# Climate MRV for Africa – Phase 2 Development of National GHG Inventory Lime production (IPPU)

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CLIMATE

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Team Leader and Key Experts


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# Lime Global Production and Uses

## Use of Lime

**Lime is used in different forms**:

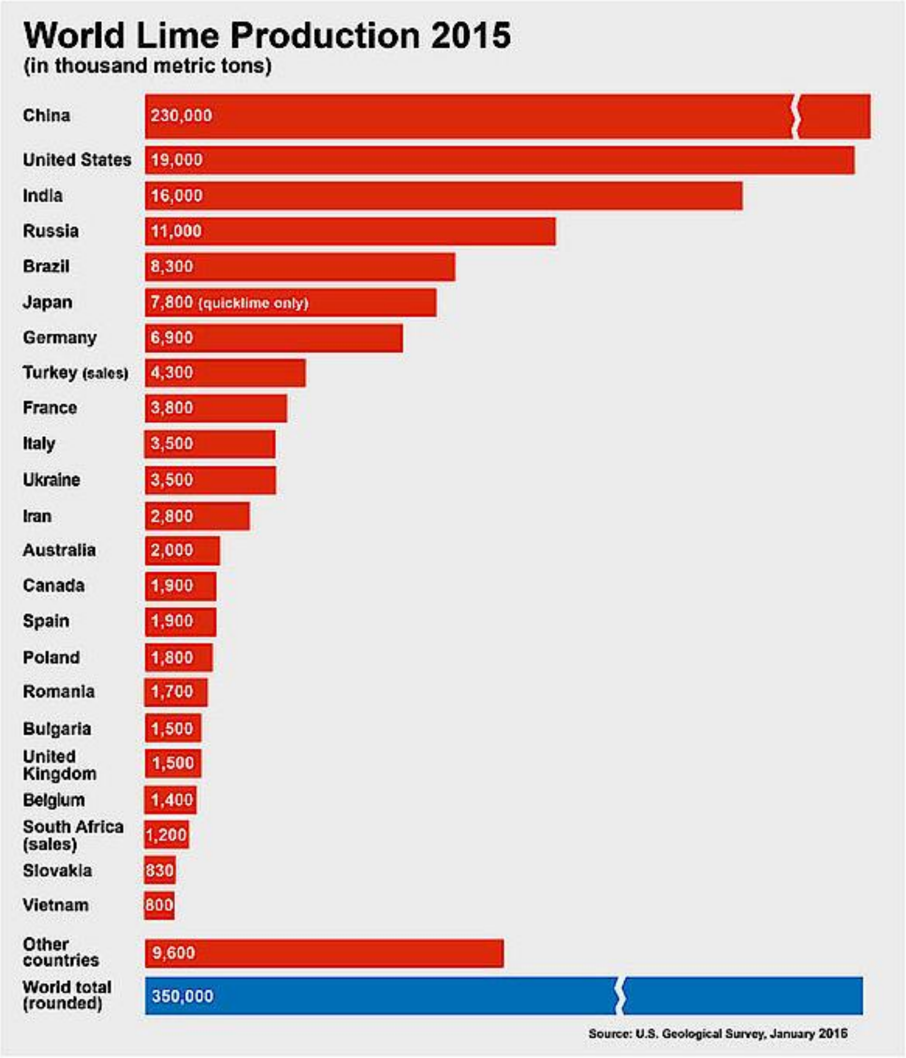
* as uncalcined calcium carbonate ($CaCO_3$)

* as burnt lime or quick lime ($CaO$)

* as hydrated lime $Ca(OH)_2$

**Lime is a key component in:**

- **Iron and Steel**
- **Construction and Building**
- **Water and Flue Gas**
- **Industrial Chemicals**
- **Agriculture, Forestry and Food**

