Climate MRV for Africa – Phase 2
Development of National GHG Inventory
Petrochemical & Carbon Black Production – Methanol

Lead partner

Project of the European Commission
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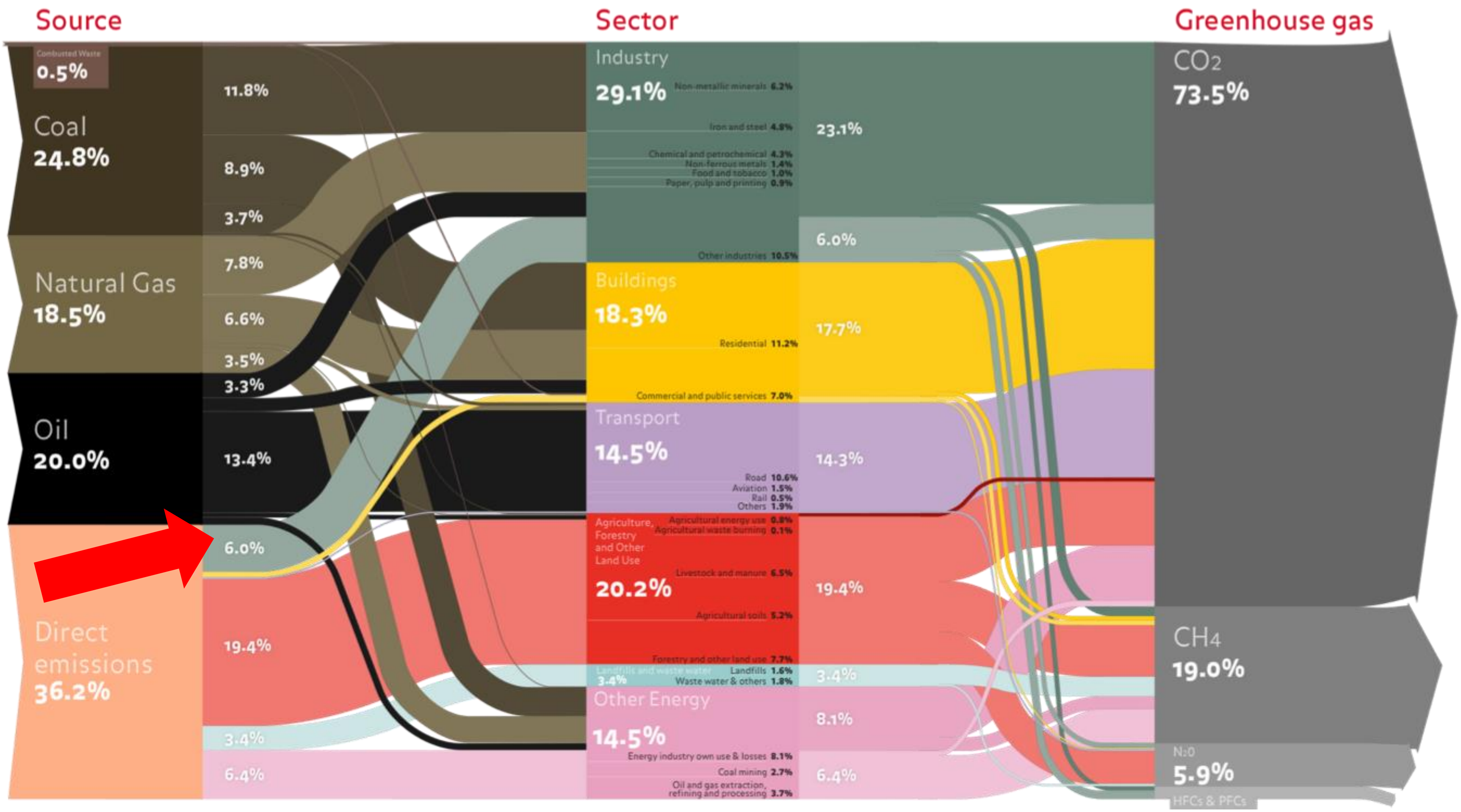
PETROCHEMICAL AND CARBON BLACK PRODUCTION and Global GHG Emissions



Source: ASN Bank and Ecofys (2016), update to the WRI 2000 figure, using 2012 data

Total emissions worldwide (2012)

51,840

$MtCO_2$ EQ

INTRODUCTION: PETROCHEMICAL AND CARBON BLACK PRODUCTION

- Petrochemical industry uses fossil fuels or petroleum refinery products as feed stocks.
- The use of primary fossil fuels may involve partial combustion of the hydrocarbon content for heat raising and the production of secondary fuels (e.g., off gases).
- Combustion emissions from fuels obtained from the feedstocks should be allocated to the source category in the IPPU Sector.

