Greenhouse Gas Emissions Estimation and Inventories
Addressing Uncertainty and Accuracy
Introduction

The assessment of greenhouse gas (GHG) emissions and emission reductions are high on policy agendas in many countries. The global oil and gas (O&G) industry has been active in this arena by contributing to the development of guidance for accounting and reporting of GHG emissions, and compiling methodologies that are appropriate for estimating GHG emissions from industry operations. This guidance has been recently augmented with guidelines to account for emissions associated with GHG projects.

The uncertainties inherent in the data used for emission inventories may affect their credibility and the acceptability of assertions of GHG emission reductions. The uncertainty of an O&G company’s GHG emission inventory, or of its quantified emission reductions, is determined by the uncertainties of the estimates of their key (largest) contributing sources. In turn, each of these uncertainties depends on the quality and availability of sufficient data to estimate emissions, or on our ability to measure emissions and properly account for their variability. With the emergence of emissions trading systems, and new reporting and disclosure schemes, data robustness is getting increased attention as a prerequisite for accurate determinations of GHG emissions and emission reductions.

As a first step to addressing this issue, the Petroleum Industry Guidelines for Reporting GHG Emissions, API, December 2003. This guidance has been recently augmented with guidelines to account for emissions associated with GHG projects.

The workshop did not aim to achieve a consensus on the issue; it merely acted as an initial step of a dialogue between industry and regulators on GHG data quality expectations. It also provided industry participants with the necessary input to start developing a list of priority actions that are needed in order to reduce uncertainty, improve accuracy and ensure that reported data meet key stakeholders expectations for both voluntary and mandatory GHG reporting schemes. In the sections below, the report will address briefly the context of these issues; and provide a summary of the workshop discussion with an initial list of priority issues.

Workshop goals

- Develop an understanding of the relative importance of the key factors that contribute to uncertainty.
- Review and discuss emerging techniques for quantitative assessment of the uncertainty and accuracy of GHG emissions estimates.
- Identify emission sources and methods where O&G industry efforts are needed to improve accuracy and reduce uncertainty to acceptable levels.
- Create a prioritized list of topics to be addressed by the O&G industry to minimize emissions estimation uncertainty and improve data accuracy.

IPIECA/API Workshop, Brussels, Belgium, 16 January 2007

Context

The issues of concern in this workshop stem from the need to ascertain the quality of GHG emission inventories at the entity level and to ensure that company strategies and actions are based on robust data. At the national level, policies and strategies such as the EU Emissions Trading System (EU ETS) must be able to demonstrate that estimates regarding emissions changes are not only measurable, but are permanent and verifiable. While uncertainty estimates are not intended to dispute the validity of data presented in GHG emission inventories, the variability that they communicate underscores both the lack of accuracy in characterizing many sources and sinks and the existing data gaps that should be the focus of future activities.

The Intergovernmental Panel on Climate Change (IPCC) addressed these issues initially in the context of national GHG emission inventories. According to their guidance, uncertainty analysis is intended to help ‘… improve the accuracy of inventories in the future and guide decisions on methodological choice …’

Currently, most countries that perform uncertainty analyses do so for the express purpose of improving their future estimates; this rationale is generally the same at the corporate—or entity—level. In either case, estimating uncertainty helps to prioritize resources and to take precautions against undesirable consequences, such as basing strategies on questionable data. Depending upon the intended purpose of an inventory, however, this may—or may not—be the extent of usefulness of conducting uncertainty analyses.

The International Institute for Applied Systems Analysis (IIASA) organized the 1st International Workshop on GHG Inventory Uncertainty. In that workshop participants focused on different attempts to improve national inventories and provide a basis for emissions inventory standardization, and on the use of detailed uncertainty analyses in enforcing compliance in emissions trading systems. While the IPCC clearly stresses the value of conducting uncertainty analyses and offers guidance on executing them, the conclusions from that workshop go well beyond any suggestions made by the IPCC and are applicable to emission inventories of complex multinational entities as well as to national inventories.

During the IIASA workshop, several potential benefits were identified for continuing to improve and standardize estimation methodologies, including quantifiable estimates of uncertainty associated with GHG inventories. Some key benefits (listed below) are applicable both to national and entity inventories:

i. Uncertainty analyses provide a standard measure that can facilitate the process of comparing inventories to one another.

ii. Uncertainty analysis helps identify the most prudent opportunities for improvement in the methods and estimates of GHG emissions and emissions changes.

iii. Uncertainties play a role in determining whether or not commitments have been credibly met.

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Summary

Emissions Trading Systems are typically developed to enable economically efficient reduction of GHG emissions and encourage new low-carbon technologies. System design should make it attractive to reduce emissions and recognize the role of reduced data uncertainty. In the USA, emissions trading systems have been operational since the 1990s. They have embedded in their design financial rewards for the availability of high quality data. The measurement and tracking system was designed to ensure quantifiable, permanent and real emissions reductions. This approach has led to a range of improvements in monitoring methods and measurement accuracy assessment techniques.