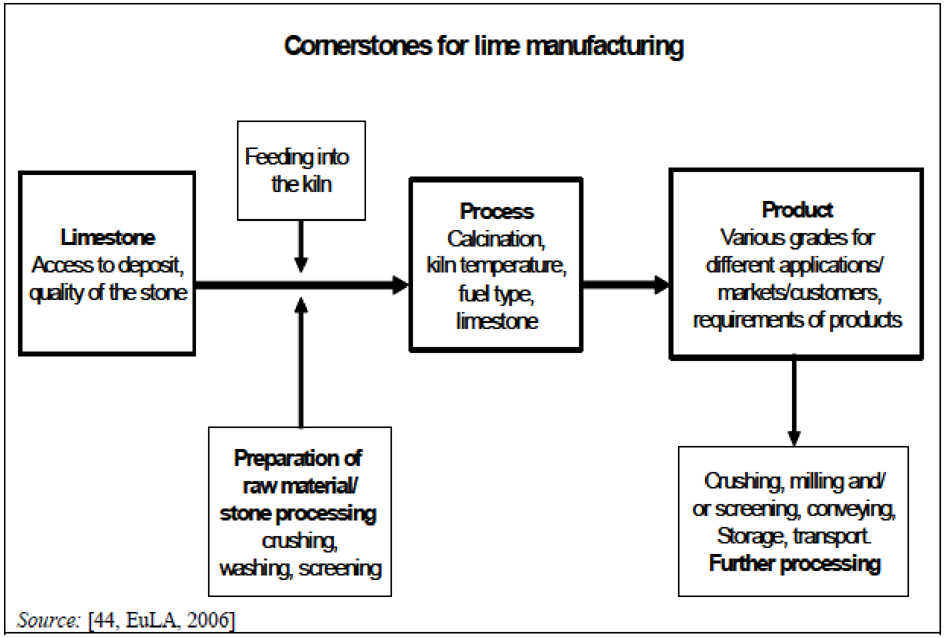


# Emissions Potential for the Category

Lime production steps:

- Quarrying of raw materials,
- Crushing and sizing
- Calcining the raw materials to produce lime.

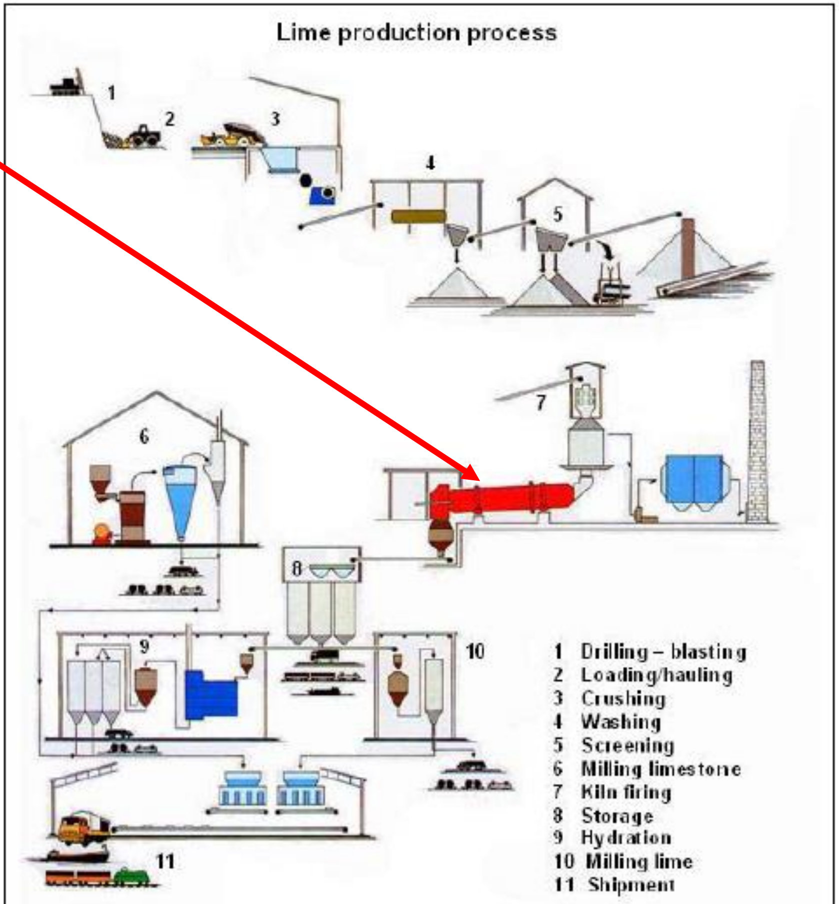
If required, lime could be hydrated to produce calcium hydroxide




“Production of Cement, Lime and Magnesium Oxide”, (BAT) Reference Document, European IPPC Bureau, 2013

