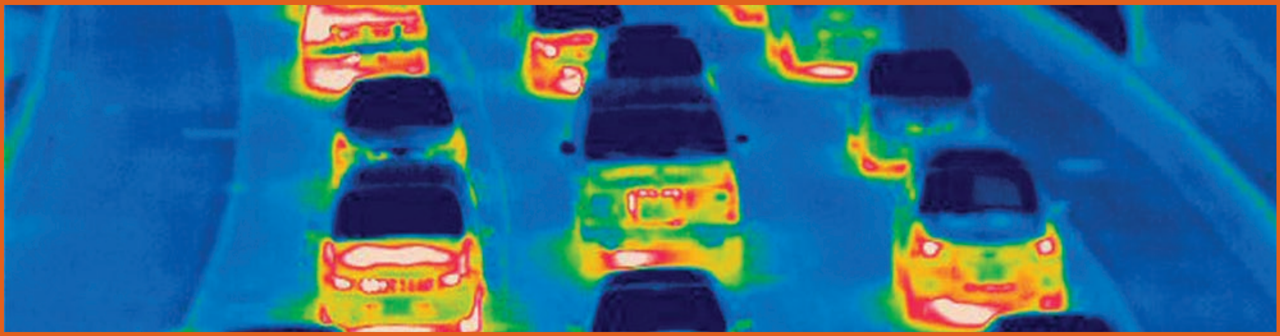
Counting the Gigatonnes:
Building trust in greenhouse gas inventories from the United States and China



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Notwithstanding the engagement of all of these contributors, the analysis presented in this report, and any residual errors, misrepresentations, or distortions are solely the responsibility of the authors. The recommendations found at the end of this report have been endorsed by WWF-US.

I.M.M., J.A.L., I.D.V.

i Note: Organizational listings above are for identification only. Neither the findings nor the information contained in this report are meant to reflect the views or endorsement of any of the organizations listed here other than WWF.

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EXECUTIVE SUMMARY

China and the United States are the world's largest emitters of greenhouse gases (GHGs), contributing more than 32% of global greenhouse gas emissions, and approximately 40% of global CO_2 emissions from energy use and industrial processes in 2005. The official GHG inventories published by the United States and China are extremely important for tracking the progress of each country in delivering on the pledges made in Copenhagen and beyond. The following report casts light on the emissions inventory processes used in the U.S. and China in reports to the international community as well as the strengths and challenges of the approaches that each country has followed. **Our findings indicate that the existing systems in China and the U.S. can be adequate for monitoring and review of each country's greenhouse gas emissions reduction claims.**

Although it will not be possible to verify each statistic for each parameter each year, there is good reason to believe that, looking at multi-year periods, the national GHG inventories of the United States and China will portray the levels and trends in energy use and greenhouse gas emissions of each country with reasonable accuracy. The process of building and strengthening these national GHG inventories can help to foster a growing trust between the United States and China, as well as within the larger international community.

The U.S. emissions inventories are based on annual surveys of energy supply and use, with broad coverage, detailed documentation, and moderate levels of statistical uncertainty. The U.S. Environmental Protection Agency (EPA) and the Department of Energy's Energy Information Administration (EIA) have many years of experience in survey data collection, analysis, and inventory preparation. Nonetheless, neither EPA nor EIA have instituted auditing and spot-checking procedures beyond statistical data checks on self-reported data from commercial energy suppliers. As the U.S. moves to regulate greenhouse gas emissions, introduction of direct emissions measurements, periodic auditing, and spot-checking procedures will be extremely helpful in ensuring continued confidence in U.S. national GHG inventories. The new EPA mandatory reporting rule, by which covered facilities will have to start reporting in 2011, will be an important step towards strengthening the U.S. national GHG inventory process. The United States could usefully learn some practical lessons from China's experience with direct measuring, auditing and spot-checking of energy and greenhouse gas emissions data.

As a developing country, China is currently preparing its second national GHG inventory, based on data from 2005, for inclusion in its Second National Communication to the UNFCCC. This new inventory will create a baseline of comparison for the carbon intensity target that China announced in Copenhagen. China has less experience in tracking GHG emissions than does the United States, so understandably there are larger uncertainties in its GHG emissions data, particularly from coal. However, with its recent energy intensity targets, China has increased its efforts at data collection and reporting. In addition, the Chinese government has recently committed to preparing and publishing a national GHG inventory every two years. China could gain from expanded cooperation with the United States on the development of statistical surveys of energy use and GHG emissions, which would be a practical complement to its current procedures. Use of such surveys could help to reduce uncertainty in China's future estimates of energy use and GHG emissions. As these new approaches are put in place, much can be gained through increased transparency in data documentation.

There are a variety of opportunities for expanding collaboration between the United States and China on energy technologies, greenhouse gas inventories; as well as satellite and atmospheric measurements and models for GHG. Expanding existing programs and developing new vehicles for enhanced cooperation can deepen trust between the two countries and reinforce shared efforts to mitigate climate change.

EXECUTIVE SUMMARY (Chinese)

碳排放统计：
建立互信的中美温室气体排放清单

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内容摘要

作为世界上最大的温室气体排放国，2005年中美两国的温室气体排放量超过了世界温室气体排放总量的32%，约占世界因工业生产和能源使用产生的二氧化碳排放总量的40%。中国和美国的国家温室气体排放清单对于掌握两国在哥本哈根大会上宣布的，以及之后可能提出的减排承诺和目标的完成进度至关重要。本报告概括了中国和美国向国际社会公布的温室气体排放清单的具体编制程序，并对两国所采用方法的优势及其所面临的挑战进行了分析。我们的研究结果表明，中美两国现有的系统和方法足以监测并审查其温室气体减排目标的完成情况。