METHANOL PROCESS DESCRIPTIONS

Conventional Reforming Process

Conventional Reforming Process for methanol production involves steam reforming and methanol synthesis.

Steam Reforming	Shift Reaction	Methanol Production
$CH_4 + H_2O \rightarrow CO + 3\ H_2$	$CO + H_2O \rightarrow CO_2 + H_2$	$CO + 2\ H_2 \rightarrow CH_3OH$
$C_nH_m + nH_2O \rightarrow nCO + (m/2 + n)\ H_2$		$CO_2 + 3\ H_2 \rightarrow CH_3OH + H_2O$

Reforming/Shift Reaction	Methanol Production
$2\ CH_4 + 3\ H_2O \rightarrow CO + CO_2 + 7\ H_2$	$CO + CO_2 + 7\ H_2 \rightarrow 2\ CH_3OH + 2\ H_2 + H_2O$

Conventional Reforming for methanol production may utilize CO2 captured from other processes as a supplemental feedstock.

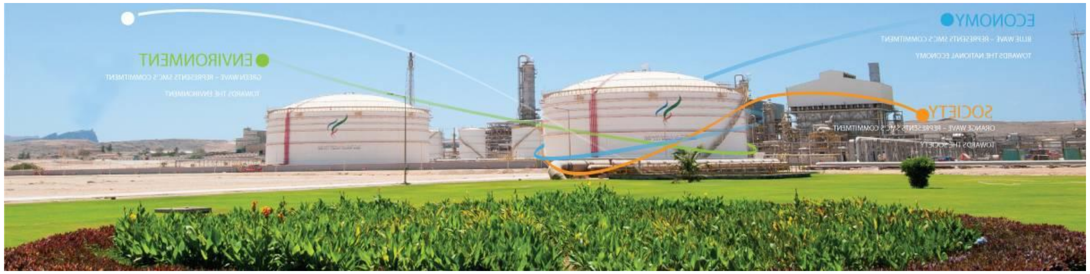
METHANOL PROCESS DESCRIPTIONS

Combined Reforming Process

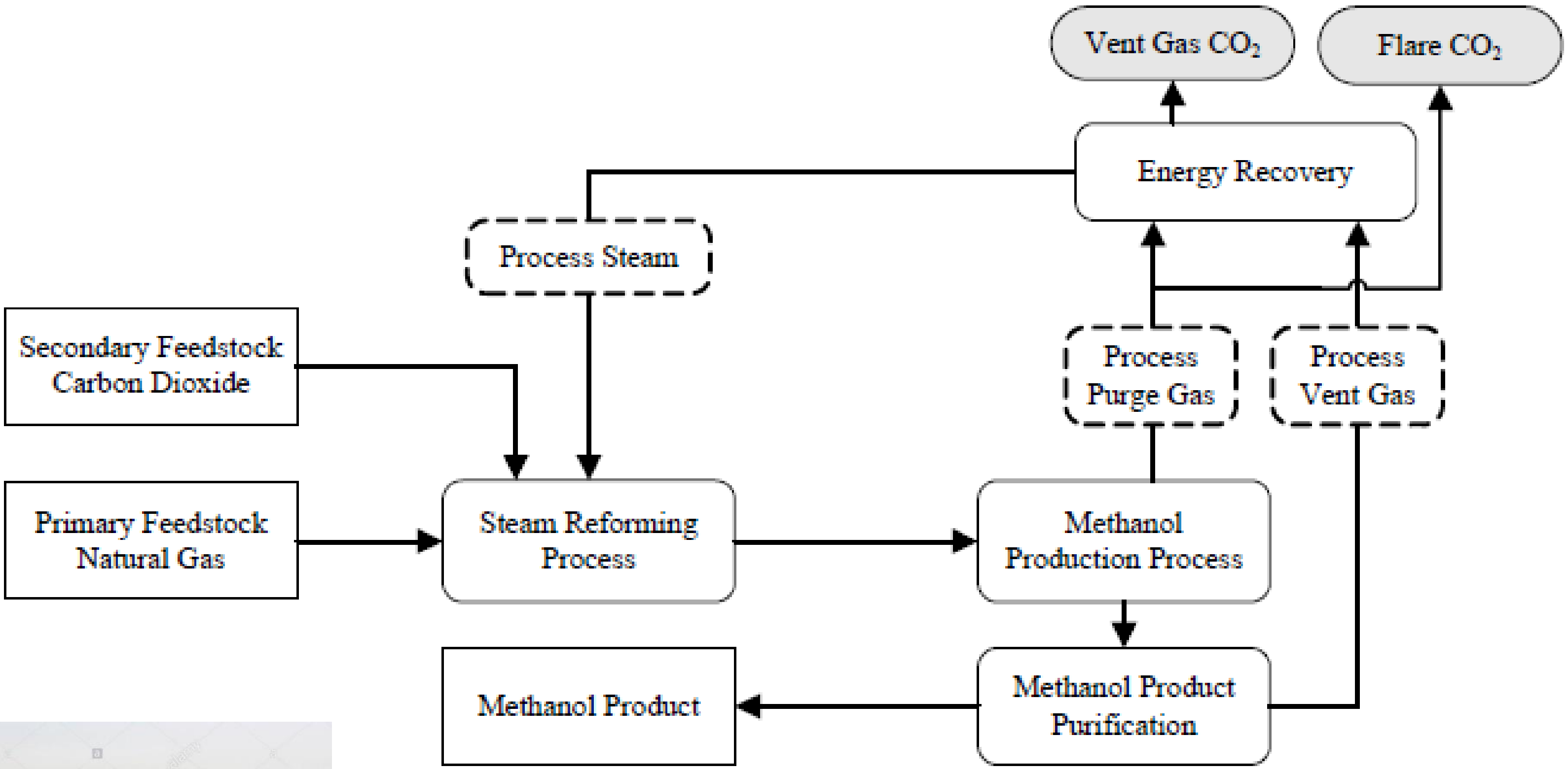
Combined Reforming Process combines the Conventional Steam Reforming process with Catalytic Partial Oxidation process.22

Methanol Steam Reforming Reaction	Feedstock Oxidation Reaction
$CH_4 + \frac{1}{2} O_2 \rightarrow CO + 2 H_2 \rightarrow CH_3OH$	$CH_4 + O_2 \rightarrow CO_2 + 2 H_2$