# Lime Production and Emissions Sources

$CaCO_3$
**Calcination**



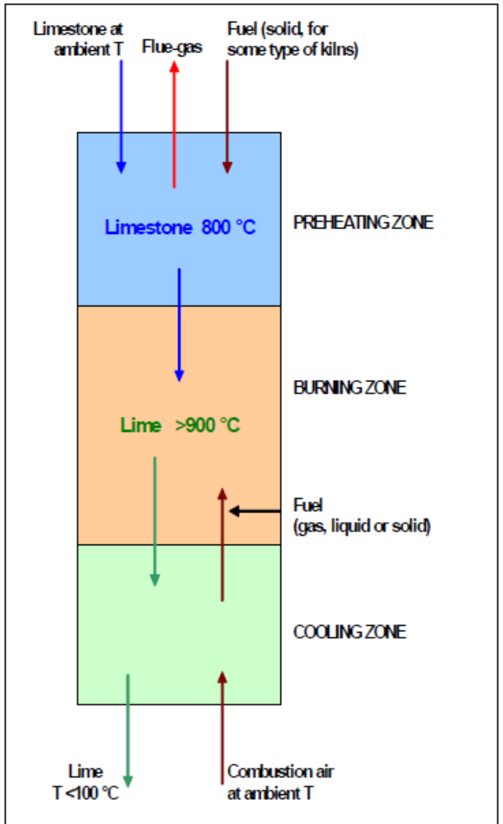

*Source:* [44, EuLA, 2006]

- Limestone: > 90% CaCO3 and a few per cent MgCO3.
- Dolomite: 54–58% CaCO3 and 40–44% MgCO3.
- Dolomitic limestone: MgCO3 higher than limestone but less than dolomite.

"Production of Cement, Lime and Magnesium Oxide", (BAT) Reference Document, European IPPC Bureau, 2013

# Emissions Potential for the Category

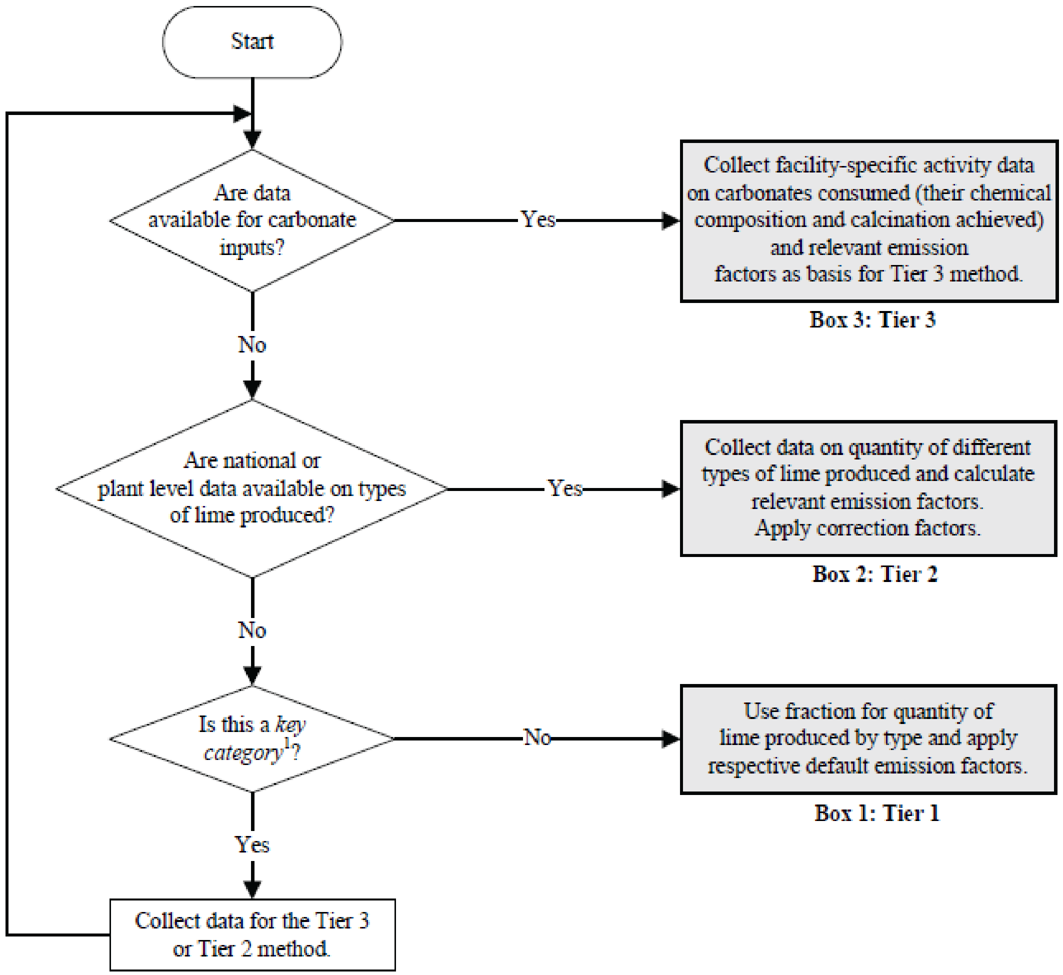
- Calcium Oxide (CaO) is formed by heating limestone to decompose the carbonates.
- Dolomite and dolomitic (high magnesium) limestones may also be processed at high temperature to obtain dolomitic lime (and release $CO_2$)