我们有足够的理由相信，虽然不可能对每年每项统计指标下的所有数据进行核实，但在多年的时间尺度上，中美两国的国家温室气体排放清单能够足够准确地反映其能源使用和温室气体排放的水平和趋势。共同合作来进一步完善和加强国家温室气体排放清单的过程可以增强中美两国间的相互信任，并促进更广泛的国际社会内的相互信任。

美国的温室气体排放清单是以年度能源供给和使用调查为基础编制而成的，其内容详细、覆盖面广，具有适度的的统计不确定性。美国国家环保局（EPA）和能源部能源信息管理局（EIA）在收集、分析调查数据和编制排放清单方面有多年的经验，不过，除了对能源供应商提供的自报数据进行统计检验之外，无论是EPA还是EIA都没有采用审计制度和抽查程序。随着美国政府即将对温室气体排放进行调控，直接测量温室气体排放，定期进行审计并实施抽查，将对确保对美国国家温室气体排放清单的持续信心起到极为重要的作用。EPA新发布的温室气体排放报告制度规定，从2011年开始，凡是纳入该制度的排放企业都必需提交报告，这是在完善国家温室气体排放清单编制程序上迈出了重要的一步。在对能源数据和温室气体排放数据的直接测量、审计和抽查方面，美国可以从中国的工作中学到一些有益而实用的经验。

作为发展中国家，中国正在根据2005年的数据编制第二次国家温室气体排放清单。该清单将列入中国向《联合国气候变化公约》秘书处提交的第二次国家信息通报，作为中国在哥本哈根气候变化大会上宣布的碳排放强度减排目标的参照基准。与美国相比，中国在统计温室气体排放量方面的经验较少，因此，中国的温室气体排放数据，尤其是与煤炭使用相关的数据具有更多的不确定性。但随着最近其能源强度目标的提出，中国正在逐步加大在数据收集和完善报告制度上的努力和投入。中国政府最近还宣布，将每隔两年准备和公布一次温室气体排放清单。扩大与美国在能源使用和温室气体排放数据调查上的合作，将是对中国现有程序和方法的有益补充。这类调查将减少能源使用和温室气体排放数据的不确定性，随着新方法的使用，数据透明度的提高也将显著增加数据所提供的信息。

中美两国在能源技术、温室气体排放清单、卫星和大气测量以及温室气体排放模型方面有着广泛的合作交流机会。扩大现有的合作项目并开拓新的合作渠道，必将加深中美两国彼此间的信任，并进一步促进两国减缓气候变化的共同努力。

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1. INTRODUCTION

China's actions in recent months have demonstrated a serious determination to reduce greenhouse gas emissions and out-compete the United States in building a clean energy economy. As part of its economic stimulus package, China invested nearly $221 billion — more than twice as much as the United States did in its stimulus program — in clean energy projects.[1] It currently has 76 GW of installed renewable electricity capacity excluding large hydropower — the most of any country and nearly twice that of the U.S.[2] China is the world leader in installations of solar water-heaters with more than 60% of the world market, and in 2008 it became the leading manufacturer of solar photovoltaic cells.[3] Wind energy has boomed, growing at an exponential rate in the past decade[4] and the country has set impressive investment goals, including the construction of 13,000 km of high speed rail by 2012.[5] China is positioning itself as a leader in the clean energy economy and wants to seize a powerful role in this market, while achieving significant emission reductions and contributing to the global effort to mitigate climate change.

In spite of the U.S. failure thus far to pass comprehensive energy and climate legislation, the Obama administration has acted in various areas that promise emission reductions, including investing $94 billion in renewable energy technologies, energy efficiency, low-carbon vehicles, smart grids, and mass transit through the stimulus package (i.e., the American Recovery and Reinvestment Act of 2009).[6] In addition, new regulations have been introduced to spur improvement in vehicle fuel economy and to reduce the federal government's greenhouse gas emissions.[7] The renewable energy sector, including wind and solar energy has also grown significantly in the United States. Indeed, in 2008, the U.S. led the world in installed wind capacity, with 8.4 GW added.[8]

Even with these advances, there is considerable uncertainty regarding the effect of these investments on greenhouse gas emissions (GHG). How do we know if the investments that are being made are leading to real emissions reductions? Can we trust that the U.S. and China will achieve the targets that they put forward at the Copenhagen Climate Summit? How confident can the international community be about the inventory processes used to calculate Chinese and American emissions? WWF conducted a study to answer these questions. The report of this rapid scoping study casts light on the emissions inventory processes in the U.S. and China, the

Pledges of the U.S. and China in Copenhagen

At the UNFCCC COP 15 in Copenhagen in December 2009, President Obama pledged that the United States would reduce its future GHG emissions in the range of 17% below 2005 levels by 2020, in conformity with anticipated U.S. energy and climate legislation, but contingent upon its passage by the U.S. Congress.[10] The bill passed by the U.S. House of Representatives in the summer of 2009 targets a 30% emissions reduction below the 2005 baseline in 2025, a 42% reduction by 2030 and an 83% reduction by 2050. As of May 2010, the corresponding Senate Bill, the American Power Act, has been released by Senators John Kerry and Joseph Lieberman.

The U.S. targets are modest compared to other industrialized nations as they represent less than a 5% GHG reduction by 2020 below the 1990 levels.[11] Nonetheless, passage of a climate bill would be a historic marker as the first legally binding commitment of the U.S. to reduce emissions; and as a platform for long-term reductions that will propel the U.S into the clean energy economy, providing incentives to low carbon technology through a price on carbon.

