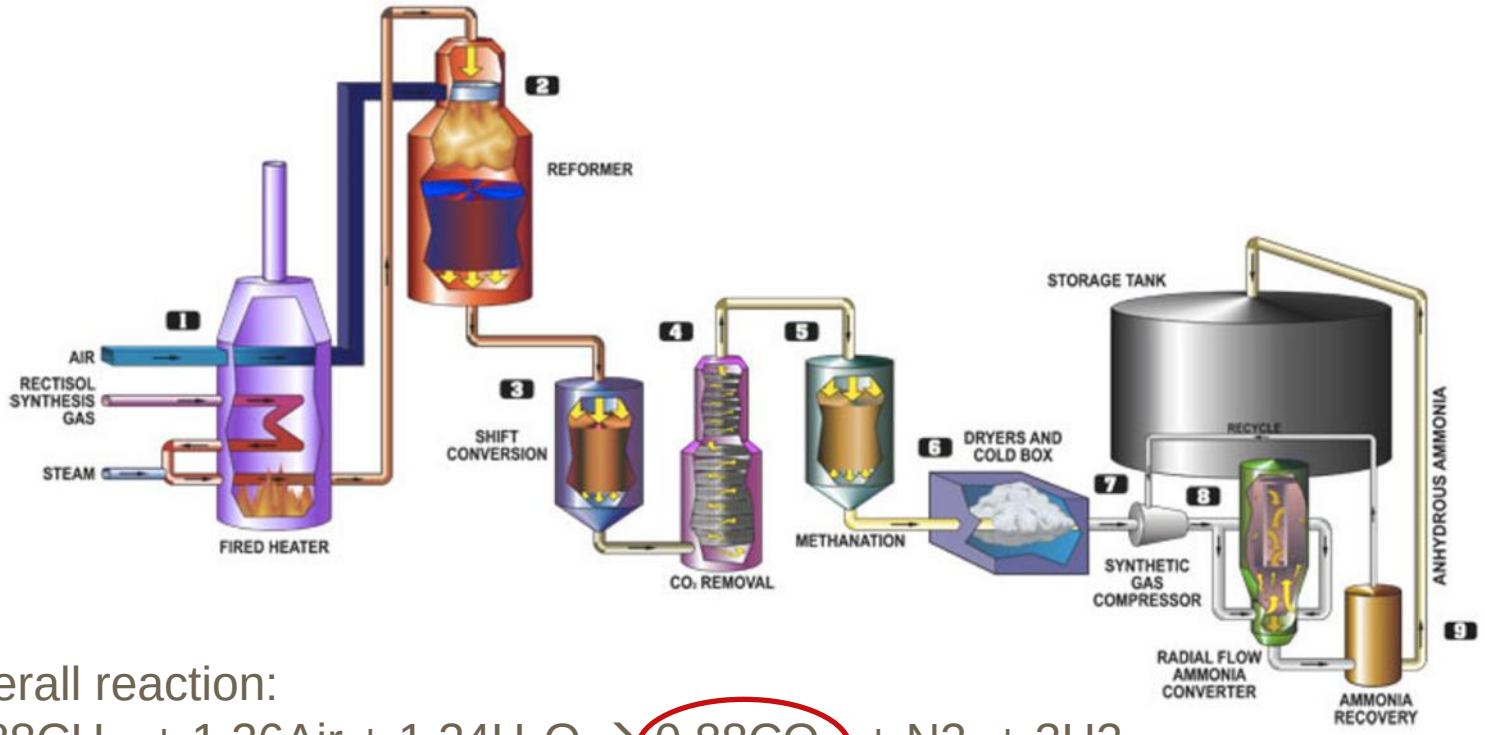
Ammonia Production and Global GHG Emissions



Source: IPCC (2014), Climate Change 2014 Mitigation of Climate Change

Total CO_2 emissions from Ammonia production worldwide in 2012: **487.39** MM tonnes CO_2

Emission Sources from Ammonia Production



Overall reaction:

$0.88CH_4 + 1.26Air + 1.24H_2O \rightarrow 0.88CO_2 + N2 + 3H2$

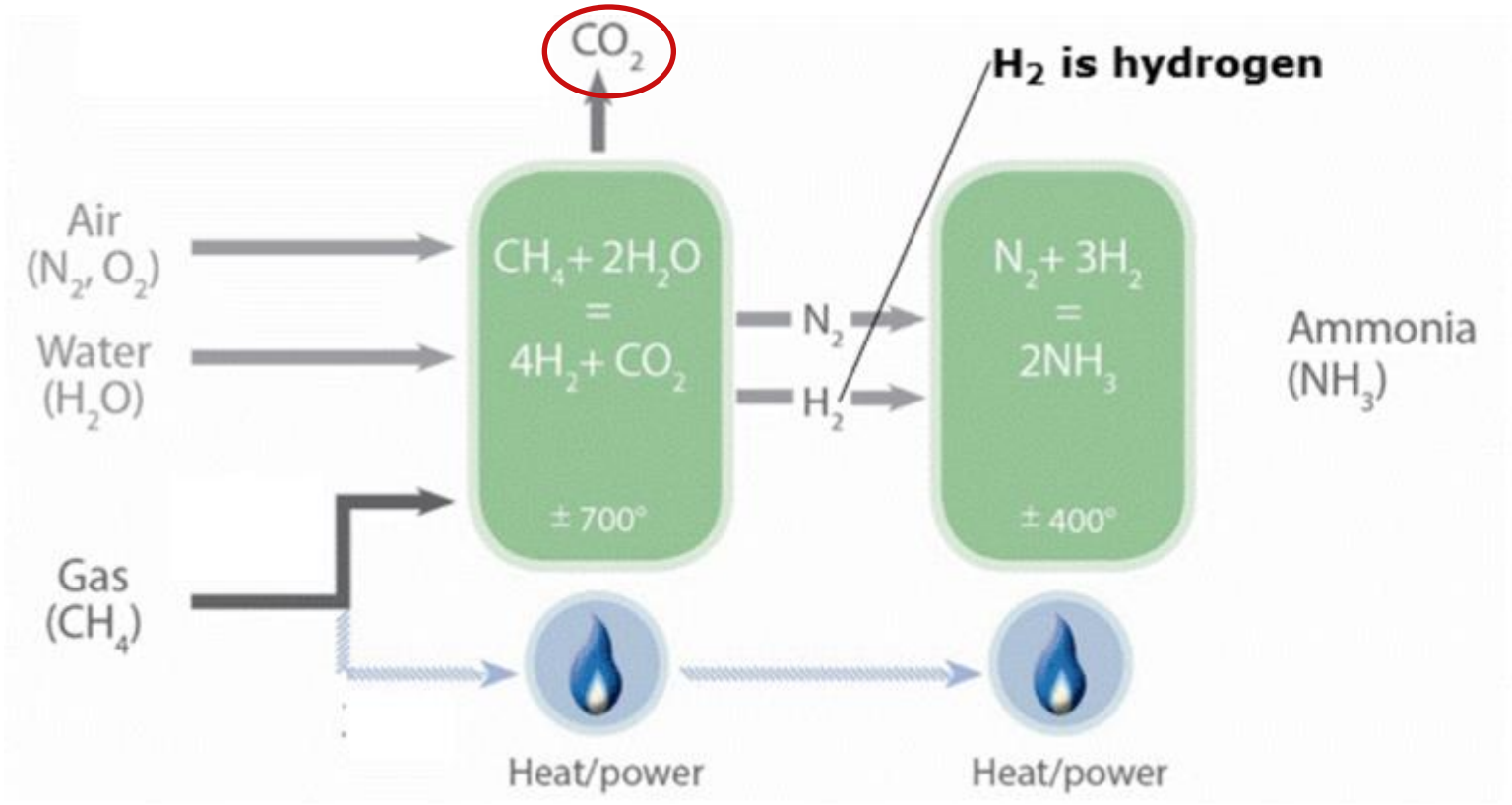
Secondary reformer process gas shift conversion