*Source:* [44, EuLA, 2006]

$CaCO_3$ (high-purity limestone) + heat → CaO (quicklime) + $CO_2$

# Decision Tree for Lime Production Emissions




Source: IPCC 2006 Vol. 3, Ch. 2, Fig. 2.2

# 2A2: Lime Production Emissions

## Tier 1 Method

# IPCC 2006: Tier 1 Method

**EQUATION 2.8**

**TIER 1 DEFAULT EMISSION FACTOR FOR LIME PRODUCTION**

$$EF_{Lime} = 0.85 \bullet EF_{high\ calcium\ lime} + 0.15 \bullet EF_{dolomitic\ lime}$$
$$= 0.85 \bullet 0.75 + 0.15 \bullet 0.77^{a}$$
$$= 0.6375 + 0.1155$$
$$= 0.75 \text{tonnes } CO_2 \text{ / tonne lime produced}$$

Notes on defaults in Equation 2.8

a: The default EF for dolomitic lime may be 0.86 or 0.77 depending on the technology used for lime production. See Table 2.4.

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.8

# Tier 1 Emission Factors

**TABLE 2.4**
**BASIC PARAMETERS FOR THE CALCULATION OF EMISSION FACTORS FOR LIME PRODUCTION**

| Lime Type | Stoichiometric Ratio [tonnes $CO_2$ per tonne CaO or CaO·MgO] (1) | Range of CaO Content [%] | Range of MgO Content[d] [%] | Default Value for CaO or CaO·MgO Content [fraction] (2) | Default Emission Factor [tonnes $CO_2$ per tonne lime] (1) • (2) |
|---|---|---|---|---|---|
| High-calcium lime[a] | 0.785 | 93-98 | 0.3-2.5 | 0.95 | 0.75 |
| Dolomitic lime[b] | 0.913 | 55-57 | 38-41 | 0.95 or 0.85[c] | 0.86 or 0.77[c] |
| Hydraulic lime[b] | 0.785 | 65-92[e] | NA | 0.75[e] | 0.59 |

c This value depends on technology used for lime production. The higher value is suggested for developed countries, the lower for developing ones.

Source: IPCC 2006 Vol. 3, Ch. 2, Table 2.4

# Tier 1 Activity Data

- Some industries produce lime and consume it for their operations. This quantity of lime may never be introduced into the market.
- It is important when collecting activity data for lime production that both marketed and non-marketed lime production are included.
- It is suggested that inventory compilers identify potential industries where non-marketed lime may be produced (e.g. metallurgy and water softeners).
- If there is no disaggregated data for the breakdown of lime types, it is *good practice* to assume: 85 % is high-calcium lime and 15 % dolomitic lime and 0% of hydraulic lime.

# Tier 1 Uncertainty

Uncertainty estimates for lime production result mainly from uncertainties associated with activity data, and to a lesser extent from uncertainty related to the emission factor.