For the emerging GHG markets, there is a need to improve the robustness of the data used for designing and tracking trading schemes’ performance. Market participants need confidence in the accuracy of the data used for establishing baselines and the allocation process. Regulators need the confidence that the methods used for monitoring, reporting, and verifying GHG emissions have a high degree of certainty to demonstrate compliance. Society at large needs confidence that real emission reductions have been attained. As a consequence there is a recognized need to improve data accuracy and reduce uncertainty.

The factors enumerated above are key to the successful operation of GHG markets. The issues at hand include the question of how market regulations should strike a balance between the need to improve accuracy of estimates for certain sources that have sparse data vs. the cost-effectiveness of such actions in view of the relative contributions of specific sources to overall estimation uncertainty.

At the same time, companies need to manage their risks and develop improved tools that will facilitate compliance with diverse GHG regimes. This is vital both to companies’ financial performance and to the protection of their reputation.
Harmonization of measurement, monitoring, and uncertainty assessment methods would assist companies in meeting their regulatory mandates and stakeholders expectations. Guidelines that are tailored specifically to given industry sectors could facilitate improved performance by ensuring that they are compatible with industry operating and maintenance practices.

A preliminary list of priority issues that should be tackled by the O&G industry sector is provided in the box on page 2. These include three priority thematic areas:

1. Measurement methods;
2. Computational methods; and
3. External communication.

To address these issues further will require expanding current industry emission estimation methodology to include considerations of data accuracy and uncertainty. It will also necessitate a continuation of the dialogue with all stakeholders to communicate recommended approaches broadly and to ensure that expectations are being met.

**Desired outcome—the ‘four Cs’**

Comparability, Consistency, Certainty and Confidence
Panel 1: Setting the stage

An industry perspective
The O&G industry recognizes the need for accurate GHG data; this is why IPIECA members and their regional oil and gas associations are considering whether additional guidance should be developed for their members on how to best estimate accuracy and uncertainty. Key reasons for industry to aspire to improve its emissions assessments are:

- manage what you measure;
- participation in emissions trading;
- material misstatement can lead to investigations; and
- need to assess business risk and avoid reputation damage.

A regulator’s perspective
Regulators view measurement accuracy (closeness to actual true value) and uncertainty (characterization of a range of values) as a fact of life; all measurements are uncertain to some degree. When considering uncertainty one has to ensure that the method selected is fit for purpose, trustworthy and compliant with data quality goals. These issues are particularly important for emissions trading schemes that are based on the use of a ‘common currency’.

The EU ETS Monitoring and Reporting Guidelines (MRG)\(^6\) have attempted to identify sources of uncertainty and reduce them as far as practicable, while ensuring that

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calculations and measurements exhibit the highest accuracy achievable. In revising the MRGs for 2007 there was an emphasis on a tiered approach, error propagation analysis, specification of sampling methods (with frequency of sampling tied to the required uncertainty threshold) and verification. Regulators are coming to the realization that how far one should go in squeezing out of system the last bit of uncertainty ought to be based on an understanding of resource constraints, effectiveness of requirements and operational practicability of sampling and calibration methodology. As the EU ETS enters Phase II there will likely be need for further guidance on how to operationalize these new requirements.

A perspective from a non-governmental organization

From a non-governmental organization’s perspective this issue includes many ‘unknown unknowns’. There is definitely a need to maintain comparability of inventories over time with improved data quality and methods for data collection. High quality data are required in order to allow emissions trading systems to function properly, and consistent methodology is important to allow international comparisons.

When evaluating the various types of uncertainty analysis (statistical, parameter and estimation) it seems that, in practice, ‘parameter uncertainty’ is the important one—this relates to the uncertainty in the activity parameters used for emission estimation. When looking into the components of ‘parameter uncertainty’ it is evident that it comprises both random variability of sample data (statistical uncertainty) and systematic bias present in the estimation process (systematic uncertainty).

For example, the EU ETS requires 95 per cent confidence intervals for all data. For proper operation of that scheme inter-comparability among facilities and sectors is critical. In order to reduce uncertainties collaborative efforts amongst industry, NGOs, governments and academia are needed. Those efforts should not be aimed at marginal reductions of uncertainty to the 1–2 per cent range but should attempt to tackle those emission sources, such as fugitive emissions from natural gas systems, where uncertainties might be greater than 100 per cent.

A global corporate perspective

Many large corporations are disclosing their CO$_2$ data through the Carbon Disclosure Project. Useful reporting metrics should be transparent, comparable, consistent and simple. The fact is that many initiatives exist but a uniform corporate reporting protocol could be of value if one can be devised. Current initiatives are based on volume/mass reporting with no link to financial standards. Therefore the 2005 CEO Roundtable (24 CEOs of large multinational corporations) resolved to urge governments of the G8 to ‘work towards convergence of existing GHG reporting
processes and systems’. To address this, a new Climate Disclosure Standards Board was launched in early 2007 to establish ‘best practice’ for reporting GHG emissions in annual reports.