$CO + H_2O \rightarrow CO_2 + H_2$

Source: Dakota Classification Company, Ammonia Process

Source: IPCC 2006 Vol. 3, Ch. 3, Fig. 3.1

Emission Sources from Ammonia Production



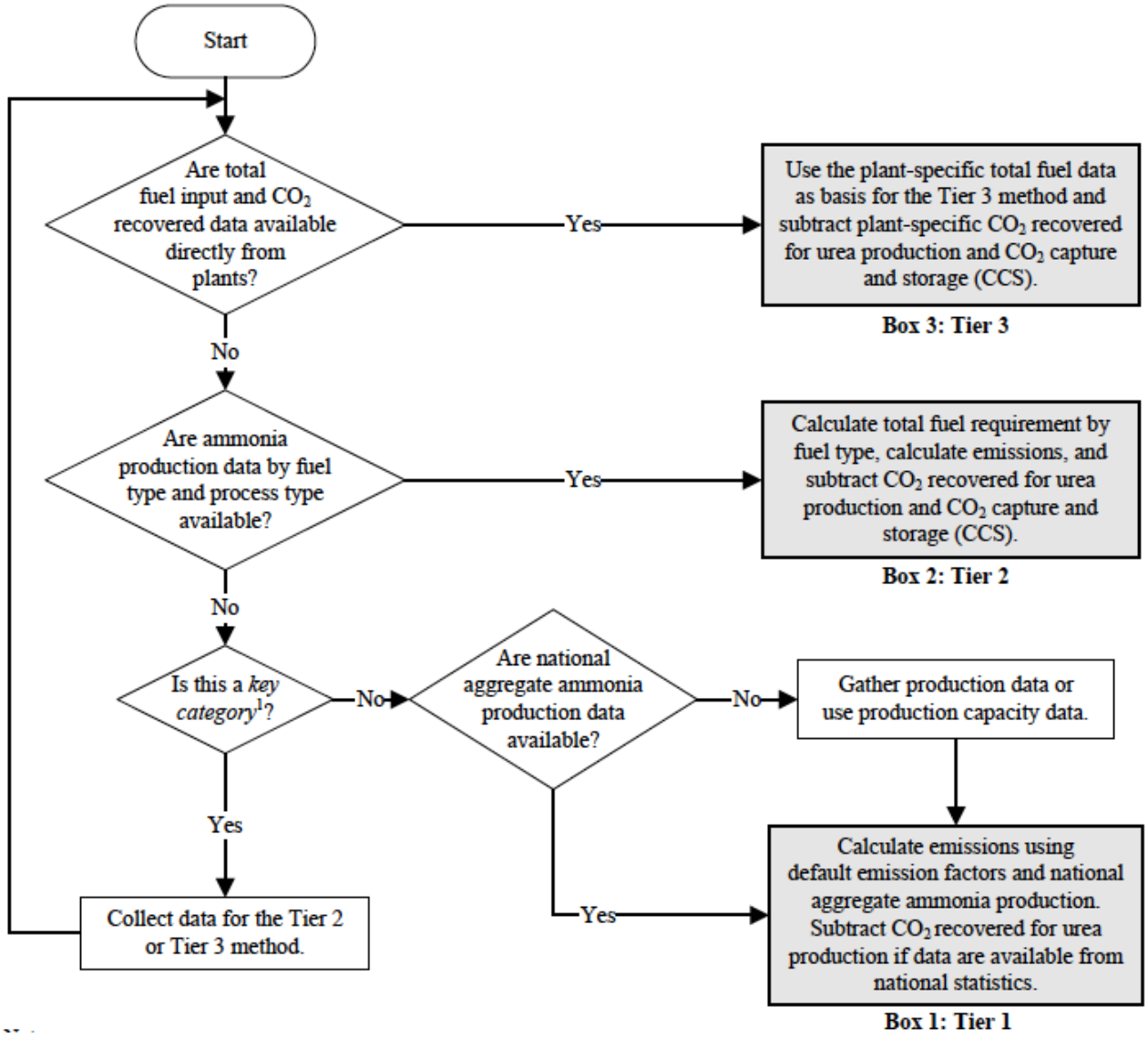
Source: Ecofys (2015), Fertilizers and Climate Change

Source: IPCC 2006 Vol. 3, Ch. 3, Fig. 3.1

Emissions Potential for the Category

- Emission factor of 2.772 tonnes of CO_2 per tonne of ammonia produced for modern plants
- 1 million tonnes of ammonia produced leads to 2,772,000 tCO_2 of direct emissions