**TABLE 2.5**
**DEFAULT UNCERTAINTY VALUES FOR ESTIMATION OF $CO_2$ EMISSIONS FROM LIME PRODUCTION**

| Uncertainty | Comment | Tier |
|---|---|---|
| 4-8% | Uncertainty in assuming an average CaO in lime | 1, 2 |
| 2% | Emission factor high calcium lime | 1, 2 |
| 2% | Emission factor dolomitic lime | 1, 2 |
| 15% | Emission factor hydraulic lime | 1, 2 |
| 5% | Correction for hydrated lime | 1, 2 |
| | Order of magnitude errors possible if non-marketed lime production is not estimated | 1, 2, 3 |
| 1-2% | Uncertainty of plant-level lime production data. Plants generally do not determine output better than this. Assumes complete reporting. | 2 |
| See Table 2.3 | Correction for LKD | 2, 3 |
| 1-3% | Error in assuming 100% carbonate source from limestone (vs. other feeds). | 3 |
| 1-3% | Uncertainty of plant-level weighing of raw materials | 3 |

Source: Based on expert judgment.

# Tier 2 Method

# IPCC 2006: Tier 2 Method

**EQUATION 2.6**

**TIER 2: EMISSIONS BASED ON NATIONAL LIME PRODUCTION DATA BY TYPE**

$$CO_2\ Emissions = \sum_i (EF_{lime,i} \bullet M_{l,i} \bullet CF_{lkd,i} \bullet C_{h,i})$$

Where:

$CO_2$ Emissions = emissions of $CO_2$ from lime production, tonnes

$EF_{lime,i}$ = emission factor for lime of type *i*, tonnes $CO_2$/tonne lime (see Equation 2.9)

$M_{l,i}$ = lime production of type *i*, tonnes

$CF_{lkd,i}$ = correction factor for LKD for lime of type *i*, dimensionless
This correction can be accounted for in a similar way as for CKD (Equation 2.5, but omitting the factor ($Ef_c/EF_{cl}$))

$C_{h,i}$ = correction factor for hydrated lime of the type *i* of lime, dimensionless (See discussion under Section 2.3.1.3, Choice of Activity Data.)

i = each of the specific lime types listed in Table 2.4

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.6

# IPCC 2006: Tier 2 Method

**EQUATION 2.9**
**TIER 2 EMISSION FACTORS FOR LIME PRODUCTION**

$$EF_{lime,a} = SR_{CaO} \bullet CaO\ Content$$

$$EF_{lime,b} = SR_{CaO \cdot MgO} \bullet CaO \cdot MgO\ Content$$

$$EF_{lime,c} = SR_{CaO} \bullet CaO\ Content$$

Where:

$EF_{lime\ a}$ = emission factor for quicklime (high-calcium lime), tonnes $CO_2$/tonne lime

$EF_{lime\ b}$ = emission factor for dolomitic lime, tonnes $CO_2$/tonne lime

$EF_{lime\ c}$ = emission factor for hydraulic lime, tonnes $CO_2$/tonne lime

$SR_{CaO}$ = stoichiometric ratio of $CO_2$ and CaO (see Table 2.4), tonnes $CO_2$/tonne CaO

$SR_{CaO \cdot MgO}$ = stoichiometric ratio of $CO_2$ and CaO·MgO (see Table 2.4), tonnes $CO_2$/tonne CaO·MgO

CaO Content = CaO content (see Table 2.4), tonnes CaO/tonne lime

CaO·MgO Content = CaO·MgO content (see Table 2.4), tonnes CaO·MgO/tonne lime

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.9

# Tier 2 Activity Data & Sources

- It is important to collect disaggregated data for the three types of lime:
  - High-calcium lime (CaO + impurities);
  - Dolomitic lime ($CaO \cdot MgO$ + impurities);
  - Hydraulic lime (CaO + hydraulic calcium silicates).

- It is important to correct for the proportion of hydrated lime in production.
- Data should be collected on all non-carbonate sources of CaO (if applicable).

# Tier 3 Method

# IPCC 2006: Tier 3 Method

- Tier 3 is based on the collection of plant-specific data on the type(s) and quantity(ies) of carbonate(s) consumed to produce lime.
- Also, the respective emission factor(s) of the carbonate(s) consumed should be employed.

Source: IPCC 2006 Vol. 3, Ch. 2, Eq. 2.3

# Tier 3 Method Emission Factor

EQUATION 2.7
TIER 3: EMISSIONS BASED ON CARBONATE INPUTS

$$CO_2\ Emissions = \sum_i (EF_i \bullet M_i \bullet F_i) - M_d \bullet C_d \bullet (1 - F_d) \bullet EF_d$$

Where:

$CO_2$ Emissions = emissions of $CO_2$ from lime production, tonnes

$EF_i$ = emission factor for carbonate *i*, tonnes $CO_2$/tonne carbonate (see Table 2.1)

$M_i$ = weight or mass of carbonate i consumed, tonnes

$F_i$ = fraction calcination achieved for carbonate *i*, fraction[a]

$M_d$ = weight or mass of LKD, tonnes

$C_d$ = weight fraction of original carbonate in the LKD, fraction[a]. This factor can be accounted for in a similar way as CKD.

