CO$_2$ EMISSIONS CALCULATION PROTOCOL FOR THE LIME INDUSTRY

ENGLISH UNITS VERSION

February 2, 2005 Revision

NATIONAL LIME ASSOCIATION

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INTRODUCTION

This protocol for calculating carbon dioxide (CO_2) emissions from lime manufacturing is designed to allow the lime industry to achieve consistency, comparability and transparency in accounting for greenhouse gas emissions and reductions, and to ensure that technically supported emission factors and other standards are used. Consistency means using the same method for the base year and subsequent years, and comparability means using methods and data that allow comparisons among facilities. Transparency means documenting data collection and calculation methods so they can be verified later. Please note that accuracy in estimating emissions and in reporting are essential. If lime companies commit to specific reductions in CO_2 intensity, inaccuracies could result in the failure to meet targets or the need to purchase emissions credits. Thus, reporting companies are urged to use actual data rather than default values as much as possible, and to sample with sufficient frequency to ensure representative data.

Emissions of greenhouse gases other than CO_2 are expected to be negligible at lime plants (about 1 per cent of total CO_2 equivalent emissions), and thus are not addressed in this protocol.

Please note that this version of the protocol uses ENGLISH units of measurements, including short tons.

GENERAL INSTRUCTIONS FOR FILLING OUT SPREADSHEETS

Accompanying these text instructions is an Excel spreadsheet on which the values and calculations described below can be entered.

IT IS IMPORTANT TO CONSULT THE WRITTEN INSTRUCTIONS BELOW BEFORE FILLING OUT THE SPREADSHEET.

The spreadsheet is designed to automatically calculate and total the relevant figures. It is designed for a lime plant with up to five kilns, using up to three fuels per kiln, and up to five fuels for quarry/mine/miscellaneous activity. It does not include automatic calculation of indirect emissions reductions or biomass fuels. Facilities having more than five kilns or otherwise needing a modified spreadsheet should contact NLA for a tailored version of the spreadsheet. If you have relevant information that does not fit on the spreadsheet, contact NLA for assistance or a customized spreadsheet. This could include situations in which a plant is burning nonstandard fuels (such as landfill gas or tires), or when it generates a non-standard waste or byproduct.

In filling out the spreadsheet, only enter data in WHITE data blocks. Blocks in blue transfer or calculate data entered elsewhere in the spreadsheet. For example, on the first worksheet, Summary Form, you should only enter data in the blocks marked "Facility Name," "Year," "Indirect Emissions Reductions" and "Emissions from Biomass Fuels."

Please note that the spreadsheet data entry blocks are designed to accept data expressed in specified units. Data entered MUST be in the specified units.

NLA will collect the ENTIRE completed spreadsheet, not just the summary page. The spreadsheet collects information that NLA will aggregate for both greenhouse gas emissions calculations and energy efficiency calculations.

Persons filling out the spreadsheet are urged to add text to the notes section or to draft a memorandum describing how they went about collecting, analyzing, and entering the data into the spreadsheet, to facilitate later review of the data, and to assist in using consistent procedures from year to year.

DIRECT CO_2 EMISSIONS FROM LIME PLANTS

For lime plants, emissions to be reported include emissions from calcination of limestone and fuel use, as described below.

Spreadsheet Tabs "Quicklime Emissions" and "Calcined Byproducts/Wastes Emissions"

These emissions result from the production of quicklime at each kiln at the plant, as well as from calcined byproducts/wastes.[1] Emission calculations are based on tonnage of each type of quicklime and calcined byproducts/wastes produced at the kiln.

The spreadsheet includes separate worksheets for quicklime and for calcined byproduct/wastes. Please be sure the relevant kiln is clearly identified so that kiln-by-kiln intensities and efficiencies can be calculated.

Emissions are calculated by multiplying amounts of quicklime and calcined byproducts/wastes produced by an emission factor, which represents the amount of CO_2 emitted for each ton of quicklime or calcined byproducts/wastes.

Definitions:

Quicklime: Quicklime produced <u>at the kiln</u>. Quicklime does not include hydrated lime (although it does include quicklime used to make other products, such as hydrated lime).