Decision Tree for CO_2 Emissions



Source: IPCC 2006 Vol. 3, Ch. 3, Fig. 3.1

Ammonia Production
Tier 1 Method

IPCC 2006: Tier 1 Method

EQUATION 3.1
CO_2 EMISSIONS FROM AMMONIA PRODUCTION – TIER 1

$$E_{CO2} = AP \bullet FR \bullet CCF \bullet COF \bullet 44/12 - R_{CO2}$$

Where:

E_{CO2} = emissions of CO_2, kg

AP = ammonia production, tonnes

FR = fuel requirement per unit of output, GJ/tonne ammonia produced

CCF = carbon content factor of the fuel, kg C/GJ

COF = carbon oxidation factor of the fuel, fraction

R_{CO2} = CO_2 recovered for downstream use (urea production), kg

Source: IPCC 2006 Vol. 3, Ch. 3, Eq. 3.1

Tier 1 Method Activity Data

- *AP*: Ammonia Production (tonnes)
  - National statistics
- R_{co2}: CO_2 recovered downstream can be estimated from urea production.
  - When a deduction is made for CO_2, it is ***good practice*** to ensure that emissions from urea are included in the inventory
  - Alternative: if data not available, assume that CO_2 recovered is zero.

Tier 1 Activity Data Alternatives

- *AP*: Ammonia Production (tonnes) at a national level, if not available information on production capacity can be used.
  - If the inventory compiler proves that utilization for a year was below capacity, then it is good practice to multiply the production capacity by a capacity utilization factor of 80% ± 10% per year.

Tier 1 Method Emission Factor

- If plant-level factors are not available, **it is good practice to use default factors** from the guidelines
  - **Default factors:** Fuel requirements / units of output (energy units)
  - **Mass units** = C content of the fuel and the C oxidation factor in Volume 2: Energy
- **When applying Tier 1,** it is good practice to use the highest total fuel requirements / ton of ammonia.
  - *If not available, use the average value for partial oxidation.*

Emission factor for ammonia production

TABLE 3.1
DEFAULT TOTAL FUEL REQUIREMENTS (FUEL PLUS FEEDSTOCK) AND EMISSION FACTORS FOR AMMONIA PRODUCTION (PER TONNE NH_3)

Production Process	Total fuel requirement (GJ(NCV)/tonne NH_3) ± Uncertainty (%)	Carbon content factor [CCF][1] (kg/GJ)	Carbon oxidation factor [COF][1] (fraction)	CO_2 emission factor (tonnes CO_2 /tonne NH_3)
Modern plants – Europe Conventional reforming – natural gas	30.2 (± 6%)	15.3	1	1.694
Excess air reforming – natural gas	29.7 (± 6%)	15.3	1	1.666
Autothermal reforming – natural gas	30.2 (± 6%)	15.3	1	1.694
Partial oxidation	36.0 (± 6%)	21.0	1	2.772
Derived from European average values for specific energy consumption (Mix of modern and older plants) Average value – natural gas	37.5 (± 7%)	15.3	1	2.104
Average value – partial oxidation	42.5 (± 7%)	21.0	1	3.273

Source: IPCC 2006 Vol. 3, Ch. 3, Table 3.1

Ammonia Production
Tier 2 Method

IPCC 2006: Tier 2 Method

Step 1: Determine the total fuel requirement:

EQUATION 3.2
TOTAL FUEL REQUIREMENT FOR AMMONIA PRODUCTION – TIER 2

$$TFR_i = \sum_j \left(AP_{ij} \bullet FR_{ij} \right)$$

Where:

TFR_i = total fuel requirement for fuel type *i*, GJ

AP_{ij} = ammonia production using fuel type *i* in process type *j*, tonnes

FR_{ij} = fuel requirement per unit of output for fuel type *i* in process type *j*, GJ/tonne ammonia produced

Source: IPCC 2006 Vol. 3, Ch. 3, Eq. 3.2

- Fuel type and process type can be obtained from producers.
- FR_{ij}: default values in Table 3.1.