Similarly, China pledged that it would reduce its carbon intensity (i.e., CO_2 emissions per unit of Gross Domestic Product or GDP, excluding land use change[12]) by about 40-45 percent below 2005 levels by 2020, and would increase energy supply from non-fossil fuels to a level that is equivalent to 15 percent of the country's primary energy consumption by 2020. China also pledged to expand forest cover by 40 million hectares by this date and to increase forest stock volume by 1.3 billion cubic meters above 2005 levels by 2020.[13]

The Chinese carbon intensity target is notable because it covers emissions from all energy and industrial processes, a much broader enterprise than many thought would emerge in the context of the Nationally Appropriate Mitigation Actions (NAMAs) by developing countries that were agreed in the Bali Action Plan of 2007. Given that China's economy and infrastructure are expected to keep growing at a rapid pace, it is anticipated that China's target will not lead to a reduction in China's absolute emissions by 2020 but rather to emission reductions compared to a business-as-usual (BAU) scenario. However, the pledges seem to be ambitious relative to China's current state of economic development, as evidenced by the efforts that have been required to meet China's current energy intensity targets.

In Copenhagen, the questions of trust and transparency were key sources of friction between the United States and China. These questions brought the issue of reporting of emission reductions to the forefront. An agreement was reached that recognized both the need to measure, report and verify mitigation actions while preserving the sovereignty of parties to the Convention.

strengths and challenges of the approaches of both countries, and future areas for improvement, including alternative methods for verification of emissions.

China and the United States are the world's largest emitters of greenhouse gases, contributing more than 13 gigatonnes[ii] of GHGs per year in 2005[iii] (expressed in CO_2-equivalent emissions) and about 40% of global CO_2 emissions from energy and industrial processes.[9] The official GHG inventories published by the United States and China are extremely important sets of information for monitoring the progress of each country in delivering on their pledges made in Copenhagen and beyond. Both countries will have to strengthen their systems for monitoring, reporting, and review of GHG emissions. With the pledges made at Copenhagen, a higher level of precision and accountability in emissions estimates will be required from the United States, while China will have to demonstrate a clear decrease in the trend of carbon intensity of its economy, along with a trend toward increasing use of renewable energy. **Our findings indicate that the existing systems in China and the U.S. can be adequate for monitoring and review of each country's greenhouse gas emissions reduction claims.**

Although individual statistics may be subject to revision, the additional attention that each side will give to the preparation of their national GHG inventories will help to reduce the margins of uncertainty in GHG emissions estimates over multi-year periods. The resulting improvements in their national GHG inventories will build confidence within the international community that both China and the United States will accurately portray the longer-term trends in energy use and greenhouse gas emissions in each country.

The U.S. and Chinese GHG Inventories in Context

The Intergovernmental Panel on Climate Change (IPCC) sets the standards for emission inventories with its Guidelines for Greenhouse Gas Inventories (see Appendix 1). National GHG inventories are usually taken at face value by the international community, but the methods and procedures to calculate emissions remain obscure to many people, even to those involved in climate policy and science. The accuracy and credibility of national GHG inventories are rapidly becoming more important as the world sees the need for monitoring of the climate commitments made by countries. The larger the uncertainties in the inventories, the more difficult it is to verify that countries are meeting their promised commitments.

China and the United States have followed different paths in terms of building their emission inventory capacity. On the one hand, the United States, like other industrialized nations, committed to annual greenhouse gas inventories as part of its obligations as an Annex 1 country under the United Nations Framework Convention on Climate Change (UNFCCC). To fulfill these obligations, the U.S. has developed a set of statistical methodologies along with an institutional system for creating and submitting the inventories. However, the U.S. decided not to participate in the Kyoto Protocol, so conducting GHG inventories has not been a regulatory requirement in the country, as it has in Europe, where the accounting of emissions is required at the company level as part of the European Emissions Trading System (ETS).

Can we trust that the U.S. and China will achieve the targets that they put forward at the Copenhagen Climate Summit? How confident can the international community be about the inventory processes used to calculate Chinese and American emissions?

On the other hand, based on the Convention's core principle of *"common but differentiated responsibilities,"* China, as a developing nation, was only required to submit an initial, simpler inventory of emissions to the UNFCCC, which was published in 2004 based on GHG emissions for the year 1994. Greenhouse gas inventories at the level of detail of Annex 1 countries require sophisticated data collection capabilities that most developing countries do not yet have. For China, inventorying GHG emissions is an immense

[ii] One gigatonne of emissions is equal to one billion metric tonnes or one thousand million metric tonnes of emissions.

[iii] This figure is the latest available for all greenhouse gases, including land use change and forestry.

challenge, given the sheer size of its population, the vast informal energy sector and the rapid economic transformation that is underway in the country.

China and the United States are the world's largest emitters of greenhouse gases, contributing more than 13 gigatonnes of GHGs per year in 2005 and about 40% of global CO_2 emissions from energy and industrial processes.

Today, China is preparing their second official inventory, based on data for the year 2005 and pledging regular emission inventories every two years, as recently announced by Xie Zenhua, Vice Minister of the National Development and Reform Commission (NDRC)[14] and the National People's Congress[15]. In so doing, they are building in parallel the capacity to collect the data required to monitor progress of their energy and climate targets. This is in line with a critical and positive agreement in Copenhagen[16]: biennial reporting for mitigation actions undertaken by Non-Annex 1 parties, according to guidance to be established by the Conference of Parties to the UNFCCC. This is a significant change from the current situation, where Non-Annex 1 countries do not have reporting deadlines for officially submitting their national communications nor the inventories included within them.

Although the level of energy-related CO_2 emissions from the two countries is about the same, the U.S. and China have considerable differences with respect to the mix of GHG emissions, the level of emissions per capita, the emissions intensity of their economy, energy consumption and historical responsibility with regard to emissions in the atmosphere, as indicated by the charts in Figure 1.