Calcined byproducts/wastes:

Lime kiln dust produced at the kiln in association with quicklime, as well as other partially calcined wastes or byproducts generated

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[1] The previous version of the instructions and spreadsheet referred to "LKD" here. This has been changed to "calcined byproducts/wastes" to make it clear that it applies to all calcined materials, including, but not limited to, LKD.

at the kiln, such as waste cores, off-spec wasted lime, scrubber sludge, etc.

Type of quicklime: Each quicklime with a consistent average chemical composition is to be considered as one type of quicklime. Examples of types of quicklime would include soft burned high calcium, hard burned high calcium, soft burned dolomitic, and dead burned dolomitic.

Type of calcined byproduct/waste:

Each calcined byproduct/waste with a consistent average chemical composition is to be considered as one type of calcined byproduct/waste. Thus, for example, one type of LKD would be produced in association with each type of quicklime.

Data Inputs:

To calculate quicklime and calcined byproduct/waste emissions for a lime plant the following plant-specific data inputs are required:

- The quantity (tons) of each type of quicklime produced **at the kiln**
- The quantity (tons) of each type of calcined byproduct/waste produced **at the kiln**
    - **All** of each type of calcined byproduct/waste produced at the kiln (including that "sold or used in a product", inventoried, or disposed of) must be included in order to estimate all CO_2 emissions.
    - The chemical composition (% total CaO and % total MgO) of each type of quicklime and each type of calcined byproduct/waste produced in order to calculate how much CO_2 was generated by the calcination of carbonates ($CaCO_3$ and $MgCO_3$) into oxides (CaO and MgO)
    - Deriving the % total CaO value for inclusion in this calculation requires particular care. Using **available** CaO in the calculation may understate emissions, because this test does not measure all of the CaO present. For soft-burned lime, this underestimation is small - approximately 1% - but it can be more for hard-burned lime. Accordingly, the protocol calls for "% CaO" rather than "% available CaO." It is strongly preferred that **total** CaO be calculated and used for "% CaO." Appendix A to these instructions describes analytical methods that can be used to calculate total CaO. Facilities with only soft-burned lime may choose to use available CaO as a surrogate. If this choice is made, total CaO should be calculated and compared to available CaO, and a correction factor should be generated that can be used to adjust future available CaO values. It is essential that the methods chosen be carefully documented, including the choice of total v. available, the derivation of any correction factors, and the methods used for analysis and calculation.
    - Accurate measurements of CaO and MgO are required. These values should be annual averages. Sampling should be performed at least monthly to obtain the data for these averages

Calculations:

The emission factor should be calculated for each type of quicklime and each type of calcined byproduct/waste produced at each plant. If more than one type of quicklime, for example high calcium and dolomitic, is produced in any year, then an emission factor for each type of quicklime produced (as well as the related calcined byproduct/waste) will be required.

The emission factor for each type of quicklime or calcined byproduct/waste (EF as ton CO_2 per ton lime) is calculated as follows:

EF = [(% total CaO * stoichiometric ratio of CO_2/CaO) + (% total MgO * stoichiometric ratio of CO_2/MgO)] which equates to

EF = [(% total CaO * 0.7848) + (% total MgO * 1.0918)]

If a plant produces wet lime sludge when using a wet scrubber, the above emission factor calculation can be used, but the input data must be derived from samples of **dry** calcined byproduct/waste before it enters the scrubber, and the emission factor must be applied to the tons of dry calcined byproduct/waste processed through the scrubber.

Once the emission factor is derived, it is multiplied by the tonnage of the relevant quicklime or calcined byproduct/waste to derive the amount of CO_2 emitted. Use the tonnage of quicklime or calcined byproduct/waste **generated at the kiln** on a dry basis, even if the material is combined with other products later.

The spreadsheet tab for Calcined Byproducts/Wastes also asks for the amount of each waste/byproduct **sold or used in a product**. This figure is needed because emissions intensity calculations are based on the ratio of CO_2 emitted to the units of product entering into commerce ("kiln output"). Thus, for example, if LKD is incorporated into a lime product, or is directly sold, the tons of such LKD should be entered here, and will be used in the intensity calculation.

If **stockpiled** calcined byproducts/wastes (such as LKD) are sold or incorporated into lime products, the amounts to be included in "kiln output" should not exceed the amount of such calcined byproducts/wastes produced in the year for which the report is being filed.