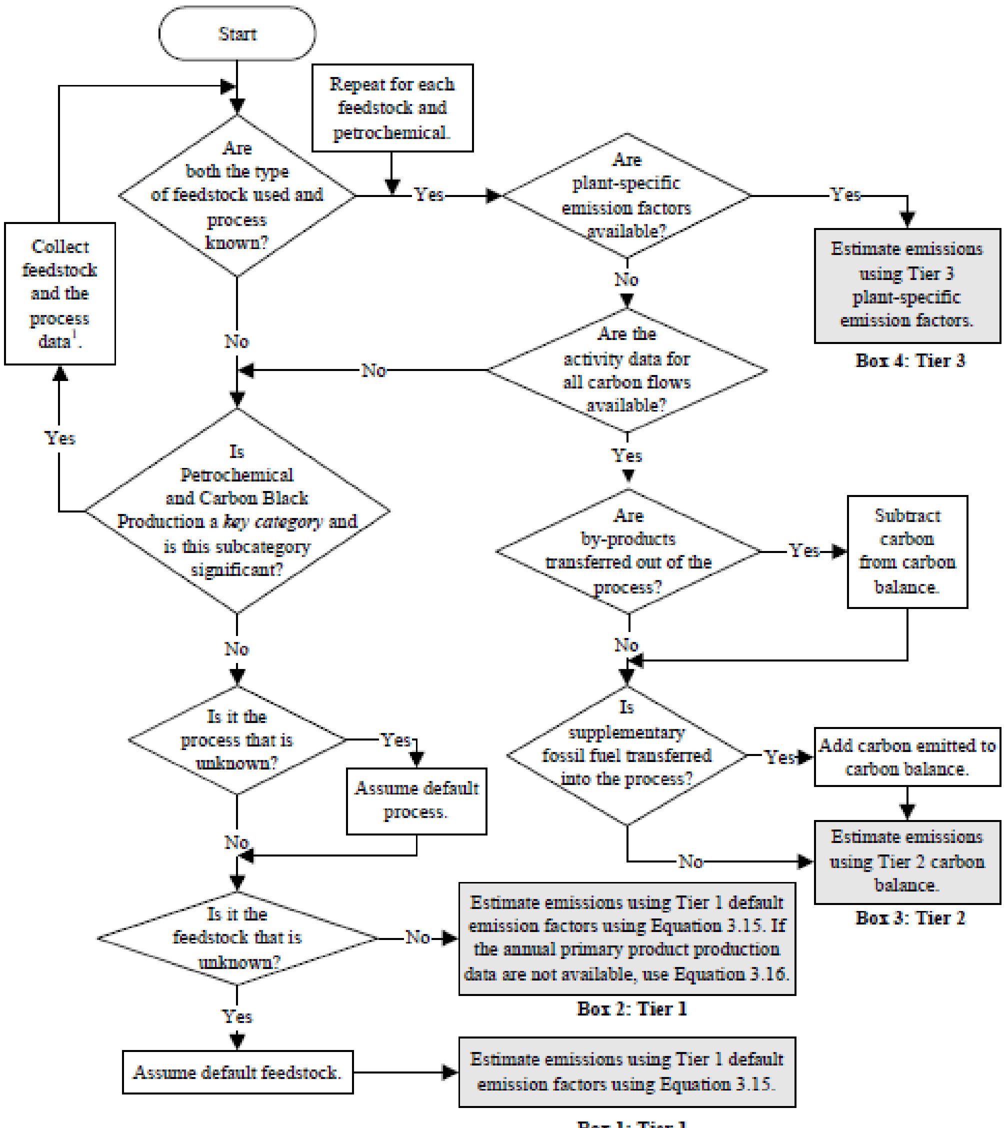
The Combined Reforming Process produces a purge gas containing CH4 that is burned for energy recovery within the methanol process.