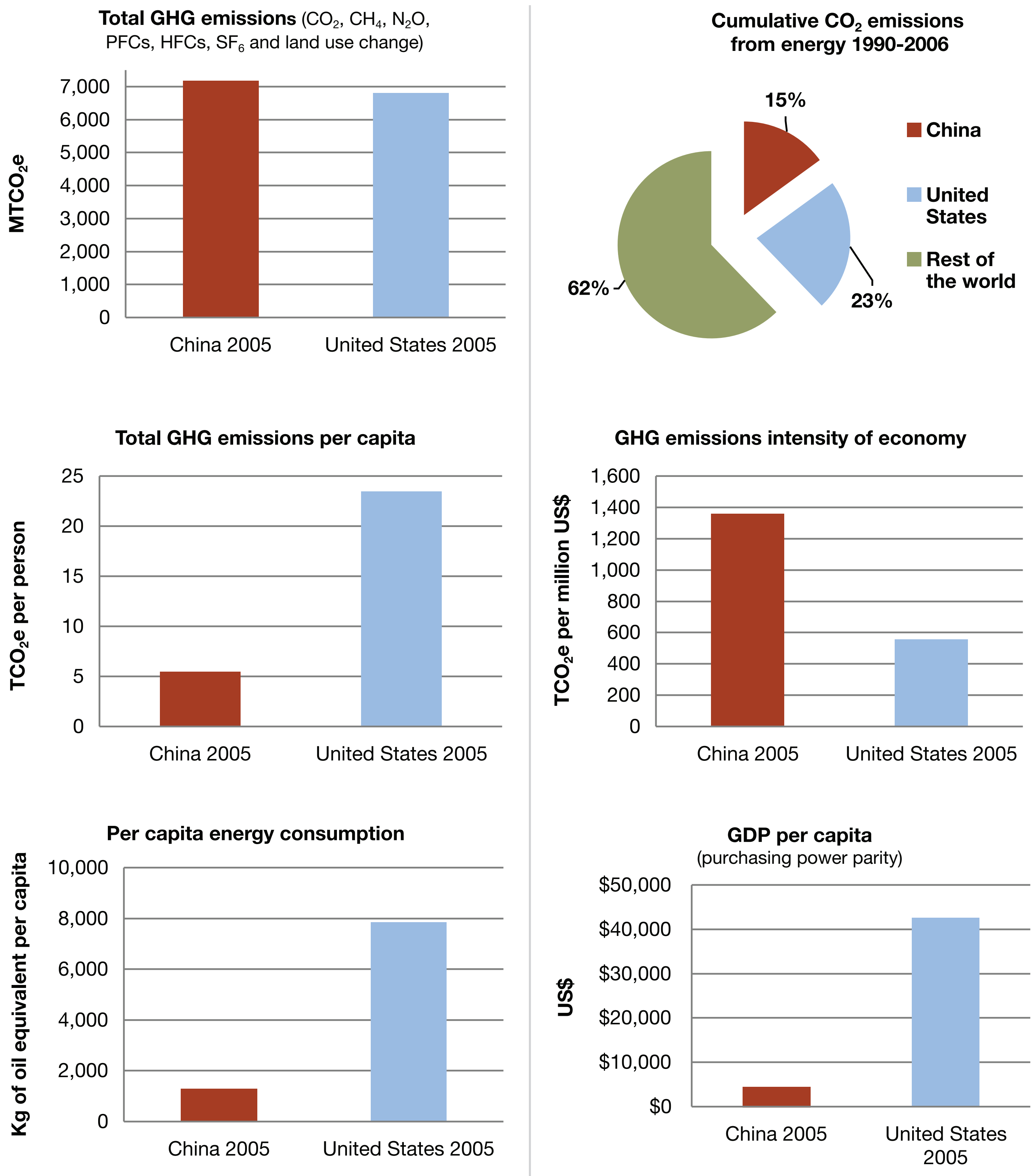
Study approach

This rapid scoping study was conducted during early 2010. The study combined a review of relevant literature, documentation, and the latest official data reported to the UNFCCC by the U.S.[19] and China;[20] together with structured interviews with 24 leading experts on energy use and GHG emissions in the two countries. To ensure frank and open discussions, the interviews were treated confidentially, with comments by all individuals aggregated into a single composite portfolio, without identifying the source of any particular view or attributing that view to a specific individual. The report's recommendations reflect the views of WWF and do not necessarily represent the views of any of the experts.

The report focuses on CO_2 emissions from energy and industrial processes, given that they represent the bulk of GHG emissions from the U.S. (84.5%) and China (77.3%) respectively, and that the combined emissions from the United States and China represent 41.5% of total CO_2 emissions worldwide, excluding land use change.[iv, 21] We focus primarily on carbon dioxide (CO_2) as the major contributor to greenhouse gas buildup from activities in the energy sector of both countries, with some reference to the other greenhouse gases: methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs) that are emitted from energy and industrial processes. Emissions from land use change and forestry, agriculture, and waste management are not accounted for in this report. These land sector inventories use different methodologies, have their own set of challenges, and would merit another entire report.

[iv] Data from 2005. Including all greenhouse gases, land use change, and international bunkers, CO_2 emissions from energy and industrial processes in the U.S. and China amount to 25.9% of the world's emissions.

Figure 1- Indicators of energy, economic development, and greenhouse gas emissions in the United States and China. Data from 2005 (World Resources Institute, World Bank) [17,18]



2. GHG INVENTORIES IN THE UNITED STATES

As an industrialized country included under Annex 1 of the UNFCCC, the U.S. is required to submit an annual greenhouse gas inventory. As of May 2010, the United States has submitted fourteen national GHG inventories covering the period since 1990. These inventories document the annual emissions by sources and uptake by sinks of the GHGs covered by the Convention up through the emissions of 2008. The gases covered by these inventories include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).