Key messages from the discussion

- Intercomparability among industry sectors is an issue, and it is not clear that all can achieve common accuracy; sector comparability is different even within sectors.
- Different approaches are appropriate to quantify actual emissions vs. being able to demonstrate that we are below a certain limit (or a ‘cap’).
- The requirement of demonstrating minimum octane may serve as an example; companies are willing to invest to improve accuracy of measurement if it helps improve the bottom line.
- There is a distinction between absolute accuracy vs. the ability to distinguish emissions trends; stakeholders are interested in the ability to make verifiable emission reductions.
- Setting different targets for different sectors and distributing emission reductions in an economically efficient manner is not always politically viable.
- Efficient reporting and cross-industry comparison are needed; they should encourage ‘transparency’ in reporting and document ‘best practices’.
- For the Kyoto Protocol, many of these issues were not considered ahead of time and they need to evolve as experience is gained in implementation.
Panel 2: Emerging approaches to assessing uncertainty and accuracy

A global view

With the understanding that uncertainties are inherent in data used for emission inventories, the International Institute for Applies Systems Analysis (IIASA) co-sponsored an international workshop on the impact of uncertainty in national GHG inventories on compliance verification and emissions trading. Uncertainty is comprised of both precision of measurements (or estimation) and its associated accuracy. It is important to distinguish between the assessment of uncertainty in ‘top-down’ inventories that are trying to make the link from global emissions, to a spatial and temporal resolution, at the country level vs. the uncertainty associated with the ‘bottom-up’ approach to emissions estimation by individual entities.

A robust verification process for national compliance will require comparison of a ‘top-down’ approach with the ‘bottom-up’ for consistency and full GHG accounting. In applying such methodology to compliance with the Kyoto Protocol the question focuses on ‘real’ emissions changes, i.e. can we detect emission changes at the country level? Thus, total uncertainty during the given commitment period (or year) is what matters. In the Kyoto process the ‘allowed amounts’ are allocations for countries, and countries, in turn, are pushing those allocations down to legal entities. Hence, it is not possible to determine compliance without uncertainty analysis.

US EPA practices and perspective

The key to assessing uncertainties of emission inventories is to incorporate the key elements for such an assessment up front into the process of planning and assembling the emissions inventories in order to prioritize actions for accuracy improvements. The Intergovernmental Panel on Climate Change (IPCC) has issued a ‘best-practice’ guideline document to provide a framework for quantifying uncertainties.

Two approaches are recommended for assessing random uncertainty: (1) error propagation analysis; and (2) Monte Carlo simulation of errors via a four-step analysis system. Key challenges in applying these methods include: the extent of knowledge of the uncertainty of the input data; and, given the availability of limited resources, how much time should be devoted to uncertainty analysis. Data sources for uncertainty calculations include: site-specific measurement studies; and country-specific...
studies for targeted sectors or activities. The US national GHG Inventory is including an uncertainty analysis, based on the Monte Carlo simulation approach.

Other approaches used in US voluntary reporting and registry programmes include the one prescribed by the US Department of Energy (DOE) for their enhanced reporting and registry programme in which they use data quality rankings ‘1 to 4’ that equate roughly to ‘low to excellent’, respectively, for data used in compiling an emissions inventory. They require an overall weighted quality rating of 3.0 in order to ‘register’ emission reductions reported by entities. For the US EPA Climate Leaders Initiative uncertainty is addressed in the Inventory Management Plan, and by identifying upfront efforts that will most significantly reduce uncertainty.

The EU ETS approach
The EU ETS framework for compliance includes: permitting, monitoring plans followed by actual monitoring and reporting, which is followed by verification and accreditation after acceptance and inspection. The EU Monitoring and Reporting Guidelines (MRG) approach does not require comprehensive analysis of overall installation emissions uncertainty; it focuses on the uncertainty in the activity data. For activity data, facilities track annual consumption of raw material and fuels and assess the accuracy of metering devices for individual measurements. The guidance on maintenance and calibration is vague and relies on expert judgment. Nonetheless, the basic principle is that the uncertainty in the overall emissions is managed by regulating the uncertainty of the basis data, i.e. activity information and applicable emissions factors.

For Phase I, the regulatory authorities did not include any economic incentives to reduce uncertainties; many improvements will be introduced in Phase II MRGs based on lessons learnt. For Phase II MRGs, expected to go into effect in 2008, uncertainty tiers would be more strictly enforced. These tiered uncertainties are: 7.5 per cent, 5 per cent, and 2.5 per cent for sources that emit <50 kilotonnes, 50–500 kilotonnes and >500 kilotonnes of CO$_2$ per year, respectively. The revised MRGs provide guidance on emission calculations, measurement systems and examples of ‘best practices’.

11 US EPA Climate Leaders, Partner Resources: www.epa.gov/climateleaders/resources/index.html
12 See Footnote 3 on inside front cover.
The role of non-energy fuel consumption

Part of an inventory uncertainty—especially for ‘top down’ national inventories—is the ability to understand the non-energy use of fossil fuels in the economy. Typically non-energy consumption of various feedstocks, such as consumption of refinery and coke oven products, could amount to 6–14 per cent of total primary energy supply. This category could include carbon storage, process emissions, and storage in products and in wastewater discharges. There is a real issue of defining system boundaries for such non-energy uses and incorporating the estimates into the appropriate sector of the economy.