Methanol production feedstock-product flow diagram

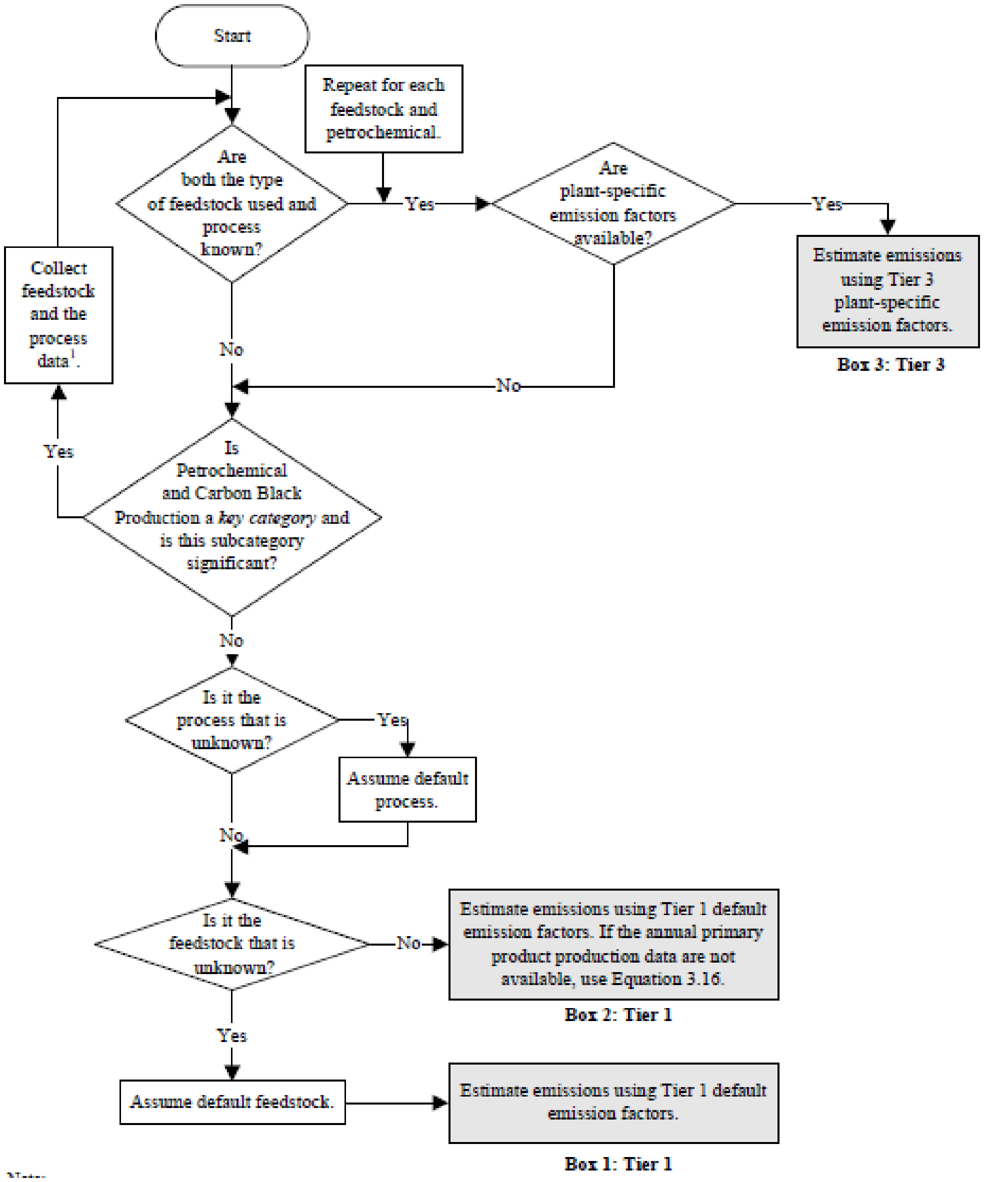


Decision Tree for Estimation of CO2 Emissions



Note:

Decision Tree for Estimation of CH4 Emissions



Tier 1 Method

IPCC 2006: Tier 1 Method

Tier 1 method calculates emissions from petrochemical processes on the basis of activity data for production of each petrochemical and the process-specific emission factor for each petrochemical, (e.g., methanol).

EQUATION 3.15

TIER 1 CO_2 EMISSION CALCULATION

$$ECO2_i = PP_i \bullet EF_i \bullet GAF / 100$$

Where:

$ECO2_i$ = CO_2 emissions from production of petrochemical *i*, tonnes

PP_i = annual production of petrochemical *i*, tonnes

EF_i = CO_2 emission factor for petrochemical *i*, tonnes CO_2/tonne product produced

GAF = Geographic Adjustment Factor

IPCC 2006: Tier 1 Method

- If activity data for annual primary product production are not available, primary product production may be estimated from feedstock consumption.

EQUATION 3.16
PRIMARY PRODUCT PRODUCTION ESTIMATE CALCULATION

$$PP_i = \sum_k \left(FA_{i,k} \bullet SPP_{i,k} \right)$$

Where:

PP_i = annual production of petrochemical *i*, tonnes

$FA_{i,k}$ = annual consumption of feedstock *k* consumed for production of petrochemical (i), tonnes

$SPP_{i,k}$ = specific primary product production factor for petrochemical *i* and feedstock *k* ,tonnes primary product/tonne feedstock consumed

Tier 1 CO2 Emissions

TABLE 3.12
METHANOL PRODUCTION CO_2 EMISSION FACTORS

Process Configuration / Feedstock	tonne CO_2/tonne methanol produced				
Process Configuration **Feedstock**	**Nat. gas**	**Nat. gas + CO_2**	**Oil**	**Coal**	**Lignite**
Conventional Steam Reforming, without primary reformer (a) (Default Process and Natural Gas Default Feedstock)	0.67				
Conventional Steam Reforming, with primary reformer (b)	0.497				
Conventional Steam Reforming, Lurgi Conventional process (c1)	0.385	0.267			
Conventional Steam Reforming, Lurgi Low Pressure Process (c2)	0.267				
Combined Steam Reforming, Lurgi Combined Process (c3)	0.396				
Conventional Steam Reforming, Lurgi Mega Methanol Process (c4)	0.310				
Partial oxidation process (d)			1.376	5.285	5.020
Conventional Steam Reforming with integrated ammonia production	1.02				