Spreadsheet Tabs "Emissions from Kiln Fuels" and "Emissions from Quarry/Mine/Miscellaneous Fuels"

These emissions result from the combustion of **all** fuels at each lime plant, **including fuels used in contiguous or adjacent mines or quarries** if they are owned, operated or

controlled by the same legal entity as the manufacturing facility.[2] Also include emissions from off-site quarries or mines, if they are owned, operated or controlled by the same legal entity as the manufacturing facility.

Emission calculations are based on the quantity of each type of fuel combusted. Please note that only energy supporting the production of lime products should be included. If the facility has significant other product lines (such as significant aggregate sales), energy use should be allocated, and the method for allocation should be described in the accompanying narrative. If stone or fines sales are small and incidental to the production of lime, energy allocation is not necessary.

Direct CO_2 emissions from fuel are calculated by multiplying the quantity of each type of fuel combusted by an **emission factor** derived as described below. The emission factor incorporates the percentage of carbon in the fuel, the ratio of carbon to CO_2, and a combustion efficiency factor.

The spreadsheet seeks data on kiln fuel use on a kiln-by-kiln basis, to allow calculation of energy efficiency for each kiln. Thus, for kiln fuels, fuel use should be reported for *each kiln*, even if the same fuel is combusted in more than one kiln.

Btu data for each fuel are also requested. Although not part of the emissions calculation discussed below, energy use and energy efficiency estimates have proven helpful in the QA/QC process.

Definitions:

Fuel: All solid, liquid or gaseous fuels including alternative fuels such as tires, waste oil, and landfill gas (except for biomass fuel—see discussion below).

Type of fuel: Each fuel with a consistent chemical composition is to be considered as one type of fuel. Examples of generic types of fuel would include coal, petroleum coke, bunker oil, or natural gas. Within each generic type of fuel there could be different specific types of fuel, for example different types of coal or oil.

Data Inputs:

To calculate fuel emissions for a lime plant the following data inputs are required:

- The quantity of each type of fuel combusted in lime kilns
- The quantity of each type of fuel combusted in equipment other than lime kilns
    - Includes fuel combusted in hydrators, conveyors, dryers, boilers and other stationary equipment, fuel combusted in on-site mobile equipment (such as in the mine or quarry), and lab fuels. Emissions from off-site

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[2] If the mine or quarry is contiguous to the lime plant, but you believe that it is not owned, operated or controlled by the same legal entity, please consult NLA staff on whether to collect fuel use data from the mine or quarry.

transportation of raw materials and products are excluded (i.e., fuel used in trucks to move product to an off-site terminal).
- The chemical composition of (or a default emission factor for) each type of fuel combusted
  o Accurate measurements of carbon content are required. These values should be annual averages. Sampling should be performed at least monthly to obtain the data for these averages.

(Note: this protocol assumes that all fuels are combusted for energy production, and are not used as a feedstock or for waste disposal (e.g., incineration).)

Calculations:

Default emission factor values are available for certain fuels. However, it is strongly recommended that actual data be obtained for all kiln fuels to ensure accuracy of emissions figures. Because fuels used in the quarry, mine, or miscellaneous activities constitute a significantly smaller proportion of total fuel use, it may be appropriate to use default values for these fuels, although actual data should be obtained if there is any reason to doubt that the fuel conforms to the default specifications. If you use a default value, be sure that the units in the emission factor are the same as those for the fuel you are reporting.

Coal and Petroleum Coke: The CO_2 emission factor for coal and petroleum coke should be calculated for each type of coal or coke combusted at each plant. If more than one type of coal or coke is combusted in any year then an emission factor for each will be required.

To calculate the emission factor for coal and coke, data on the percentage of carbon in the fuel is required. This should be obtained from the **ultimate analysis** of the coal or coke involved. Ultimate analysis gives the percentage of carbon present in the fuel, including carbon in the solid fuel as well as the carbon in the volatile component of the fuel. **Do not** use a fixed carbon percentage obtained from proximate analysis—this will omit the carbon in the volatile component, and thus will understate the carbon content of the fuel (in one case NLA observed, by 20%). The ultimate analysis figures should be available from the fuel supplier.

Because ultimate analysis is performed on a **dry basis**, data for coal or coke consumed must be entered in the spreadsheet on a dry basis as well. In many cases, coal and coke are purchased on an "as received basis," which accounts for moisture content. If the facility maintains coal and coke consumption records based on an as received basis, a calculation must be done to convert this figure into a dry basis before entering the amount consumed on the spreadsheet.