The University of Utrecht presented their Non-Energy Use Accounting Tables (NEAT) methodology and its application to improving GHG emission estimates for three case studies drawn from the German national inventory. The cases studied were for emissions associated with ammonia production and the production of methanol (natural gas based feedstock); emissions associated with carbon black production (coal-/lignite-based feedstock); and emissions from petrochemical steam cracking (petroleum based feedstock). All these emissions were missing in the German inventory. This approach was incorporated into the 2006 IPCC guidelines for national inventories. It can serve as a tool for improving the completeness of the inventories developed although it does not address the uncertainty of emissions from product use.

A perspective on industry data limitations

Climate change regimes such as the EU ETS should focus on annual emission inventories rather than on individual measurements on a daily, hourly or instantaneous basis. The main issue facing facilities is how to translate the information they have—that is based on spot measurements—to a quantifiable uncertainty assessment for annual values. For that we need a good understanding of the order of magnitude of measurement variability and the relative contribution of distinct sources to the overall inventory.

The preferred approach for tracking carbon emissions should rely on the use of mass of fuel and its carbon content, where emission factors are provided in terms of ‘mass CO$_2$/heat content’ (e.g. grammes CO$_2$/MegaJoules). Since CO$_2$ reporting is relatively new there is a need to ensure internal consistency of data reported in

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different venues. One approach to ensure this might be for refineries to establish a refinery-wide carbon balance as part of their planning and process optimization. In reality refinery processes are merely designed to rearrange the carbon and hydrogen atoms and their ratio. It would be simpler and prevent ‘double counting’ if climate change regimes concentrated on tracking direct emissions from site operations. Moreover, the uncertainty of assigning GHG emission factors to indirect energy purchases contributes to the overall uncertainty for assessments that rely on both direct and indirect emission estimates.

Key messages from the discussion

● It does not make sense to put continuous emissions monitoring systems (CEMS) on every emission source; this would not be a cost-effective strategy for reducing uncertainty; monitoring methodology should be appropriate for the particular application.
● There is a need for incentives to improve performance; facility operators could be incentivized if large uncertainties were ‘penalized’.
● There is a need to understand better how to track carbon emissions; in the EU ETS there should be a rethinking of what needs to be measured, i.e. quality of fuel, carbon balance or something similar.
● Reporting sources have made significant strides in increasing data accuracy and improving monitoring.
● Reduction in uncertainty could be linked to value creation by requiring higher data accuracy to demonstrate compliance when emissions are closer to the ‘cap’.
Panel 3: Industry sectors examples

An upstream example
Main issues for quantifying GHG emissions from upstream activities include: CO\textsubscript{2} emission factors for upstream operations; flare efficiencies; emissions from power generation; and emissions associated with well tests. Key contributors to emissions are CO\textsubscript{2} emissions from fuel combustion and from flaring. For example for 2005 from a total of 6.44 million tonnes of CO\textsubscript{2}, 82 per cent was attributable to the fuel gas, 12 per cent to flaring and 6 per cent to diesel combustion. One approach to evaluate emission trends is to view the emission intensity per produced unit of oil equivalent. Higher intensity indicates a higher percentage of gas production and compression.

In general, mass emissions = (activity data x emission factor), where on-line metering is used for each fuel system, and average composition for fuel and flare gas is assumed. For diesel, volumes are based on volumes purchased and used, and the composition is expressed as a weighted average annual composition.

The example provided is based on a CO\textsubscript{2} tax scheme that has been implemented by the government since 1991; it is based on fuel gas, flare gas and diesel burned. The system does not require third-party verification—just inspection by the relevant authorities. Data quality requirements for fuel gas are 1.8 per cent accuracy for total volume (with 1 per cent for newer facilities); for flares it is 5 per cent of total volume, with documentation of the total uncertainty of the metering system.

Quantification issues include the fact that fuel gas composition is variable, and therefore average composition from purchase records is not adequate. This raises the need to have better measurements (or knowledge) of fuel gas volumes, net calorific values of the fuel gas, and information on the adequacy of emission factors to be used. In Norway the system is well documented due to the CO\textsubscript{2} tax requirements. Some of the required information might not be uniformly available from all upstream operations in all parts of the world.

A downstream example
Observation uncertainty as is employed in the EU ETS refers to total annual emissions (cap value), which is distinctly different from that associated with single readings from measurement instruments. For refineries, uncertainty requirements for fluid catalytic cracking units (FCCUs) and flares are tight and hard to meet because of the stringent requirements for accuracy of the orifice meters used to monitor flows. Variability of an orifice meter is based on measurement frequency, variability of fluid/gas properties, variability of flows, any step changes that occur and the potential for missing data.
Flow meters are usually installed for process control and the type of issues encountered are the ability to determine bias vs. measurement repeatability, and the fact that meters might not be present for some streams (e.g. flares).