Tier 1 CO2 Emissions

TABLE 3.13
METHANOL PRODUCTION FEEDSTOCK CONSUMPTION FACTORS

	GJ feedstock input /tonne methanol produced				
Process Configuration **Feedstock**	**Nat. gas**	**Nat. gas + CO_2**	**Oil**	**Coal**	**Lignite**
Conventional Steam Reforming, without primary reforme (a) (Default Process and Natural Gas Default Feedstock)	36.5				
Conventional Steam Reforming, with primary reformer (b)	33.4	29.3			
Conventional Steam Reforming, Lurgi Conventional process (c1)	31.4				
Conventional Steam Reforming, Lurgi Low Pressure Process (c2)	29.3				
Combined Steam Reforming, Lurgi Combined Process (c3)	31.6				
Conventional Steam Reforming, Lurgi Mega Methanol Process (c4)	30.1				
Partial oxidation process (d)			37.15	71.6	57.6

Nat. gas + CO_2 feedstock process based on 0.2-0.3 tonne CO_2 feedstock per tonne methanol

Tier 1 CH_4 Emissions

- CH_4 emissions from the plants accounted for approximately 0.5 percent to 1.0 percent of the total greenhouse gas emissions from the plants.
- The default CH_4 emission factor to be applied for methanol production is 2.3 kg CH_4 per tonne of methanol produced.

- Much of the uncertainty in emission estimates is related to the difficulty in determining activity data.
- If assuming that all of the national methanol production is from natural gas feedstock, such assumption would introduce some uncertainty.

TABLE 3.27 UNCERTAINTY RANGES FOR EMISSION FACTORS AND ACTIVITY DATA				
Tier 1	Table 3.12	Methanol production CO_2 emission factors	-30% to +30%	Expert judgement by Lead Authors of Section 3.9.
Tier 1	Table 3.13	Methanol Production Feedstock Consumption Factors	-30% to +30%	Expert judgement by Lead Authors of Section 3.9.

QUALITY ASSURANCE AND QUALITY CONTROL
Emission Factors

- **Tier 1** method depends upon the application of activity data production and/or activity data for feedstock consumption. Activity data should not be expected to vary by more than about +/- 10 percent year to year.

- If the activity data vary by more than about +/- 10 % year to year, it is *good practice* to assess and document the country-specific conditions that account for the differences.