The emission factor for each type coal or coke is calculated as follows:

EF = %C (ultimate analysis) * (44/12) * combustion efficiency factor

Typical emission factors for coal and coke consumption in a lime kiln assume a combustion efficiency of 99%. Actual combustion efficiency figures should be used where available, however. Please note that ideally, combustion efficiency is the efficiency of that fuel as combusted in the particular kiln.

For convenience, the spreadsheet workbooks include the ability to calculate the emission factor for coal or coke by inputting carbon content and combustion efficiency. **Do not** use this calculation for other fuels. Reporters should be sure to document the methods and calculations used to derive the emission factor.

Once the emission factor is derived, it is multiplied by the quantity, **on a dry basis**, of the relevant coal or coke combusted to derive the amount of CO_2 emitted.

Landfill Gas: Lime plants using landfill gas will need to derive and document an emission factor for these fuels in cooperation with the supplier. Emissions from burning these gases must be included in direct emissions totals, although there may be indirect emissions reductions available due to their use, as explained in a later section. Do not use the emission factor for natural gas.

Tires: Lime plants burning tires will need to derive and document an emission factor from sampling.

Other Fuels:

Listed below are standard default emission factors for selected fuels. If you use a different default factor, be sure to document its source.

Fuel	Default Emission Factor[3]	Assumed combustion efficiency
Heavy Fuel Oil (No. 4 & heavier)	0.0129 ton CO_2/gallon combusted	99%
Light Fuel Oil (Distillate & waste oil)	0.0118 ton CO_2/gallon combusted	99%
Diesel (Stationary Sources)	0.0114 ton CO_2/gallon combusted	99%
Diesel (Mobile Source – Heavy Duty Vehicles)	0.0114 ton CO_2/gallon combusted	100%
Diesel (Mobile Source – Light Duty Vehicles)	0.0114 ton CO_2/gallon combusted	100%
Gasoline (Mobile Source)	0.0098 ton CO_2/gallon combusted	100%
Natural Gas	0.0589 ton CO_2/1000 cubic feet (MCF) gas combusted	99.5%
Propane (Stationary Source)	0.0467 ton CO_2/1000 cubic feet	99.5%

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[3] The default values given here are converted from Olsen, K et al; Canada's Greenhouse Gas Inventory, Greenhouse Gas Division Environment Canada, 2002.

	(MCF) gas combusted	
Propane (Mobile Source)	0.0467 ton CO_2/1000 cubic feet (MCF) gas combusted	100%

Please note that units vary from fuel to fuel. **It is essential that the units used in the emission factor match the units of fuel combusted.**

   Biomass Fuels: Emissions from biomass fuels, such as wood chips, are considered climate-neutral when sustainable forest and agricultural management practices are in place, because biomass materials are part of the natural "carbon cycle." Thus, emissions from burning these materials are recorded as a "memo" item, but are not included in national emissions totals. It may be necessary for facilities to report these emissions to national or state authorities, but they should be calculated separately and not added to total emissions amounts. NLA can provide assistance in calculating emission factors for these fuels.

Do not use the fuel worksheets in the spreadsheet to calculate biomass fuel emissions, because the spreadsheet will automatically include those emissions in total emissions.

INDIRECT CO_2 EMISSIONS

Indirect CO_2 emissions are those that result from the activities of the reporting entity, but are generated by other entities. For the lime industry, these include external production of electrical power consumed by the lime plant, production and processing of fuels, quarrying of purchased stone (for some units), and offsite transportation of raw materials and products.

Spreadsheet Tab "Indirect Emissions from Electric Power"

Of these categories, the only one that can be calculated readily and consistently is CO_2 emissions from electrical power generation.

Data Inputs:

To calculate indirect emissions from electric power for a facility the following facility specific data inputs are required:

- The quantity of power consumed (kwhr)
- Emission factor

Calculations:

An **emission factor** will be required from the power supplier. **A default should not be used**, because a particular supplier's factor will vary depending on the source of the electrical power (i.e., fossil fuels, nuclear, and/or hydroelectric). Some lime plants have

encountered challenges in obtaining this information, but power suppliers should be able to generate these values if pressed to do so.

