Risk Based Verification of Green House Gas Emissions for Emission Reductions and Trading

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En 1997, le Protocole de Kyoto a été adopté, il prévoit un engagement des pays industrialisés (ref Annexe 1) en vue de réduire leurs émissions combinées de gaz à effet de serre d'au moins 5% au dessous du niveau de 1990 au cours de la période 2008-2012. Chaque pays a convenu d'adopter légalement des objectifs contraignants (7% pour les E.U). En dehors des actions locales qui peuvent être entreprises le Protocole de Kyoto fixe trois voies dans lesquelles des actions prises à l'étranger pourraient aider les pays a atteindre leurs propres objectifs de réduction des émissions. Ces "mécanismes de Kyoto" comprennent deux mécanismes à base de projets, une mise en œuvre conjointe (JI) et le Mécanisme de Développement propre (CDM) et les Echanges Internationaux d'émissions. Alors que les règles de ces mécanismes sont encore débattues, il est clair que, dans la plupart des cas, la certification par un auditeur représentant des tiers indépendants internationalement sera nécessaire afin d'acquérir une reconnaissance internationale que les réductions d'émissions annoncées sont de bonne foi.

Les protocoles employés pour certifier les émissions de gaz de serre sont acceptables pour un vaste éventail de participants. Plusieurs projets ont été lancés pour déterminer les méthodologies les plus efficaces et efficientes, en vue d'auditer et de vérifier les émissions. Une approche basée sur le risque, focalisée sur les sources d'émissions susceptibles d'être très mal interprétées et ont un grand impact sur l'ensemble des émissions d'un produit, atteint la confiance nécessaire tout en minimisant l'effort nécessaire pour la vérification.

Pourquoi les gaz à effet de serre ?

L'effet naturel des gaz à effet de serre permet la vie sur terre. Sans les niveaux naturels des gaz de serre dans l'atmosphère, la température globale moyenne serait d'environ 0°F (-18°C) plutôt que le niveau doux de 60 °F (15°C) que nous connaissons actuellement. Les gaz de serre existant naturellement sont l'oxygène, l'ozone; le dioxyde de carbone et la vapeur d'eau.

Introduction

In 1997, the Kyoto Protocol was adopted, and provides a commitment by the industrialized countries (referred to as Annex I) to reduce their combined greenhouse gas emissions by at least 5% below 1990 levels by the period 2008-2012. Individual countries agreed to take on legally binding targets (7% by the US). In addition to domestic actions that may be taken, the Kyoto Protocol set up three ways in which action taken abroad could help countries to meet their own targets for emissions reductions. These “Kyoto Mechanisms” include two project based mechanisms, Joint Implementation (JI) and the Clean Development Mechanism (CDM), and International Emissions Trading. Whilst the rules for these mechanisms are still being debated, it is clear that in most cases, certification by an independent, internationally

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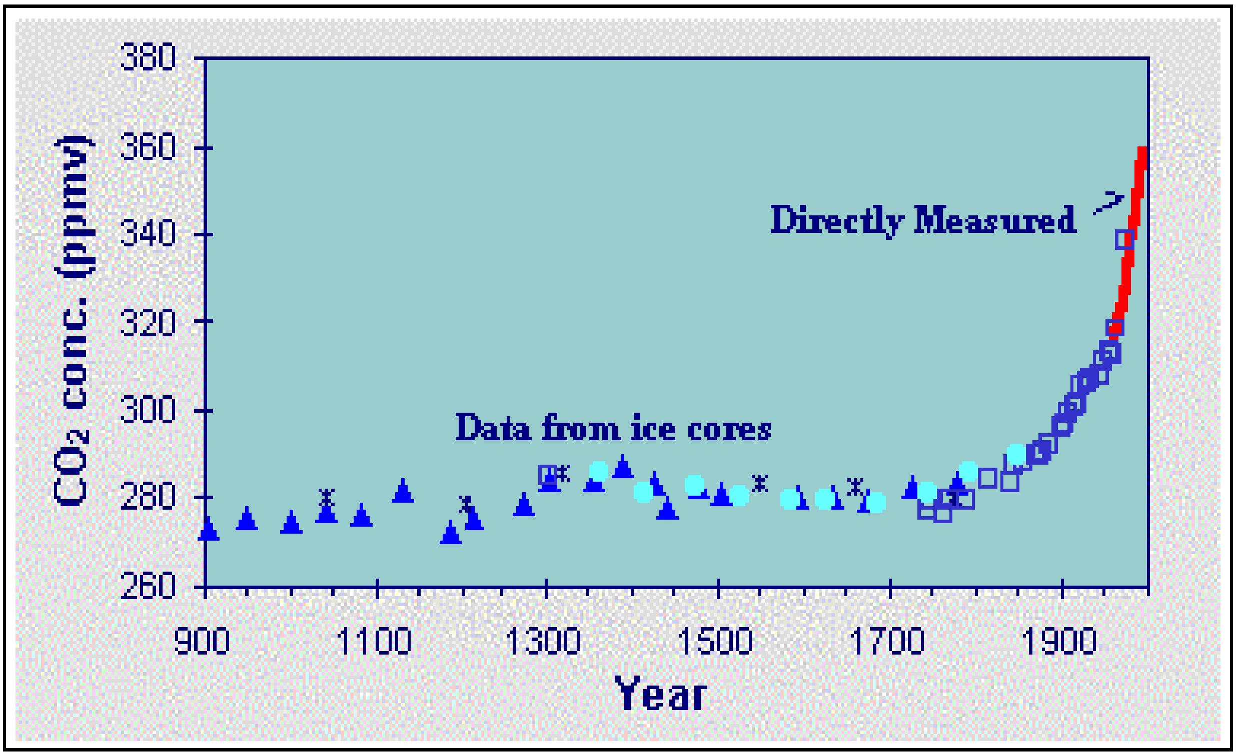
recognized third-party auditor will be required in order to gain international acceptance that the claimed emissions reductions are bona-fide.