For Annex 1 countries, the annual inventory is independent from the *National Communications* to the UNFCCC, as the latter are not submitted every year, although summarized inventory information is included within each new National Communication.[22] The inventory is submitted in a *Common Reporting Format* and a *National Inventory Report* that includes a detailed documentation of the data, assumptions and methods employed.[23] The inventory is reviewed by an international team of experts appointed by the UNFCCC, which assesses the methodology, assumptions and data sources employed, and also carries out statistical analyses to identify unexpected anomalies.[24]

GHG Inventory Process in the United States

The Environmental Protection Agency (EPA) conducts the U.S. greenhouse gas inventory and submits the results to the UNFCCC through the State Department. The EPA collects data from numerous agencies in order to conduct the annual GHG inventory. In the Energy and Industrial Process sectors, the EPA relies on the Department of Energy's Energy Information Administration (EIA) and on the Department of Defense for data on fuel consumption, including bunker fuels used in marine shipping and aviation. The Federal Highway Administration, the Federal Aviation Administration, the Department of Transportation, the Department of Commerce and various research institutions also give activity data[v] to the EPA. In addition, there are a number of companies that conduct emissions inventories of their own and supply their data to the agency.[25] The EPA also collects some data directly and uses it to estimate emissions for non-CO_2 greenhouse gases (e.g., HFCs).

The Office of Atmospheric Programs at the EPA is responsible for the inventory calculations and reporting. The inventory calculations are carried out by individual experts in different emission sources who are in charge of collecting data, evaluating or developing methodologies and calculating emissions. The EPA team follows the IPCC revised 1996 guidelines for inventories,[26] the 2000 IPCC uncertainty guidelines[27] and the 2003 IPCC LULUCF guidelines.[28] Additionally, the latest 1990-2008 U.S. emissions inventory incorporated some of the new methodologies and data from the revised 2006 IPCC inventory guidelines.[29]

Following an internal quality assurance and quality control procedure as well as an uncertainty analysis for the inventory, the *U.S. National GHG Inventory* is distributed for review by a panel of selected experts outside the EPA and then enters a 30-day period of public review. After integrating the comments received in this review process, the EPA prepares the final version of the *National Inventory Report* and formats the inventory data into the UNFCCC *Common Reporting Format*. These documents are subsequently submitted to the UNFCCC by the U.S. Department of State, and made available to the public.[30]

During September 2009, EPA promulgated a mandatory reporting rule that will require large stationary sources of emissions (i.e., facilities emitting more than 25,000 metric tons of CO_2-equivalent per year, suppliers of fossil fuels, suppliers of industrial greenhouse gases and manufacturers of vehicles and engines) to report their annual GHG emissions to EPA, beginning in 2010. The EPA projects that 85% of the country's GHG emissions will be reported under this rule. The agency will verify the submitted data internally and will not require third-party verification. The EPA indicates that this bottom-up reporting rule will not change the procedure for the *U.S. National GHG Inventory*, but it may lead to changes in methodologies and data sources for particular sectors. In addition, it will provide a point of comparison for the emissions estimates.[31] Some emission sources were exempt from the reporting rule, such as electronics manufacturing, oil and natural gas systems and underground coal mines.

[v] In the context of this report, the term "activity data" refers to the "magnitude of human activity resulting in emissions or removals taking place during a certain period of time" (IPCC, 1997). For example, vehicle-miles traveled is one activity data for fuel consumption and hence emissions in the transportation sector.

Figure 2 on the next page illustrates the institutional structure of the system used in the U.S. to prepare the annual greenhouse gas inventory for reporting to the UNFCCC.

Energy data collection by the EIA

The Energy Information Administration collects and aggregates energy data from a range of sources in the United States and employs methods of statistical quality control to test the accuracy of its reports on energy supply and use. Commercial fuel and electricity suppliers are surveyed by EIA on an annual basis, tallying information on physical quantities of energy sold, the associated energy end-uses and the concurrent prices for each type of fuel and electricity. The data provided by the supplier surveys are complemented with sectoral energy consumption surveys. There are numerous additional sources of data for particular sectors, for example, trade association statistics for natural gas distribution. The EPA employs EIA's *Annual Energy Review, State Energy Data Report*, and *Monthly Energy Review* to estimate sectoral emissions of CO_2.[32] These publications compile supply and consumption data obtained from multiple sources, including some surveys exclusively dedicated to end-use consumption. Supply-side services are performed regularly and provide the bulk of the data to calculate emissions, whereas end-user consumption surveys are performed with less frequency and offer complementary information on the distribution and behavior of energy consumers.

The EIA surveys are all self-reported and data are collected in different formats (facsimile, email, secure file transfer through the Internet). Follow-up calls to non-respondents are used to reduce non-response rates, and subsequent formal notifications may be sent in cases of chronic lack of response. There are relevant statutes that specify penalties in case of non-reporting. Once data is collected, there are automated procedures to check for consistency with past data and to impute missing data. Anomalies are flagged and revisions are made episodically throughout the year, so that annual data are more reliable than the corresponding monthly values. Surveys such as the *Petroleum Supply Monthly (PSM)* claim a very high response rate (98-100%), and cover the entire universe of suppliers.[33]

Energy supply and consumption surveys

Data describing the behavior of U.S. markets for petroleum products are collected from weekly and monthly surveys. The *Weekly Petroleum Status Report (WPSR)* and the *Petroleum Supply Monthly (PSM)*, incorporate input from all companies and facilities involved in the American primary supply and distribution system for petroleum products. Production data are collected for motor gasoline, distillate fuel, jet fuel, residual fuel oil, propane, and "other oils." The PSM summarizes the weekly data for the month and includes production and inventory data for all petroleum products, plus estimates for field production, refinery output, imports, and for unaccounted crude oil that remains along with changes in inventory stocks.[34]