If a default factor must be used, please use the values shown in the Department of Energy's Instructions for Voluntary Greenhouse Gas Reporting—Appendix C (ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/1605INST02.pdf). Note that these values are set on a state-by-state basis, and are thus not as accurate as emission factors obtained directly from the energy supplier. However, it may be useful to perform a "reality check" of the emission factor supplied by the power supplier by comparing it to the default value for the state involved.

The spreadsheet assumes the emission factor will be stated in **pounds per kilowatt/hour**, and converts to short tons. Please be sure the emission factor provided by the power supplier is expressed in pounds per kilowatt/hour, or convert it into those units.

Once the emission factor is derived, it is multiplied by the quantity of power (in kilowatt-hours) consumed to derive the amount of CO_2 indirectly emitted.

Please note that only electrical power supporting the production of lime products should be included. If the facility has significant other product lines (such as significant aggregate sales), energy use should be allocated, and the method for allocation should be described in the accompanying narrative. If stone or fines sales are small and incidental to the production of lime, energy allocation is not necessary.

DIRECT CO_2 REDUCTIONS FROM ON-SITE SEQUESTRATION

Spreadsheet Tab "Emissions Sequestered"

At some lime plants, quicklime and/or calcined byproducts/wastes are processed in a manner that reabsorbs carbon dioxide. The primary process of this kind is PCC manufacturing. Please note that sequestration is limited to processes that **actually reabsorb** CO_2, and not procedures such as landfilling or storing calcined byproducts/wastes. The discussion below describes how to calculate the CO_2 that is sequestered in such processes, and this amount should be subtracted from total emissions.

The sequestration factor for quicklime and for calcined byproducts/wastes should be calculated for each type of quicklime (and each related calcined byproduct/waste) processed at each plant. If more than one type of quicklime is processed in any year then a sequestration factor for each type will be required.

The *sequestration* factor (SF) for any quicklime or calcined byproduct/waste (ton CO_2 per ton quicklime or calcined byproduct/waste) is the same as the *emission* factor for the same material, as follows:

SF $=$ [(% CaO * stoichiometric ratio of CO_2/CaO) + (% MgO * stoichiometric ratio of CO_2/MgO)] or

$SF = [(\% \; CaO * 0.7848) + (\% \; MgO * 1.0918]$

This calculation assumes that all CO_2 emitted in the calcination of the quicklime or calcined byproduct/waste is reabsorbed in the relevant process.

Other methods of sequestration may require tailored calculations. For example, some facilities "bubble" stack gases through water in their water treatment system to reduce the acidity of the wastewater. The amount of CO_2 sequestered by this process should be calculated by determining the difference in alkalinity (as $CaCO_3$) between treated and untreated water, multiplied by the milliequivalent weight of CO_2 to determine the mg/L of CO_2 it took to lower the alkalinity. That figure is then multiplied by the volume of treated water discharged.

INDIRECT GREENHOUSE GAS EMISSION REDUCTIONS

Indirect reductions of greenhouse gas emissions occur when actions at a lime plant result in reduced emissions elsewhere. This protocol provides for subtracting certain of these indirect emissions from total emissions. This information must be entered **by hand on the initial summary sheet** under "indirect emissions reductions." The spreadsheet does not include a worksheet for calculating indirect reductions. Please consult NLA for assistance on how to generate these figures.

There may be issues as to which entity has the right to receive credit for indirect reductions, and thus they should be separately accounted for. *Please include a text narrative explaining what indirect reductions are being included, and how they were calculated.* Reductions in emissions from electrical power plants from reduced power usage should not be included, because any such reductions are already reflected in changes in indirect emissions from electrical power usage.

Use of Landfill Gas

Using landfill gas results in indirect emissions savings at the landfills where these gases would otherwise be emitted. Lime plants using landfill gas should, in cooperation with the fuel sources, calculate the emissions that have been avoided at the offsite location due to use of this fuel. In some cases, this will be methane, a more potent greenhouse gas, and thus carbon dioxide equivalents should be calculated. (Note: as indicated above, emissions from the combustion of landfill gas at the lime plant must be included in emission totals.)[4]

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[4] There are no similar indirect reductions from the use of "spec" waste oil, because this material would not otherwise be incinerated. Similarly, there is no reduction from the use of tires, because their disposal would not lead to CO_2 emissions. Currently, these are the only waste-derived fuels used at lime plants. If others are used in the future, such as paper waste that would otherwise be incinerated, indirect reductions may be available.