IPCC 2006: Tier 2 Method

Step 2: Determine total emissions as follows:

EQUATION 3.3
CO_2 EMISSIONS FROM AMMONIA PRODUCTION – TIER 2 AND 3

$$E_{CO2} = \sum_i (TFR_i \bullet CCF_i \bullet COF_i \bullet 44/12) - R_{CO2}$$

Where:

E_{CO2} = emissions of CO_2, kg

TFR_i = total fuel requirement for fuel type *i*, GJ

CCF_i = carbon content factor of the fuel type *i*, kg C/GJ

COF_i = carbon oxidation factor of the fuel type *i*, fraction

R_{CO2} = CO_2 recovered for downstream use (urea production, CO_2 capture and storage (CCS)), kg

Source: IPCC 2006 Vol. 3, Ch. 3, Eq. 3.3

Tier 2 Method Emission Factor

- The total fuel requirement values per unit of output in Table 3.1 can be used in conjunction with data on NH_3 production by fuel type and process type, along with:
  - Default or country specific data on the C content factor
  - Carbon oxidation factor of the fuels.

Tier 2 Activity Data & Sources

- Requires plant-level production data, disaggregated by fuel type and production process.
- Plant-level data on CO_2 recovered downstream use or other application are required.

Ammonia Production
Tier 3 Method

IPCC 2006: Tier 3 Method

Requires fuel requirement to be obtained from each NH_3 production plant.

EQUATION 3.4
TOTAL FUEL REQUIREMENT FOR AMMONIA PRODUCTION – TIER 3

$$TFR_i = \sum_n TFR_{in}$$

Where:

TFR_i = total fuel requirement for fuel type *i*, GJ

TFR_{in} = total fuel requirement for fuel type *i* used by plant *n*, GJ

Source: IPCC 2006 Vol. 3, Ch. 3, Eq. 3.4

Source: IPCC 2006 Vol. 3, Ch. 1, Eq. 2.3

IPCC 2006: Tier 3 Method

Once the TFR_i are collected, then CO_2 emissions can be derived using Equation 3.3 (same as Tier 2)

It is good practice to:

- Use carbon content factor (CCF) and carbon oxidation factor (COF) from producers or country specific energy sector information.
- CO_2 emissions from urea production should be obtained from producers.

IPCC 2006: Tier 3 Method- Double Counting

- Urea use:
  - As a fertilizer should be included in the Agriculture Forestry and Other Land Use (AFOLU).
  - In automobile catalytic converter should be accounted for in the Energy Sector.

Tier 3 Method Emission Factor

- Plant-level data on total fuel requirement provides the most rigorous data for calculation of CO_2 emissions from ammonia production.
  - Using plant-level ammonia production depends on: Accurate fuel requirement per unit of output, and information on the other variables.
- It is considered ***good practice*** to gather information on the CCF and COF either from producers or country-specific Energy Sector data.
  - Carbon Content Factor (CCF): Key EF to calculate the CO_2 emissions.

Source: IPCC 2006 Vol. 3, Ch. 1, Eq. 2.1

Tier 3 Activity Data & Sources

- **Plant-level data required for Tier 3 method:**
  - Total fuel requirement classified by fuel type.
  - CO_2 recovered for downstream use or other applications.
  - Ammonia production. Although data on ammonia production is not used in the calculation under Tier 3 method, it should be collected from producers for reporting purposes.

Uncertainty in Ammonia Emissions Estimates

Source of uncertainty	Range	How to mitigate
Tier 1 •Default emission factors •National production data	•±6-7% •±5%	N/A Consult with agency about source of data
Tier 2 •Activity data from producers	•±2%	N/A
Tier 3 •Activity data from producers	•±2%	N/A

Based on: IPCC 2006 Vol. 3, Ch. 4, Table 4.4

Ammonia Production
QA/QC

QA/QC for Ammonia Emissions

- **Recommendation 1:** Conduct extensive quality control checks according to the increasing level of tier methods.
- **Recommendation 2:** Compare estimated emission factors with the default values provided by Tier 1 method. Assess and document any difference.
- **Recommendation 3:** The inventory compiler must ensure all data comply with national or international standards in order to consider the use of the data for the methodology.

Considerations for Reporting

- To ensure protection of confidential production and process data it is recommended to apply appropriate techniques, including aggregation of data. (Section 2.2, Volume 1)
- Develop a consistent time series:
  - Re-calculate emissions whenever there is a change in the emission calculation methods & include complete data from all the years.
- **Some specific documentation for the report:**
  - Description of the method used as per Volume 1
  - References to source data

Thank you!

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