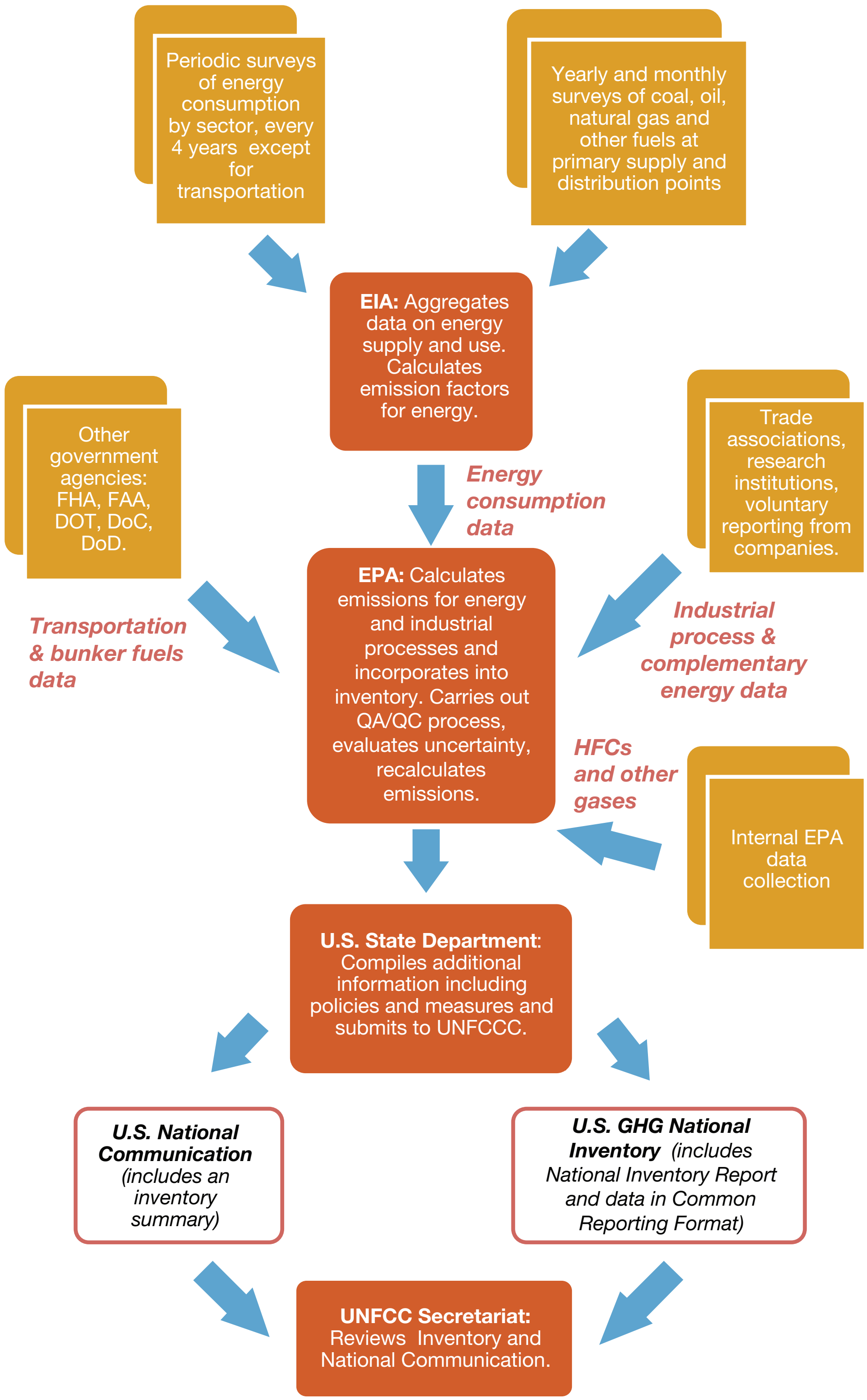
Data on U.S. natural gas supply and distribution are collected by EIA through weekly and monthly surveys of natural gas producers, pipeline operators, and distribution systems. These data are published in the Agency's *Natural Gas Monthly* and *Natural Gas Storage Report*. EIA also publishes the *Annual Quantity and Value of Natural Gas Production* that summarizes the monthly survey reports and includes additional data.[35]

The EIA's *Weekly Coal Production (WCP)* Report uses surveys of railroad car loading data to estimate U.S. coal production on a state-by-state basis. These weekly reports are summarized monthly by EIA. The monthly data are revised on a quarterly basis, using the results of the Mine Safety and Health Administration's own surveys.[36]

EIA conducts a number of surveys to develop a comprehensive picture of the U.S. electricity supply sector called the *Monthly Flash Estimates of Electric Power.* These *Flash Estimates* are compiled from the *Monthly Electric Utility Sales and Revenues with State Distributions* report, the *Power Plant Report*, the *Combined Heat and Power Plant Report*, and the *Power Plant Operations Report*. The underlying data are collected from a statistically significant sample of 450 electric utilities and other energy providers as well as from the operators of approximately 1600 power plants. A review and compilation of these monthly data are summarized in EIA's *Electric Power Monthly* report.

Data on energy consumption by sector is gathered at the supply and distribution level, from electric utilities, refineries, natural gas distributors and similar entities. However, other less frequent demand-side surveys carried out by the EIA are used to complement data for particular sectoral categories of the inventory. For instance, the quadrennial *Residential Energy Consumption Survey (RECS)* and *Commercial Building Energy Consumption*

Figure 2- Data collection and institutional process for the U.S. GHG Inventory



METHODOLOGY FOR ESTIMATING CO_2 EMISSIONS FROM FOSSIL FUEL COMBUSTION IN THE U.S.[37,38]

1. Fuel Consumption Data are Determined by Fuel And by Sector

The EIA provides fossil fuel consumption data by sector and fuel type (e.g. kerosene, jet fuel, diesel oil) primarily from the *Monthly Energy Review*. Fuel consumption data are determined by EIA surveys. Data from U.S. territories are disaggregated by fuel type but not by sectors.

2. Subtraction of Fuels Used in Non-energy Processes

To prevent double counting, some fuels that the industrial sector employs for non-energy purposes are subtracted from this sector and allocated to the Industrial Process sector, where the associated emissions will be counted. Other fuels have their carbon "locked in," and do not generate emissions, such as fuels used as feedstocks in the manufacture of plastics, asphalt, and lubricants.