Off-Site Reabsorption of CO_2 from Lime Use

In many uses of lime, CO_2 is reabsorbed by the CaO and stable carbonates are formed. The degree to which this occurs varies depending on the use of lime, but current estimates are that approximately 20-25% of calcination-related emissions will ultimately be reabsorbed by lime products.

Because this reabsorption generally occurs at facilities beyond the lime producer's ownership or control, and because the levels of reabsorption are difficult to quantify, this protocol currently does not include provisions for accounting for this reabsorption as a greenhouse gas emission saving, except for on-site sequestration as described above.

Purchased Credits or Other Offsets

Companies may have the opportunity to purchase greenhouse gas credits, or to otherwise obtain or create offsets. The source of any such credits or offsets should be clearly documented if these amounts are to be included on the protocol summary form.

Reductions through Heat and Power Exports

Any heat and power exports should be reported separately, and can be netted against indirect emissions from purchased electrical power.

CALCULATION AND REPORTING

Adding the direct emissions from calcination and from fuel use to the indirect emissions from purchased electrical power, and then subtracting any credits from sequestration and indirect reductions, results in total CO_2 emissions. Emissions resulting from the use of biomass fuel should not be included in the total, but should be recorded.

Spreadsheet Tab "Calculating Emissions Intensity"

Intensity calculations are made automatically based on the inputs on other portions of the spreadsheet. Do not enter data on this worksheet.

Total CO_2 emissions intensity is calculated by dividing total CO_2 emissions by kiln output. "Kiln output" is the amount of quicklime generated at the kiln, and the amount of calcined byproducts/wastes generated at the kiln sold or incorporated into products entering commerce. It does not include calcined byproducts/wastes that are landfilled or otherwise disposed. If quicklime is incorporated into other products, such as hydrated lime, mortars, etc., only the actual tonnage of quicklime itself is added to the total kiln output. Similarly, only the tonnage of calcined byproducts/wastes generated at the kiln on a dry basis is included.

CO_2 emissions intensity from energy use is calculated by dividing energy-related emissions only by kiln output. Energy-related emissions include direct emissions from

fuel use other than biomass as well as indirect emissions from electric power. The amount of emissions is reduced by any indirect emissions reductions attributable to use of alternate fuels (such as reductions at landfills due to use of landfill gas). If total emissions have been reduced by amounts of CO_2 sequestered by processes onsite, the energy-related emissions are reduced by a percentage of such reductions proportional to the percentage of total emissions that are energy-related.[5]

QUALITY ASSURANCE AND QUALITY CONTROL

Accuracy, Consistency and Documentation:

High-quality data are required for accurate and consistent estimation of emissions. Data collection content and format should be consistent year to year to ensure consistency of emission calculations.

Each facility should document all input data, the sources of emission factors and other relevant information, such as the methodology used, data sources, assumptions, complete references, and conversions.

QA/QC Plan:

Users of this protocol should develop a QA/QC plan. The plan should outline QA/QC activities that will be implemented, and include a scheduled time frame that follows emission inventory preparation from its initial development through final reporting.

The QA/QC plan is an internal document to organize, plan, and implement QA/QC activities. Once developed it can be referenced and used in subsequent inventory preparation, or modified as appropriate.

The QA/QC plan should incorporate QA and QC procedures similar to the following:

QC Procedures

The focus of general QC techniques is on processing, handling, documenting, archiving, and reporting procedures. The following table lists the QC checks that should be routinely used. Most of these checks can be performed by cross-checks, recalculation, or through visual inspections.

QC Activity	Procedures
Check for transcription errors in data input and reference.	• Cross-check a sample of input data for transcription errors

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[5] The formula that allocates a portion of sequestration to energy-related emissions has been corrected.