The protocols used to certify green house gas emissions must be acceptable to a wide range of stakeholders. Several projects have been undertaken to determine the most efficient and effective methodologies for auditing and verifying emissions. A risk based approach, focussing on the emissions sources which are most likely to be mis-stated and have greatest impact on the overall emissions from a facility, achieves the necessary confidence while minimizing the effort required for the verification.

Why Green House Gases?
The natural green house gas effect enables life on earth. Without natural levels of green house gases in the atmosphere, the average global temperature would be about 0^{o}F (-18^{o}C), rather than the balmy 60^{o}F (15^{o}C) we actually experience. These naturally occurring green house gases are oxygen, ozone, carbon dioxide and water vapor.

However, a problem is arising as a result of human activities. Levels of carbon dioxide in the atmosphere have been rising dramatically since about 1800, with most of the increase



occurring since 1900. Furthermore, there are other green house gases resulting primarily from human activities, including methane, nitrous oxide, hydro- and perfluorocarbons, and sulfurhexafluoride. These green house gases, notably methane, contribute additionally to the overall level of green house gas present. The expected result over the next 50 to 100 years is an increase in average global temperature, with predictions ranging from 1.5 to 2.5^{o}C.

So what? Implications of such an increase in global temperature include changing local weather conditions, increase in sea level, displacements of the Earth's vegetation zones, melt of snow, ice and permafrost, and increased range of tropical diseases such as malaria. The good news is that little of this appears to be occurring, yet. The bad news is that clear proof of these negative consequences may not be available until it is too late to take action. As stated in the Climate Convention from the environmental conference in Rio de Janeiro in 1992, “if serious or irrevocable damage threatens, the lack of full scientific proof must not be a reason to delay taking precautionary measures.”

As a result of the Rio conference, 154 states signed the United Nations Framework Convention on Climate Change (UNFCC). This agreement entered into force on 21 March 1994, with the stated objective of “the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous manmade interference with the climate system.” In December 1997, the Kyoto Protocol was adopted, creating a legal obligation for industrialized countries to reduce their collective greenhouse gas emissions by at least 5% below 1990 levels.

Why Verification?
The Kyoto Protocol identifies three mechanisms that can be used to help achieve emissions reductions:
- ♦ Clean Development Mechanism (CDM)
- ♦ Joint Implementation (JI)
- ♦ International Emission Trading

GHG emissions reduction projects must demonstrate that reductions are real, measurable and long-term, and that the reductions are additional to those that would have occurred on a business as usual basis. Without going into the details of each of these, suffice to say that in each case, a real reduction in green house gas emissions must occur, and the possibility exists for the buying and selling of these “emission reduction credits.” In order to give credence to claims of emission reduction, and therefore be able to buy and sell the credits, it will be necessary to have an independent third party verify the reduction. Reductions can be verified on a specific project, or, as in the case study presented here, for an entire facility from year to year. This process is actually quite similar to the way an accounting firm would verify a company’s financial records.