As a way forward uncertainty associated with different sources ought to be characterized, with the understanding that the largest sources are not necessarily the largest contributors to uncertainty. Uncertainty is typically dominated by a handful of sources. Some potential ways to reduce uncertainty include: inspection of all orifice meters during maintenance; incorporation of on-line analysis of flue gas for FCCUs; and measurements of the volume of gas diverted to flares, to name just a few. As more mandatory reporting and compliance schemes are emerging it is important to evaluate suitability of measurement and estimating methods including instrumentation calibration and sampling campaigns.

A product transport example

Emissions associated with product transport are important for consideration in entity inventories. Such emissions could be classified as: Scope 1: direct emissions from operation of owned vehicles; Scope 2: indirect emissions related to electricity production, such as for electric trains; and Scope 3: indirect emissions due to operations commissioned to third parties. The methodology discussed included developing a GHG inventory for all transport activities and evaluating the impact of changing, rearranging or selecting alternative modes to transport products. Government and industry have jointly developed this methodology\(^\text{15}\) and it provides calculation tools per transport mode with inventory consolidation options.

The approach consists of conducting a simple estimate of transport GHG emissions based on fuel consumption by vehicle type and quantity transported. If these emissions are significant a more refined analysis could be undertaken. Actual implementation in other situations would vary among different operations due to the complexity and detail of the data collected, as well as the ultimate definition of the entity emissions inventory boundaries and its expected level of completeness.

\(^{15}\) www.epe-asso.org
An aluminum industry example
Main topics of importance when estimating GHG emissions for the aluminum industry include: smelting for aluminum production; electricity consumption; anode consumption; and generation of perfluorocarbon (PFC) gases. To guide its members, the International Aluminum Institute (IAI) has developed guidance for direct GHG emissions estimation. It has teamed up with the US EPA to develop the PFC measurement protocol in order to improve emission coefficients used for estimating PFC emissions. The international aluminum industry was able to document a 76 per cent reduction of PFC emissions during the period from 1990–2005.

Additionally, the industry sector was involved in developing the 2003 Quebec GHG audit manual, providing guidelines on planning, execution and completion of audits. More detailed guidance was provided in the 2005 audit implementing guidelines that sets uniform requirements that are essential to ensure a common understanding of audit expectations as well as standard practices that allow benchmarking of performance and recommendations for improvements.

A natural gas transmission pipeline example
For high-pressure pipelines that are transmitting natural gas over long distances the main GHG emissions of concern include CO₂ from combustion, and CH₄ from venting and fugitive emissions. The Interstate Natural Gas Association of America (INGAA) has developed guidance for its members. According to that guidance, key emission sources include: reciprocating engines and turbines; vents from gas blow-down; and fugitive emissions from pipeline operation. The example provided demonstrated that, of the overall emissions, CH₄ accounts for 57 per cent, CO₂ for 37 per cent, and N₂O for 6 per cent.

Major areas of data uncertainty include: estimation methods; equipment inventory; activity data; and emission factors. One of the main issues with such widespread operation over a continent is that the basic activity data is highly variable in quality. The uncertainty of combustion emission is primarily due to variable fuel composition and unknown consumption rates. There is usually good data for large sources, but a lot of effort is required for small emission sources at multiple locations. For vented
emissions there are usually good records in the USA due to regulatory requirements to keep (and report) gas vented or released. However, pneumatic device data are outdated.

With current methodology, fugitive emissions are the weakest portion of inventory, accounting for ~40 per cent of GHG emissions, although component-based emission factors are mostly outdated and an accurate component count is difficult. Emission estimates still rely on mid-1990s vintage data and new emission factors that better represent current operational practices and equipment are sorely needed.

Key messages from the discussion

- The drivers for the effort by the aluminum sector include value creation, understanding the risk and creating an opportunity.
- Industry sectors ought to consider the value of collaborative efforts vs. competitive issues.
- It is important to industry to ‘put uncertainty on the map’; data should be reported with ranges to indicate confidence intervals.
- It is hard to quantify annual error bars, and there is a potential that if data uncertainty ranges are displayed with the data that stakeholder will be confused and start questioning data validity.
- Companies should be prepared to provide uncertainty data, if needed, but should not necessarily include it together with their reported emissions; e.g. it could be provided as an addendum.
- Cost-effectiveness should be considered when chasing all venues for reducing uncertainty.
Panel 4: Approaches to prioritizing uncertainty reduction

An example of the role of compliance
Reducing uncertainty is a direct outcome of strict compliance and enforcement of requirements. There is a need to define a clear structure of responsibilities between parties and use compliance as a tool to gain trust in emissions trading as both an environmental measure and a ‘high risk’ financial instrument.

During the first trading period (2005–2007) the EU ETS was not implemented uniformly by all member states. Countries opted to use their national allocation plans (NAPs) for protection of national industries. Due to no experience in member states with compliance, the need for uniform procedures to ensure such compliance was undervalued. The key learning was the need for a harmonized compliance system backed by uniform standards. Especially critical is the uniformity in the verification process and in accrediting verifiers.