Check that emissions are calculated correctly.	• Reproduce a representative sample of emissions calculations
Check that parameter and emission units are correctly recorded and that appropriate conversion factors were used.	• Check that units are properly labeled in calculation sheets • Check that units are properly carried through from beginning to end of calculations • Check that conversion factors are correct
Check the integrity of spreadsheet or database files.	• Confirm that the appropriate data processing steps are correctly represented in the spreadsheet or database • Confirm that data relationships are correctly represented in the spreadsheet or database • Ensure that data fields are properly labeled and have correct design specifications • Ensure that adequate documentation and model structure and operation are archived
Check for consistency in data.	• Identify parameters (i.e. activity data, constants) that are common to multiple sources and confirm that there is consistency in the values used for these parameters in the emission calculations
Check that the movement of inventory data among processing steps is correct.	• Check that emissions data are correctly aggregated from lower reporting levels to higher reporting levels when preparing summaries • Check that emissions data are correctly transcribed between different intermediate products
Undertake review of internal documentation.	• Check that there is detailed internal documentation to support the estimates and enable duplication of the emission estimates • Check that inventory data, supporting data, and inventory records are archived and stored to facilitate detailed review • Check integrity of any archiving arrangements of outside organizations involved in inventory preparation
Check methodological and data changes	• Check for temporal consistency in time

resulting in recalculations.	series input data for each source • Check for consistency in the algorithm/method used for calculations throughout the time series
Undertake completeness checks.	• Confirm that estimates are reported for all sources and for all years • Check that known data gaps that result in incomplete source emissions estimates are documented
Compare estimates to previous estimates.	• For each source/facility, current inventory estimates should be compared to previous estimates. If there are significant changes or departures from expected trends, recheck estimates and explain any difference
Compare estimates for different facilities.	• For each facility, estimates should be compared with those from other facilities (if available) to check for inconsistencies that reflect errors, different measurement techniques, or real differences in emissions, operating conditions, or technology

These checks should be applied irrespective of the type of data used to develop the emissions inventory and are equally applicable to sources where default emission factors are used.

QA Procedures

An objective review should be done of emissions calculations and the report. Reviewers should be someone who has not been involved in preparing the emission calculations or report.

Reporters may wish to have their data, estimates and QA/QC procedures checked by audits or by periodic spot checks, including measurements to confirm estimates.

Documentation, Archiving, and Reporting

All information required to produce emission estimates should be documented and archived. This includes:

- Assumptions and criteria for selection of activity data, quantity data and emission factors
- Emission factors used, including references to published documentation for default factors

- Rationale for choice of methods
- Methods used
- Changes in data inputs or methods from previous years
- Details of electronic spreadsheets or databases used in production of the estimates, including versions, manuals, instructions and any other information required to enable their later use
- Worksheets and interim calculations for source estimates and aggregated estimates and any recalculations of previous estimates
- Final report and any analysis of trends from previous years
- QA/QC plans and outcomes of QA/QC procedures

Documentation should be maintained and archived in such a way that every report is fully documented and can be reproduced if necessary. Records should be unambiguous and full references to particular documents should be provided. This is necessary because default emission factors are occasionally updated.

Records of QA/QC activities should be archived, including checks/audits/reviews that were performed, when they were performed, who performed them, and corrections and modifications to the calculations and report resulting from the QA/QC activity.

A summary of implemented QA/QC activities and key findings should be reported as a supplement to the emissions estimate report. The summary should describe which activities were performed internally and what external reviews were conducted in accordance with the QA/QC plan. The key findings should describe major issues regarding quality of input data, processing, or archiving and how they were addressed or plan to be addressed in the future.

QUESTIONS?

For questions on the interpretation of this protocol, please contact Hunter Prillaman at **hprillaman@lime.org**. For technical questions on using the spreadsheet, please contact Lisa McFadden at **lmcfadden@lime.org**.

APPENDIX A

Estimating Calcination Emissions Using NLA GHG Protocol

NLA's GHG protocol includes calculations to estimate the amount of CO_2 generated by calcination based on the amount of CaO and MgO in the material leaving the kiln (both quicklime and calcined byproducts/wastes). The instructions note that accurate measurements of percentage CaO and MgO are required. The instructions and form use the expression "% total CaO" rather than "% <u>available</u> CaO" because the available lime test does not measure all of the CaO present and may measure some MgO. For soft-burned lime, it may underestimate CaO concentrations by 1-2%; for hard-burned lime, even more. As noted in the instructions, some plants may choose to use available CaO as a surrogate for total CaO (ideally with a correction factor), although this is discouraged. This appendix describes methods for determining total CaO and total MgO.