Why Risk-Based?
In the absence of standards for auditing green house gas emissions, we call upon international standards for financial and environmental auditing. The purpose of the audit is to provide a reasonable level of assurance that the information being audited is free from material misstatement. A material misstatement occurs when omissions or misstatement of information has the potential to change or influence the opinion or decisions of a reasonable user who is relying on the reported information. There are recognized standards for material misstatements in financial auditing, but none so far for green house gases. We therefore again call on the standards for financial auditing, and consider a material misstatement to be in the range of 5% of the stated emissions.

In determining green house gas emissions in a chemical plant, assumptions must often be made concerning process stream compositions and flow rates, combustion efficiencies, etc. Obviously, the greater the emission from a single source, the greater the risk that a misstatement in that emission would be material to the total site emissions. Therefore the first reason for using a risk based approach to green house gas emission verification is to address the sources where misstatement is most likely to be material.

Likewise, when the determination of the emissions is based on incomplete information, or the information is of questionable reliability, it is more likely that a misstatement could occur. This then becomes the second reason for a risk based approach – address the sources where misstatement is most likely to occur.

Finally, the data management processes will vary, depending on the source of the data, any quality assurance efforts in place, and the physical processes for gathering and using the data. The third risk to consider is then where errors in data handling (e.g. transposition errors, calculation errors, etc.) are most likely to occur.

Scenario

Consider the case of a chemical plant manufacturing ammonia and urea. Primary feedstock is natural gas, which is also used for steam production.

Methane in natural gas feed is converted to hydrogen by way of reforming according to the reactions

$$CH_4 + H_2O \rightarrow CO + 3\ H_2$$

$$CH_4 + \text{air} \rightarrow CO + 2\ H_2 + N_2$$

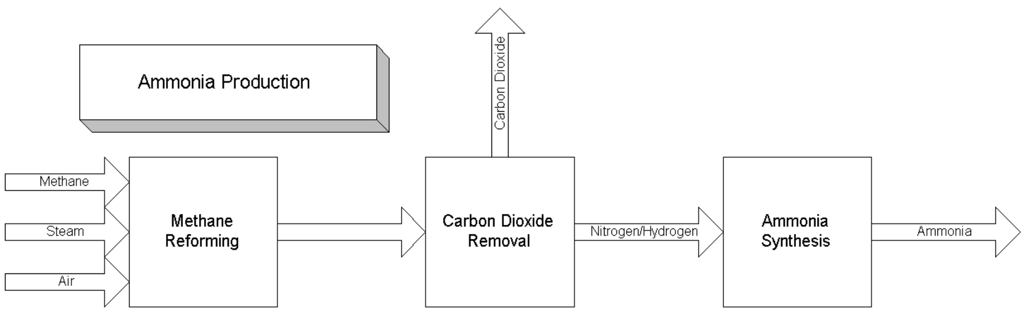
$$CO + H_2O \rightarrow CO_2 + H_2$$

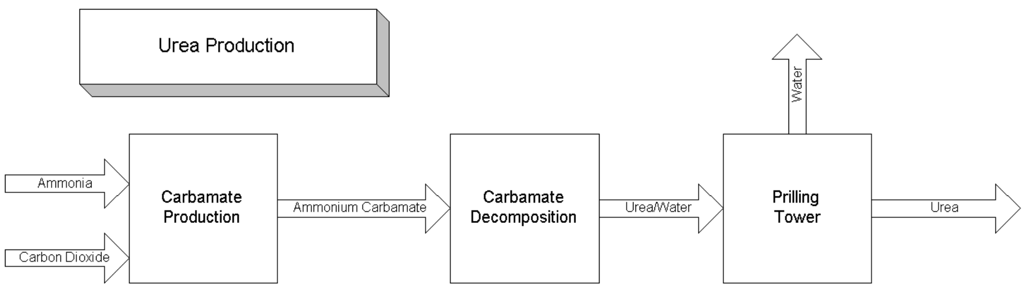
Carbon dioxide is removed from the product hydrogen through caustic and amine absorption, with final polishing by a methanation reaction. The purified hydrogen/nitrogen stream is then converted to ammonia:

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

Some of the ammonia product is further converted to urea by reaction with carbon dioxide:

$$CO_2 + 2\ NH_3 \rightarrow NH_4CO_2NH_2 \rightarrow NH_2CONH_2 + H_2O$$





Product ammonia leaves the plant via rail car and tank truck. Product urea is prilled and bagged for sale.

Green House Gas Sources

The green house gases of most concern in this scenario are carbon dioxide and methane. The major sources of carbon dioxide are combustion of natural gas for steam and electricity production, and by-product carbon dioxide from ammonia production. A small quantity of carbon dioxide is emitted from fugitive sources in the systems where the carbon dioxide is purified and transferred. There is also an emergency flare that burns natural gas for its pilot.