For Phase II the system will rely on permits for spelling out compliance obligations. A companion monitoring plan will become the focal point for listing the requirements for managing uncertainty. It will use the ‘tier’ structure as its basic element, ensure a ‘level playing field’ for all participants, and indicate data back-up needed to justify selected options. Industry associations such as IPIECA, API and CONCAWE could have a role to play in developing such good practices guidance.

An example of data accuracy and certainty for emissions trading
Measures designed to enhance data accuracy and certainty for emissions trading typically rely on several key elements: specific monitoring and data collection procedures; quality assurance requirements; automated and standardized reporting; incentives for completeness and accuracy; and data validation through auditing.

For example, the US EPA specifies measurement options and the required elements of the monitoring plan, while sources install, certify and maintain monitoring equipment. In addition to the sources’ on-site quality assurance, the sites and the data are open for inspection and audits either by the federal EPA or by local authorities.

Measurement data are collected either via continuous emissions monitoring systems (CEMS) or by periodic stack measurements. Continuous measurements may include direct measurement of \( \text{SO}_2 \), \( \text{NO}_x \) and \( \text{CO}_2 \) in the stack, or measurement of heat input from stack flow and diluents (\( \text{CO}_2 \) or \( \text{O}_2 \)) measured at the stack exit. For non-CEMS options the measurements may rely on fuel flow meters and fuel analysis for sulphur, carbon and heat content. These non-CEMS fuels-based methods work well with
homogenous fuels such as gas and oil but not with solid fuels such as coal. Additionally, they are well suited for estimated carbon (or CO$_2$ emissions) but not NO$_x$ since it depends on the specific combustion conditions.

Periodic stack testing is the method of choice for low emitting sources using solid fuels or for NO$_x$ determination. Typically, applying the results of periodic stack testing to annual emissions results in a conservative approach that tends to overestimate emissions. For SO$_2$ emissions trading in the USA, typically 36 per cent of the installations use CEMS, while 64 per cent use other methods. However, in terms of tons of emission, 96 per cent are determined by CEMS. For CO$_2$ emissions, 13 per cent of sources use non-CEMS methods, and 47 per cent of them use CEMS (already have CEMS for SO$_2$ and NO$_x$) with CEMS accounting for 87 per cent of the emissions.

Relative accuracies of SO$_2$, NO$_x$, flow rate and CO$_2$ are typically better than 3 per cent, with valid data availability at 99 per cent. Reporting typically consists of mass emission rates for the individual gases (SO$_2$, NO$_x$ and CO$_2$) and other parameters such as rate of fuel intake. A comprehensive quality assurance programme is required consisting of specified checks and calibrations, and requirements for instrument performance and competency of test personnel. EPA audits of the data include: electronic audits; hard-copy data audits; and targeted field audits. The system has built-in incentives and automatic penalties that are greater than the value of the allowances. In short, emissions data quality is crucial to show reductions and gain confidence in the allowances market. However, the process took some time to evolve (from its initial start in implementing the US Acid Rain Program pursuant to the US 1990 Clean Air Amendments) in order to get to the point where it is today.

Examples of voluntary and mandatory regional programmes
States and regional associations of states continue to lead in implementing the climate initiative. The main US voluntary GHG reporting programmes are: the US DOE 1605(b) Program, which was originally initiated in 1993 and revised extensively in 2006$^{19}$; the US EPA Climate Leaders Program that was started in 2000$^{20}$; and the California Climate Action Registry (CCAR), initiated in 2001$^{21}$. Among the mandatory GHG reporting programmes are those of Maine, Connecticut and New Jersey that require facilities to report under their Air Permits (Title V) but the data

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$^{20}$ www.epa.gov/climateleaders
quality for these is not rigorous. Conversely, California is now developing a system for mandatory reporting as a consequence of recent state legislation, and this will initiate reporting by some sectors of the California economy in 2009\textsuperscript{22}. The Regional Greenhouse Gas Initiative (RGGI) was developed as a regional initiative by nine states and applies only to the electric generation sector (> 25 MW). The RGGI is currently developing a model rule that each of the participating states will have to adopt with a programme start date of 2009. It is expected that the states will choose different methods for initial allocation, with the state of New York possibly opting to auction 100 per cent of allowances.

The activities of the different states have triggered a move towards a common multi-state GHG registry. Such a system is in development and will be known as The Climate Registry. Fourteen Western States, eight mid-west states, the nine RGGI states and the state of North Carolina have subscribed to the initial development of this common registry. In total, The Climate Registry is engaging more than 30 states, and is designed to be policy-neutral and provide states with a common framework to collect and certify GHG emission inventories. A Memorandum of Understanding (MOU) has been signed in May 2007 by 39 states and tribal authorities, with the reporting system expected to become operational on 1 January 2008. Data quality for the GHG estimation methods for The Registry would consist of two ‘tiers’, with methods designated as either ‘preferred’ or ‘default’. States are expected to follow the precedent set by the US Clean Air Act as far as data quality requirements for major sources (such as power generation) are concerned; but the regulatory approach to uncertainty for other sources (industrial, commercial, mobile, fugitives) are yet unclear.