3. Subtraction of Biofuels and Synthetic Natural Gas

Biofuels are assumed to have net zero CO_2 emissions when burned since the plants used to produce the fuels are assumed to absorb exactly as much carbon from the atmosphere as is released when the fuel is burned.[vi] Thus, ethanol consumption is subtracted from gasoline consumption, as is methane generated through biomass. There are also quantities of synthetic natural gas made from coal, which are deducted from the overall natural gas totals to avoid double counting, as the corresponding emissions are calculated as coal consumption.

4. Adjustment of Sectoral Allocations of Distillate Fuel Oil and Gasoline

The EPA adjusts EIA data on gasoline consumption allocated to the transportation sector following analysis of end-use consumption from the Federal Highway Administration. This is an example of an adjustment of sectoral emission estimates through the use of surveys, which helps allocate supply-side estimates more accurately into different sectors.

5. Subtraction of International Bunker Fuels and Exports of CO_2

International bunker fuels for aviation and shipping are not added to the national inventory but are calculated separately following UNFCCC guidelines. There is also a small quantity of CO_2 that is exported to Canada via pipeline from the Dakota Gasification plant, and this is subtracted as well.

6. Conversion of Fuel Units to Their Energy Equivalents

Quantities of each fuel type are converted by the EIA to British thermal units (BTU) in order to have a common metric for all fuel types. The U.S. uses a higher heating value[vii] for estimating this energy equivalent, as opposed to the lower heating values referenced in the IPCC guidelines.

7. Determination of the Total Carbon Content of the Fuels

The total carbon content is estimated by multiplying the average amount of carbon (C) in each fuel by the quantity of fuel consumed. The carbon content of each fuel is given in mass units of carbon per unit of energy for each fuel type. The emission factors are these carbon coefficients multiplied by 44/12, which translate the molecular weight of carbon in the fuel (12 atomic mass units) into the molecular weight of carbon dioxide (44 atomic mass units). Many of these emission factors have been developed at the Carbon Dioxide Information and Analysis Center (CDIAC) at DOE´s Oak Ridge National Laboratory.[viii] EIA publishes these emission factors with their annual inventory.[39]

8. Determination of CO_2 Emissions

Assuming 100% combustion efficiency,[ix] all the carbon in each unit of fuel is fully oxidized and converted into CO_2. Estimated emissions from each fuel and sector are obtained by multiplying the emissions factor by the adjusted estimate of the quantity of each fuel consumed.

9. Allocation of Transportation Emissions by Vehicle Type

The EPA disaggregates emissions data from the transportation sector to provide a detailed account of emissions by vehicle type and transportation mode.

[vi] Emissions incurred in the production of biofuels from fertilizer production and use, fuel used by farm machinery and emissions from land-use change are counted in other sectors.

[vii] The term "higher heating value" is also known as the "gross calorific value of a fuel." The higher heating value of a fuel takes into account the latent heat of vaporization of water entrained or embedded in the fuel. By contrast, the lower heating value of a fuel refers to its **net** calorific value and represents the amount of heat that can be usefully delivered to boil water in a steam generator.

[viii] The CDIAC emissions factors tend to be slightly lower than the equivalent emissions factors used internationally because they are based on the higher heating values for fossil fuels typically reported in the United States.

[ix] This assumes that all carbon is burned and none is left as ashes or is partially oxidized into carbon monoxide (CO) or other gases.

Survey (CBECS) provide statistically representative samples of energy consumption patterns of American residential, commercial, and institutional buildings. The *Manufacturing Energy Consumption Survey (MECS)* surveys most of the manufacturing base in the United States. In 2006, the latest *MECS* collected data from approximately 15,500 establishments that represented around 98 percent of the manufacturing payroll in the United States.

Energy consumption in the transportation sector is tracked through surveys of suppliers and marketers of specific fuels. These surveys cover motor gasoline, diesel fuel, jet fuel, compressed natural gas, and heavy fuel oil, among others. In addition, the *National Household Travel Survey (NHTS)* and the *American Travel Survey (ATS)* are compiled by the U.S. Department of Transportation. These surveys query a sample of U.S. households about their daily trips and daily miles traveled, the modes of transport used, and the purpose of their trips.

Calculation of emissions

Each emissions source has a different methodology for calculation of emissions. The U.S. follows a very similar methodology to that outlined in the IPCC 2006 guidelines.[40] (See box on page 8.)

The estimate of emissions from the energy sector contained in the U.S. National GHG Inventory includes by-product emissions and fugitive emissions of greenhouse gases not directly related to fossil fuel combustion.

Industrial processes[x] often emit gaseous CO_2, CH_4, and N_2O as wastes, and calculation of emissions follows specific models for each process and gas.[xi] In addition, other industrial processes may lead to emissions of HFCs, PFCs, and SF_6, all of which are greenhouse gases with high global warming potential.

U.S. National Greenhouse Gas Inventory 1990-2008

The United States submitted its most recent and 14th iteration of the inventory, the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (1990-2008), to the UNFCCC secretariat on April 2010.[41]

The inventory shows that CO_2 represented 85.1% of total U.S. greenhouse gas emissions in 2008. The next largest contribution came from methane (CH_4) emissions, which accounted for 8.2%, and nitrous oxide (N_2O), which accounted for 4.6% of the total GHG emissions in that year. The remaining emissions were made up of a mix of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), with 2.2% (Table 1). Ninety-three percent of emissions in the energy sector are from fossil fuel combustion. Carbon dioxide accounts for 96% of sectoral emissions (Table 2). Emissions in 2008 showed a 2.9% drop from their highest peak in 2007, when total emissions reached 7168.1 million metric tons CO_2 equivalent ($MTCO_2e$). Hence, total emissions in 2008 were very similar to 2000 levels.