Carbon dioxide emissions are decreased by the amount of carbon dioxide used in urea production, as well as by that sold for carbonated beverage manufacture.

The major sources of methane are fugitive emissions from natural gas containing equipment, and unburned methane in exhaust gases from combustion equipment and the flare.

Data Sources

Incoming natural gas passes through two custody transfer meters, one owned by the supplier and another owned by the operator. These measurements are used to determine the total quantity of methane used by the plant. There are also internal meters on the various methane users, including the flare.

Flow rates and composition of the two main product streams are monitored continuously. Flow rate of carbon dioxide recovered from the caustic/amine system is also measured continuously, and a sample taken daily for analysis. Feed rates of carbon dioxide and ammonia to the urea unit are measured continuously, and balanced daily against measured urea production to determine plant yield.

Emergency flaring activity is recorded in the operating logs. Information includes the duration of the event, likely source if known, and a qualitative description of the severity. There is no direct measurement or analysis of flared gas.

Sales of ammonia by rail car are measured by volume and converted to weight for the sales ticket. Tank truck shipments are weighed directly.

Urea is packaged in bags by weight, with sales recorded by number of bags.

Carbon dioxide is transferred to the beverage plant via pipeline, monitored through a custody transfer meter.

Control Mechanisms

The custody transfer meters are proven quarterly to 0.25% accuracy. The two meters are compared monthly, and any discrepancies greater than 0.5% are resolved immediately. Internal meters are calibrated monthly. An overall methane balance is performed monthly, correcting all the internal meters to the custody transfer meters. All analyzers, both on-line and in the laboratory, are subject to statistical process control procedures, as is the urea packaging line.

Production, sales and inventories are reconciled each month-end.

Emissions Estimates
Plant management appointed a co-ordinator for GHG emissions reporting. This individual developed a spreadsheet application for recording all data, calculating emissions, and preparing reports. The calculation methodologies were reviewed by the plant process engineer.

Data Collection
Flow meters and on-line analyzers are linked to the process control computer. These data are queried once each minute, with hourly and daily averages stored for later recall. Laboratory analyses are recorded manually in a laboratory information system on the facility network computer system. Likewise, sales numbers and end-of-month inventories are recorded manually in the accounting system.

The GHG co-ordinator uses a spreadsheet application each month to query the other computer databases for the necessary data. This application takes the daily averages of flow rates and on-line analyses, and the daily laboratory analyses, and generates a single, monthly average for each parameter.

The co-ordinator estimates the quantity and composition of flared gas based on the operating logs.

Calculations
The simplest methodology for calculating carbon dioxide emissions in this case is to perform a mass balance on carbon around the entire facility. Specific sources can also be determined, and provide a check against the overall mass balance. The individual source emissions are also needed for assessing materiality, and for determining where emission reduction projects might be appropriate.

Carbon enters the facility only in the natural gas, which flow rate is well known through the two custody transfer meters, and composition from the supplier quality control procedures. Carbon not counted as GHG emissions exits the facility in the product urea and as product carbon dioxide, both of which are also well quantified. All other carbon is emitted as either carbon dioxide or methane.

Let:
a = moles carbon in with natural gas
b = moles carbon emitted from incomplete combustion in boilers/furnaces/engines
c = moles carbon emitted from incomplete combustion in flare pilot
d = moles carbon emitted in natural gas fugitive emissions
e = moles carbon in urea
f = moles carbon in CO_2 sold
g = moles carbon emitted as CO_2

Then:
$g = a - b - c - d - e - f$

Using the reaction stoichiometry and other conversion factors:
a = scf natural gas feed to facility x 0.0028 mol carbon per scf natural gas
b = scf natural gas feed to boilers/furnaces/engines x 0.005 x 0.0028 mol carbon per scf natural gas (assumes 99.5% combustion efficiency)

c = scf natural gas feed to flare pilot x 0.02 x 0.0028 mol carbon per scf natural gas (assumes 98% combustion efficiency)
d = number of components in natural gas service x scf natural gas per component x 0.0028 mol carbon per scf natural gas
e = lb urea production x 0.011 mol carbon per lb urea
f = lb CO2 sold x 0.023 mol carbon per lb CO2

Therefore, knowing:

1. the total quantity of natural gas feed to the facility;
2. the quantity of natural gas feed to boilers/furnaces/engines;
3. the quantity of natural gas feed to the flare pilot;
4. the number of components in natural gas service and emission factor;
5. the quantity of urea produced; and
6. the quantity of carbon dioxide sold as product;

the quantity of carbon dioxide emitted to the atmosphere can be calculated. Using this mass balance approach eliminates the need to estimate individual sources, some of which are quite difficult to quantify (emergency flaring, for example).