**An industry perspective on prioritization of uncertainty reduction efforts**

The principal goal of the EU cap-and-trade emissions scheme is to provide for required emission reductions at the lowest overall cost. However, the cost-benefit analysis for uncertainty reduction projects is not well understood; and it is unclear whether the scope and cost of meeting all the accuracy and certainty requirements are fully recognized. It is also not evident that they can be (or are being) implemented uniformly across facilities or industry sectors. For petroleum and natural gas facilities, instrument maintenance and calibrations could be tied to facility process units’ shutdown for maintenance, but this is infrequent. Or, it could be done on its own schedule (more frequently), but this would be costly for operations (if units have to be

It ought to be recognized that greater certainty does not necessarily lead to lower emissions; and some of the issues are due to the fact that there are differences between the emissions allocation basis and the emissions reporting basis. Hence there is a need for: better common understanding of ‘cost-effectiveness’ of emission estimation choices; knowledge of key contributors to facility/entity emissions inventory uncertainty; uniformity of application of monitoring and verification requirements across states and regions; and an implementation timeframe for uncertainty reduction efforts that avoids business disruptions and takes into account the normal maintenance cycle.

A verifier view on reducing uncertainty

For the petroleum and natural gas industry, metering technology used for gas systems consist predominately of differential pressure orifice plates (> 80 per cent). Other technologies are emerging to track fuel gas systems. For upstream operations most fuel gas systems meet Tier 2 (EU ETS) requirement due to their use as ‘custody transfer’ points for product sales. In some cases for downstream operations it is hard to designate a certainty tier due to the inaccessibility of the flow meters for inspection. Since measurements and uncertainty determinations depend on knowledge of the condition of the primary measurement devices, reference standards cannot be applied to verify relative accuracy if they are not accessible for inspection.

Inaccuracies in the operating conditions of the fluid in the pipes could result in errors when determining its flow. For example, a 0.26-bar error in pressure would lead to a 0.5 per cent error in flow rate, and a 2°C error in temperature would amount to a 0.4 per cent in derived flow rate. Actions that could be taken to improve accuracy and certainty of flow measurements for orifice plate meters might include: inspection, calibration and certification of all plate meters prior to start of operations; calibration of differential pressure transmitters associated with metering; analysis of fluid densities at regularly scheduled intervals; or installation of improved metering technology.

In short, a well documented management system for metering devices would facilitate the demonstration and documentation that the system meets the required certainty tier. Such a system should consist of: documented uncertainty analysis; metering system maintenance manual; calibration records; calculations and configuration records; metering system logbooks; erroneous measurements; and independent audit reports.
Key messages from the discussion

- It is important to distinguish between data uncertainty (variability) vs. accuracy (bias).
- When comparing existing SO₂ and NOₓ markets to CO₂ it is important to note the large differences in emissions scope.
- The existing US ‘Acid Rain’ emissions trading system has flexibility and is designed to help industry be successful in attaining compliance at lowest possible costs, with harmonization and standardization being promoted by having a centralized approach.
- There is need for a penalty system that promotes compliance; in the US Acid Rain Program violations mean that you are surrendering allowances resulting in an automatic deduction of the emission rights originally assigned to a source.
- In the EU ETS no facility inventories were rejected but some facilities were verified with comments.
- The main differences between the EU ETS and the US Acid Rain Program are the maturity of the systems and the fact that in the USA there is a centralized authority while in the EU there is high variability between member states.
- In looking at new CO₂ programmes in the USA it is clear that some of the states are more sophisticated than others but states are organizing themselves and developing joint programmes.
- US states understand that they need consistent methods to ensure success of their programmes and are pushing to devise consistent methods and reporting frameworks.
- Dialogues among states and within countries is a challenge since there are a lot of vested interests and a variety of views are represented at the table.
- There is a need to consider that time is needed to let some of these systems mature and improve together with improvements in data collection.
Workshop programme

The speakers’ presentations can be downloaded from the IPIECA website at: http://www.ipieca.org/activities/climate_change/workshops/jan_07.php

Welcome presentation
• Arthur Lee (Chevron, IPIECA CCWG Chairman) (PDF, 275 KB)

Workshop goals and agenda review
• Karin Ritter (API) (PDF, 121KB)

Session 1
• GHG Uncertainty and Accuracy: Oil and Gas Industry Context Richard Sykes (Shell) (PDF, 235 KB)
• Regulator’s Perspective (Measurement Uncertainty) Rob Gemmill (Environment Agency, England and Wales) (PDF, 159 KB)
• NGO Perspective Rob Bradley (World Resources Institute) (PDF, 318 KB)
• Assessing the Uncertainty of Reporting Standards Randall Krantz (World Economic Forum) (PDF, 130 KB)

Session 2
• The Ongoing Debate: How to Go About Uncertainty under the Kyoto Protocol. Key Uncertainties in Perspective. Matthias Jonas (IIASA) (PDF, 101 KB)
• The Use of Uncertainty Quantification Methods for Data Quality Ranking Lisa Hanle (US EPA) (PDF, 2.03 MB)
• Uncertainty and Compliance in the EU Emission Trading System Jochen Fröhlich & Jochen Harnsich (Ecofys, Germany) (PDF, 248 KB)
• Estimating CO₂ Emissions from the Non-energy Use of Fossil Fuels—The Case of Germany (1990–2003) Martin Weiss & Martin Patel (Utrecht University) (PDF, 447 KB)
• Industry Data Limitations and Internal Consistency Jean-François Larivé (CONCAWE) (PDF, 380 KB)