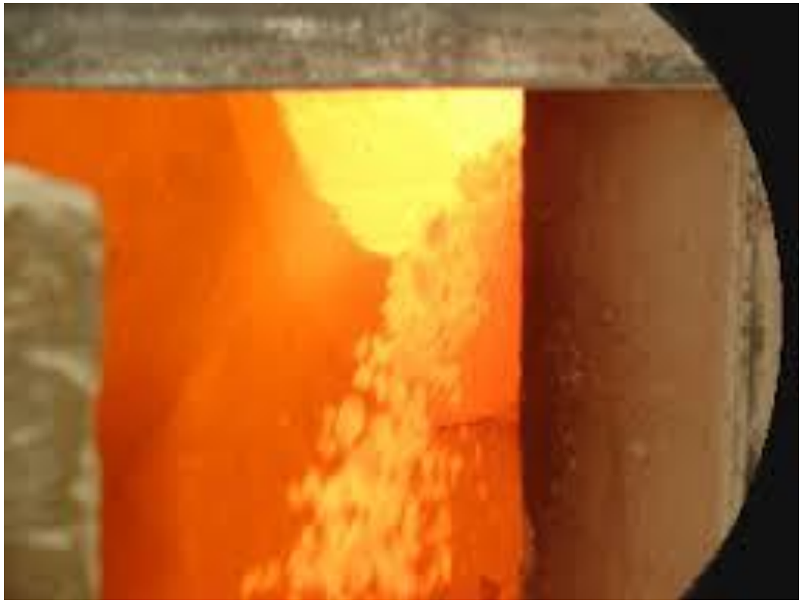
$F_d$ = fraction calcination achieved for LKD, fraction[a]

$EF_d$ = emission factor for the uncalcined carbonate in LKD, tonnes $CO_2$/tonne carbonate[b]

# Tier 3 Activity Data & Sources

- It is *good practice* to collect plant specific data for the weight fraction of carbonate(s) consumed for lime production and the fraction of calcination achieved.
- Data should also be collected for the amount (dry weight) and composition of **LKD (Lime Kiln Dust)** produced.
- Emissions from LKD should be subtracted from the Tier 3 estimates.

# Lime Kiln Dust (LKD)



# Tier 3 Uncertainty

- There is little uncertainty associated with the emission factor component in the Tier 3 approach.
- There is significant uncertainty associated with quantifying the mass of LKD produced and the degree of calcination (and thus emissions) of LKD.
- It can be assumed that the uncertainty associated with estimating LKD is at least equal to and likely greater than, the uncertainty associated with **CKD (Cement Kiln Dust).**
- Where ranges are given for the default uncertainties, the mid-range should be used unless the upper or lower estimates are more reflective of country-specific circumstances.

# QA/QC for Lime Emissions

- **Recommendation 1**: When bottom-up data are applied (Tiers 2 & 3), make a comparison with the results of the top-down, Tier 1 approach.
- **Recommendation 2**: Compare national emission factors to IPCC default factors and explain the differences.
- **Recommendation 3**: Compare Activity Data between sites to identify inconsistencies

# Considerations for Reporting

- It is *good practice* to document and archive all information required to produce the GHG inventory estimates.
- When reporting on CO2 recovery from sugar refining, precipitated calcium carbonate or water softening under Category 2H, detailed information should be reported on the methods used for calculating emissions recovered.
- Inventory compilers should document procedures undertaken to ensure that both marketed and non-marketed lime production are reported.

# Considerations for Reporting

- **Tier 2**: The procedures used to identify the CaO and/or CaO·MgO content of lime, as well as non-carbonate feeds to lime kiln also should be reported.
- **Tier 3:** Data on the quantity and fraction of calcination achieved of LKD should be collected.
- All underlying information should be documented and reported, it is not considered *good practice* to report just final emissions estimates.

# Thank you!

Amr Osama Abdel-Aziz, Assen Gasharov, Mike Bess and Laura Lahti