Further, from the above quantities numbers 2, 3 and 4, and the composition of the natural gas, the quantity of direct methane emissions can also be calculated.

For individual sources, the same ideas, applied appropriately, may be used. Thus for the steam generation facility, one would need the quantity of natural gas feed to the boiler and the combustion efficiency to determine carbon dioxide and methane emissions. Each individual source can be calculated and summed for comparison with the overall mass balance.

Factors and Estimates

Several factors and estimates are used in performing the above calculations. Probably the most critical is the actual composition of the natural gas. The above factors assume the natural gas is 95% methane, 3% ethane and 2% propane. If the facility is using a non-standard source of natural gas, this composition could be significantly different. Especially important would be the presence of hydrogen, which greatly reduces the carbon dioxide emissions from combustion, or the presence of heavier hydrocarbons, which greatly increases the carbon dioxide emissions from combustion.

Another estimate is the combustion efficiency in the various devices at the facility. Typically, the combustion efficiency in such devices as boilers, furnaces, and gas-driven engines or turbines is very high, 99% or greater. This can be estimated from stack gas analysis for carbon monoxide and/or oxygen. Very low levels of carbon monoxide or fairly high excess air both indicate very high combustion efficiency. Flare stacks tend to have lower combustion efficiency, on the order of 98%. It is much more difficult to get data for this, so using the typical value is quite common. Unburned hydrocarbon from flare stacks is generally a very small quantity relative to other sources.

Risk Analysis

In determining which green house gas sources need additional investigation to provide the necessary assurance, several factors are considered. These include the relative quantity of emissions from each source (the materiality), the likelihood of a possible mis-statement, and the uncertainty in the data or calculation methods. Auditors will track the flow of data for these sources from initial gathering, through any manual manipulations, and into the final calculations. Every step of the process in determining the emissions will be checked for accuracy and completeness. Systems for assuring that the process is performed correctly each and every time must also be verified. This will include a documented procedure for the data management and reporting process, clear definitions of individual roles and responsibilities within the process, and quality assurance checks applied, both during process development (e.g. how were spreadsheet applications verified) and as part of the reporting process.

Materiality
Any single emission source that contributes 5% or greater to the total facility emissions should be carefully investigated to assure accurate reporting. Relatively small errors in these sources would be of significance to the facility. For the case presented above, the material sources are the combustion of methane in boilers/furnaces/engines, and the by-product carbon dioxide from ammonia production. The methods used for measuring, calculating and reporting these quantities must be very well controlled to demonstrate the required degree of accuracy in the reported emissions.

Mis-statements
Source data should be checked carefully wherever the potential for mistakes in the data management process appears relatively high. This could include, for example, any manual transfer of data, where transposition errors could occur. An example is laboratory analysis of feed or product streams, where the analytical results are manually transferred to the database. Auditors will look for quality assurance procedures, such as an independent check of the input data, to verify the accuracy of the process.

Uncertainties
Likewise, source data should also be checked carefully where there are known uncertainties in the data, for example combustion efficiencies for flare stacks. If these uncertainties may result in material errors in the reported emissions, then action should be taken to reduce the uncertainty. An alternative method of determining the emissions that does not rely on the uncertain value, or some means of verifying that value, such as stack testing, could be used.

Conclusions
Once a baseline verification is completed, the facility can proceed with projects for reducing green house gas emissions. The results of the verification audit can be used to help the facility prioritize where the most cost effective reductions could take place. There have even been cases where the recovery of methane has an immediate economic benefit to the facility, not considering any emission reduction credits that may be obtained. Additional improvements in data management can also be identified, resulting in more accurate emissions estimates with less effort by facility staff.

Following implementation of an emission reduction project, the verification audit is repeated to assess the new emissions. In order for emission reductions to be certified, there must be sufficient assurance in the accuracy of the data. These certified emission reductions (CER) may then be tradeable as a commodity. Several international entities, both business and government, are already well on their way to establishing CER trading schemes. If a given entity is able to reduce its green house gas emissions below the target more cheaply than another entity, then the excess reduction could be sold for profit.

In conclusion, the critical factors to consider in verification of green house gas emissions are:

- independence of the verifiers;
- accuracy and reliability of data;
- data management and control mechanisms.