Tier 2 Method

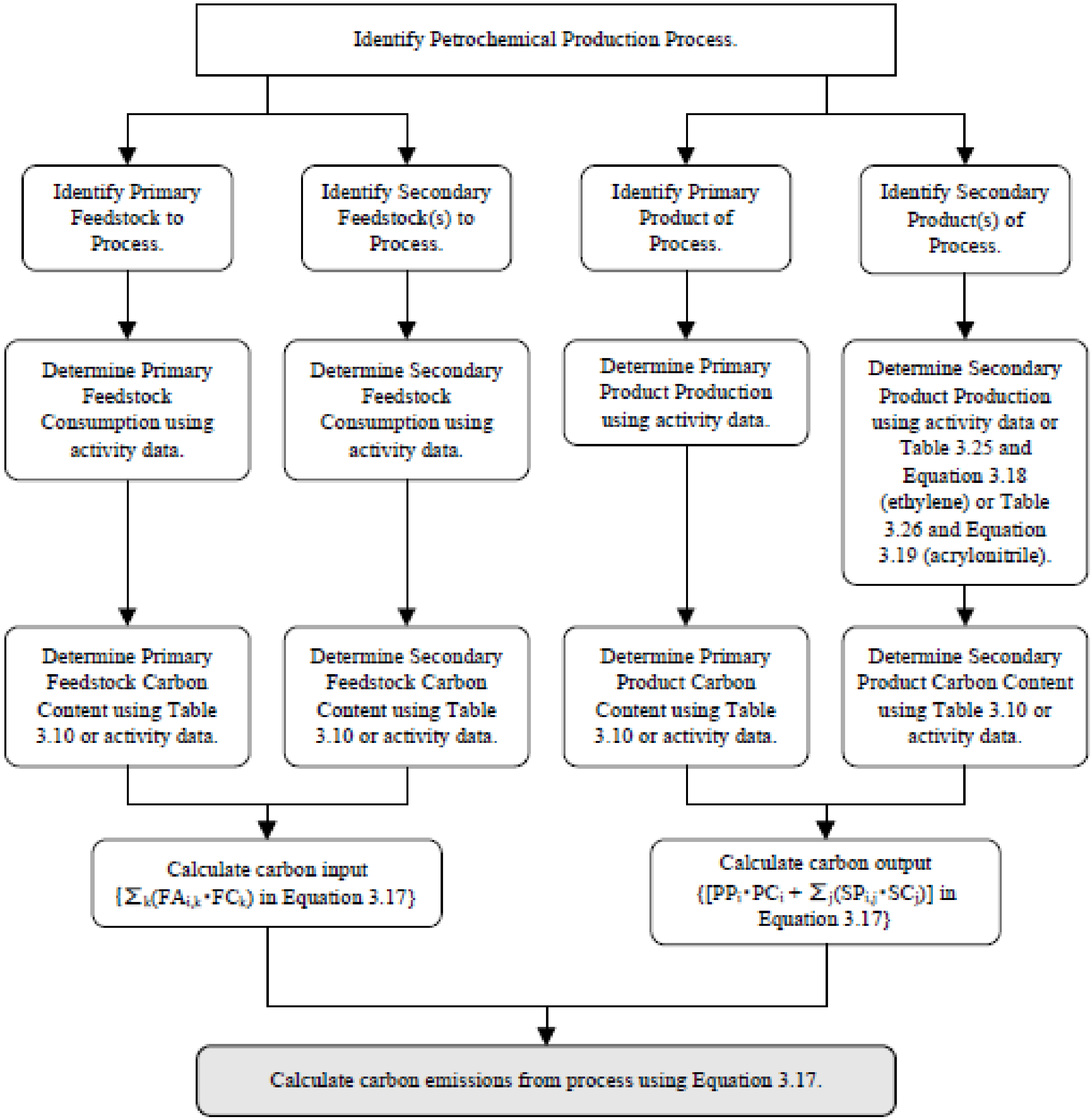
IPCC 2006: Tier 2 Method

- The Tier 2 method is a feedstock-specific and process-specific carbon balance approach.
- This approach is applicable in cases where activity data are available for both feedstock consumption and primary and secondary product production and
- disposition.

IPCC 2006: Tier 2 Method

- Tier 2 method is a feedstock-specific and process-specific carbon balance approach.
- This approach is applicable in cases where activity data are available for both feedstock consumption and primary and secondary product production and disposition.
- Activity data for all carbon flows are required to implement the Tier 2 methodology.

Tier 2 : Carbon mass balance flow diagram



Tier 2 : Carbon mass balance flow diagram

Tier 2 method calculates the difference between the total amount of carbon entering into the production process (primary and secondary feedstock) and the amount of carbon leaving the production process as methanol.

EQUATION 3.17
OVERALL TIER 2 MASS BALANCE EQUATION

$$ECO2_i = \left\{ \sum_k \left(FA_{i,k} \bullet FC_k \right) - \left[PP_i \bullet PC_i + \sum_j \left(SP_{i,j} \bullet SC_j \right) \right] \right\} \bullet 44/12$$

Where:

$ECO2_i$ = CO_2 emissions from production of petrochemical *i*, tonnes

$FA_{i,k}$ = annual consumption of feedstock *k* for production of petrochemical *i*, tonnes

FC_k = carbon content of feedstock *k*, tonnes C/tonne feedstock

PP_i = annual production of primary petrochemical product *i*, tonnes

PC_i = carbon content of primary petrochemical product *i*, tonnes C/tonne product

$SP_{i,j}$ = annual amount of secondary product *j* produced from production process for petrochemical *i*, tonnes

The value of $SP_{i,j}$ is zero for the methanol, as there are no secondary products produced from this processes.