Analytical issues arise because quicklime is a mixture of hard and soft-burned calcium and magnesium oxides. In addition, uncalcined calcium carbonate may be present.[6] The following guidelines discuss how % CaO and % MgO can be accurately measured in quicklime and calcined byproducts/wastes. You should work with your own analytical chemists to identify which of these or other procedures are most appropriate for your company. Be sure to document the method chosen in a text narrative accompanying your reported data.

Sampling: The purpose of the protocol is to accurately estimate CO_2 emissions, including those from the calcination of limestone in the lime kiln, which transforms carbonates into oxides. To measure these oxides, quicklime samples should be taken as they leave the kiln or soon after they are placed in storage. Likewise, calcined byproducts/wastes samples should be taken as close as possible to the point of generation, before they are exposed to air and water.

Analytical Methods

CaO in Quicklime: There are no methods that <u>directly</u> measure only CaO. Instead, total calcium, including calcium present in $CaCO_3$, is measured.[7] Thus the amount of Ca in CaO must be estimated by subtracting the amount of Ca in $CaCO_3$ from the total calcium. As shown in the table below, there are several methods to measure total calcium. The amount of $CaCO_3$ present can be measured using the Loss on Ignition (LOI) or Total Carbon Tests.

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[6] Other calcium compounds may be present, such as sulfates or silicates. The methods discussed below assume that all Ca is present in the limestone as $CaCO_3$. Quicklimes and calcined byproducts/wastes produced from limestone with high levels of impurities may require special analytical protocols to accurately estimate calcined oxides. The unhydrated oxides test in ASTM C25 can be used in conjunction with other tests to accurately measure CaO and MgO.

[7] The names of ASTM's test methods may create confusion. For example, the "gravimetric method for <u>calcium oxide</u>" (ASTM C25, section 16) actually measures total <u>calcium</u>, and assumes all calcium is present as CaO using a simple molecular weight conversion.

To summarize the steps that should be considered by your analytical chemists:
1. Measure the total calcium in quicklime.
2. Estimate the quantity of Ca in uncalcined $CaCO_3$ by measuring the CO_2 or total carbon in quicklime and converting to units of Ca in $CaCO_3$.
3. Subtract the quantity of Ca in $CaCO_3$ from the total calcium, and convert the remainder to units of CaO.

MgO in Quicklime: Measurement of MgO in quicklime is a little different because $MgCO_3$ is not likely to be present, since it calcines at much lower temperatures than $CaCO_3$. Thus, methods that measure the total amount of magnesium present in quicklime can be used directly, including: Gravimetric Magnesium Oxide (ASTM C25, section 18) and Magnesium Oxide Alternative EDTA Titration Method (ASTM C25, section 31).

Test (ASTM C25, except as noted)	Calcium Fraction			Magnesium Fraction*
	CaO (soft)	CaO (hard)	$CaCO_3$	MgO
Available Lime	X			(some)
Total (ICP, XRF)**	(total Ca)			(total Mg)
Total (EDTA, pH>6.5)	(total Ca)			(total Mg)
CaO (gravimetric)	(total Ca)			
MgO (gravimetric)				(total Mg)
Total (volumetric)	(total Ca + Mg)			
LOI***			X	
Total carbon****			X	

* All $MgCO_3$ can be assumed to be present in quicklime as MgO, due to its low calcination temperature.

** ICP & XRF tests are in ASTM C1301 & C1271.

*** The LOI test can also be used to measure $Ca(OH)_2$, which should be considered when estimating the non-calcined fraction of calcined byproducts/wastes, especially if weathered.

**** Total carbon test assumes that all carbon present is inorganic (i.e., carbonate). If organic carbon is present (e.g., unburnt fuel in calcined byproducts/wastes), other tests (e.g., Volumetric CO_2) should be used.

Calcined byproducts/wastes: In general, unweathered calcined byproducts/wastes can be analyzed with the same methods used for quicklime. LKD, for example, is a mixture of coal ash, calcined lime, and uncalcined limestone particles. As noted above, however, if organic carbon is present (e.g., unburnt fuel), tests to measure inorganic carbon (e.g., Volumetric CO_2) should be used to distinguish between inorganic carbon in uncalcined carbonates and organic carbon in unburnt fuel.