Session 3
• Reporting of CO₂ Emissions in Statoil: An Upstream Example of Reporting CO₂ Emissions Gard Tore Pedersen (Statoil ASA) (PDF, 1 MB)
• Uncertainty Assessment Under the EU ETS: Exploring the Iceberg Dop Schoen (ExxonMobil Downstream and Chemical H&E) (PDF, 305 KB)
• Product Transport Brigitte Poot (Total) (PDF, 712 KB)
• Providing to Public Authorities GHG Emission Values, Measured, Verified and Audited: Lessons from Alcan, Practical Experience for the Aluminium Smelting Industry Thierry Berthoud (Alcan) (PDF, 848 KB)
• GHG Emissions Inventory Development Experience Fiji George & Katarzyna Chruscik (El Paso Corporation) (PDF, 1.37 MB)

Session 4
• Emissions Trading in the EU: The Importance of Compliance and Reducing Uncertainty Chris Dekkers (Netherlands Ministry of Environment) (PDF, 226 KB)
• Measures Designed to Enhance Accuracy and Certainty for Trading Programs Reynaldo Forte (US EPA) (PDF, 319 KB)
• US Voluntary and Mandatory GHG Reporting Programs: Data Quality and Uncertainty Assessment Heather Kaplan (NESCAUM) (PDF, 270 KB)
• Oil Industry Perspective Dugald Wright (BP) (PDF, 108 KB)
• Verifiers’ Perspective Steve Ross (DNV) (PDF, 213 KB)
IPIECA’s Climate Change Working Group

Formed in 1988, the IPIECA Climate Change Working Group (CCWG) monitors, analyses and informs the membership of key developments in the issue, especially those taking place at the UNFCCC and IPCC. The CCWG encourages the development of policy options that strike a balance between the projected consequences of potential climate change and the estimated costs of response options to mitigate or adapt to climate change. The CCWG sponsors dialogues and workshops addressing key aspects of the ongoing negotiations, and provides a technical publication series as a means of constructive input to the process.

Publications in the IPIECA Climate Change series include:

- Increasing the Pace of Technology Innovation and Application: Enabling Climate Change Solutions
- Natural Gas as a Climate Change Solution: Breaking Down the Barriers to Methane’s Expanding Role
- International Policy Approaches to Address the Climate Change Challenge
- Transportation and Climate Change: Opportunities, Challenges and Long-term Strategies
- Carbon Dioxide Capture and Geological Storage: Contributing to Climate Change Solutions
- Petroleum Industry Guidelines for Reporting GHG Emissions
- Energy, Development and Climate Change: Considerations in Asia and Latin America
- Development and Climate Change: Issues and Approaches in Asia
- Climate Change: a Glossary of Terms
- Critical Issues in the Economics of Climate Change
- Long–Range Scenarios for Climate Change Policy Analysis
- Opportunities, Issues and Barriers to the Practical Application of the Kyoto Mechanisms
- Technology Assessment in Climate Change Mitigation—an IPIECA Workshop
- Buenos Aires and Beyond—a Guide to the Climate Change Negotiations
- A Guide to the Intergovernmental Panel on Climate Change
- Long-Term Energy and Carbon Management: Issues and Approaches

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IPIECA
The International Petroleum Industry Environmental Conservation Association (IPIECA) was founded in 1974 following the establishment of the United Nations Environment Programme (UNEP). IPIECA provides one of the industry’s principal channels of communication with the United Nations.

IPIECA is the single global association representing both the upstream and downstream oil and gas industry on key global environmental and social issues. IPIECA’s programme takes full account of international developments in these issues, serving as a forum for discussion and cooperation involving industry and international organizations.

IPIECA’s aims are to develop and promote scientifically-sound, cost-effective, practical, socially and economically acceptable solutions to global environmental and social issues pertaining to the oil and gas industry. IPIECA is not a lobbying organization, but provides a forum for encouraging continuous improvement of industry performance.

American Petroleum Institute (API)
The American Petroleum Institute is the primary trade association in the United States representing the oil and natural gas industry, and the only one representing all segments of the industry. Representing one of the most technologically advanced industries in the world, API’s membership includes more than 400 corporations involved in all aspects of the oil and gas industry, including exploration and production, refining and marketing, marine and pipeline transportation and service and supply companies to the oil and natural gas industry.

API is headquartered in Washington, D.C. and has offices in 27 state capitals and provides its members with representation on state issues in 33 states. API provides a forum for all segments of the oil and natural gas industry to pursue public policy objectives and advance the interests of the industry. API undertakes in-depth scientific, technical and economic research to assist in the development of its positions, and develops standards and quality certification programs used throughout the world. As a major research institute, API supports these public policy positions with scientific, technical and economic research. For more information, please visit www.api.org.