QUALITY ASSURANCE AND QUALITY CONTROL
Emission Factors

- **Tier 2** method depends upon the application of activity data production and/or activity data for feedstock consumption. Activity data should not be expected to vary by more than about +/- 10 percent year to year.

- If activity data vary by more than about +/-10 % year to year, it is *good practice* to assess and document the country-specific conditions that account for the differences.

Tier 3 Method

Tier 3 : direct estimate of plant-specific emissions

- In order to apply the Tier 3 method, plant-specific data and/or plant-specific measurements are required.
- Overall CO2 emissions from the petrochemical production process are calculated using Equation 3.20

EQUATION 3.20

TIER 3 CO_2 EMISSIONS CALCULATION EQUATION

$$ECO2_i = E_{Combustion,i} + E_{Process\ Vent,i} + E_{Flare,i}$$

Where:

$ECO2_i$ = CO_2 emissions from production of petrochemical *i*, tonnes

$E_{Combustion,i}$ = CO_2 emitted from fuel or process by-products combusted to provide heat or thermal energy to the production process for petrochemical *i*, tonnes

$E_{Process\ Vent,i}$ = CO_2 emitted from process vents during production of petrochemical *i*, tonnes

$E_{Flare,i}$ = CO_2 emitted from flared waste gases during production of petrochemical *i*, tonnes

$E_{combustion}$ and E_{flare} are given by Equations 3.21 and 3.22 where plant specific or national net calorific value data should be used.

Tier 3 : direct estimate of plant-specific emissions

EQUATION 3.21
FUEL COMBUSTION TIER 3 CO_2 EMISSIONS CALCULATION

$$E_{Combustion,i} = \sum_k \left(FA_{i,k} \bullet NCV_k \bullet EF_k\right)$$

Where:

$FA_{i,k}$ = amount of fuel k consumed for production of petrochemical i, tonnes

NCV_k = net calorific value of fuel k, TJ/tonne
(Note: In Table 1.2 in Chapter 1 of Volume 2, net calorific values are expressed in TJ/kg)

EF_k = CO_2 emission factor of fuel k, tonnes CO_2/TJ

EQUATION 3.22
FLARE GAS TIER 3 CO_2 EMISSIONS CALCULATION

$$E_{Flare,i} = \sum_k \left(FG_{i,k} \bullet NCV_k \bullet EF_k\right)$$

Where:

$FG_{i,k}$ = amount of gas k flared during production of petrochemical i, tonnes

NCV_k = net calorific value of flared gas k, TJ/tonne
(Note: In Table 1.2 in Chapter 1 of Volume 2, net calorific values are expressed in TJ/kg)

EF_k = CO_2 emission factor of flared gas k, tonnes CO_2/TJ
(Note: In Table 1.4 in Chapter 1 of Volume 2, CO_2 emission factors are expressed in kg/TJ)

Activity Data

- Emissions of CO_2 may be calculated from specific feedstock (e.g., natural gas) consumption, production activity data and carbon mass balance calculations.
- Plant-specific activity data should be obtained from the production plants.
- Direct measurements of the total flow to the steam cracker and flare system and analysis of the gas carbon content provide accurate emissions estimate.
- Plant specific energy balance and/or carbon balance may also be used to derive plant specific emission factors.

Uncertainty Assessment

- Much of the uncertainty in emission estimates for methanol production is related to the difficulty in determining activity data.
- If activity data are not available for consumption feed-stocks other than natural gas, it may be assumed that all of the national methanol production is from natural gas feedstock. This assumption would introduce some uncertainty.

TABLE 3.27
UNCERTAINTY RANGES FOR EMISSION FACTORS AND ACTIVITY DATA

Method	Reference	Factor	Uncertainty Range	Source
Tier 3		Direct measurement of fuel consumption together with gas composition samples for all substances	- 5 to + 5 %	Expert judgement by Lead Authors of Section 3.9, on the basis of discussions with national industry January 2005.

QUALITY ASSURANCE AND QUALITY CONTROL

- It is *good practice* to check the consistency of the total annual consumption figure with the production, import and export data.

- It is recommended to compare the amounts discarded, recovered and combusted and the amount used in 2-stroke engines, if available, with total consumption figures to check consistency of activity data and ODU factors.

Thank you!

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