The U.S. National GHG Inventory also summarizes CO_2 emissions from fuel combustion by end use economic sector, allocating electricity generation to each sector. In 2008, transportation accounted for 32% of emissions, industry for 27%, the residential sector for 21% and the commercial sector for 19%. The EPA also performed calculations of CO_2 emissions from fuel combustion using the reference approach indicated by the IPCC (See Appendix 1). Both sectoral and reference approaches gave very similar results, with a discrepancy of 1.2%.[42]

In cases where there are methodological changes or updates in data from longer time series, the EPA recalculates emissions for the overall time series. In 2008, there were recalculations in various categories, amounting to an overall correction of +0.3%.[43] Recalculations in the energy and industrial sectors were due to updates in activity data, updated emission factors and corrections to previous errors in calculations of emissions from iron and steel production (Table 3).[44]

[x] It is important to distinguish between emissions from industrial processes (non-energy related) and emissions from the industrial sector, which also include the energy-related emissions allocated to industrial use of electricity and direct combustion of fossil fuels.

[xi] Processes with significant emissions of CO_2, CH_4, and N_2O include iron and steel production and metallurgical coke production, cement production, ammonia production and urea consumption, lime manufacture, limestone and dolomite use (e.g., flux stone, flue gas desulfurization, and glass manufacturing), soda ash manufacture and use, titanium dioxide production, phosphoric acid production, ferroalloy production, silicon carbide production and consumption, aluminum production, petrochemical production, nitric acid production, adipic acid production, lead production, and zinc production.

Table 1: Trends in annual GHG emissions in the United States, by gas, in $MTCO_2e$ (extracted from 1990-2008 inventory)[45]

GAS	1990	2000	2008
CO_2	5100.8	5977.2	5921.2
CH_4	613.4	586.0	567.6
N_2O	322.3	345.5	318.2
HFCs	36.9	103.2	126.9
PFCs	20.8	13.5	6.7
SF_6	32.6	19.1	16.1
Total emissions	**6126.8**	**7044.5**	**6956.8**
Land use, land use change and forestry (sinks)	-909.4	-664.2	-940.3
Net emissions (sources minus sinks)	**5217.3**	**6380.2**	**6016.4**

Table 2: Emissions from Energy in the United States in 2008, in $MTCO_2e$ (adapted from 1990-2008 inventory)[46]

SOURCE	CO_2	CH_4	N_2O
Fossil fuel combustion	**5572.8**	**8.7**[xii]	**40.32**[xiii]
Electricity generation	2363.5		
Transportation	1785.3		
Industrial	819.3		
Residential	342.7		
Commercial	219.5		
U.S. Territories	42.5		
Non-energy use of fuels	**134.2**		
Natural gas systems	**30.0**	**96.4**	
Incineration of waste	**13.1**	**<0.05**	**0.4**
Petroleum systems	**0.5**	**29.1**	
Coal mining		**67.6**	
Abandoned underground coal mines		**5.9**	
*International bunker fuels**	*135.2*	*0.2*	*1.2*
*Wood biomass and ethanol consumption***	*251.8*		
Total Energy sector	**5750.5**	**207.8**	**40.8**

* International bunker fuels are not counted in the U.S. totals

** Biofuel emissions are not counted in the U.S. totals

[xii] Both stationary and mobile combustion

[xiii] Both stationary and mobile combustion

Table 3: Emissions from Industrial Processes in the United States in 2008 (adapted from 1990-2008 inventory) [47]

SOURCE /GAS	$MTCO_2e$
CO_2	**162.1**
Iron and steel production & metallurgical coke production	69.0
Cement production	41.1
Others[xiv]	52.0
CH_4 (mainly petrochemical and iron and steel production)	**1.6**
N_2O (nitric acid and adipic acid production)	**21.1**
HFCs	**126.9**
Substitution of ozone-depleting substances	113.0
Others (HCFC-22 and semiconductor manufacturing)	13.9
PFCs (Aluminum production and semiconductor manufacturing)	**6.7**
SF_6 (electrical transmission/distribution, semiconductor manufacturing, magnesium production/processing)	**16.1**
Total	**334.5**

U.S. National Communications to the UNFCCC

The United States submitted its *Fourth National Communication on Climate Change*[48] to the UNFCCC Secretariat on 27 July 2007. This report complied with the UNFCCC *Reporting Guidelines* and provided a clear and comprehensive overview of the climate policies of the United States. The policies and programs surveyed in the U.S. *Fourth National Communication* included the policy announced in 2002 setting a national goal of reducing the emissions intensity of the U.S. economy (expressed as CO_2-equivalent emissions per dollar of GDP) by 18 percent during the period from 2002 to 2012. The U.S. *Fourth National Communication* included all required sections specified in the UNFCCC reporting guidelines, but left out some of the specific required elements that are related to the discussions of policies and measures, future projections, and estimated impacts of policies and measures that have been instituted at the national level.[49]

The U.S. is overdue in submitting its *Fifth National Communication*[50] to the UNFCCC, which was due January 1, 2010. Currently, this communication includes summary information from the 1990-2007 Inventory; it does not incorporate the latest 2008 inventory, just published. As of May 2010, the period of public review of the final document ended, and after incorporation of corrections, the U.S. State Department will submit the *Fifth National Communication* to the UNFCCC.

[xiv] Other significant sources include production and consumption of lime, ammonia, urea, limestone, dolomite, soda ash, titanium dioxide, carbon dioxide, phosphoric acid, ferroalloys, silicon carbide, aluminum, petrochemicals, lead and zinc.

3. GHG INVENTORIES IN CHINA

As a developing country, China includes its national GHG inventory within its *National Communication on Climate Change* to the UNFCCC. China submitted its *Initial National Communication* to the UNFCCC Secretariat in 2004, providing an emissions inventory for the year 1994, and is currently preparing its *Second National Communication*[51] with an emissions inventory for the year 2005. Non-Annex 1 Parties are eligible for financial assistance by the Global Environment Facility (GEF) to prepare these communications, and there is no specified interval for completion of the subsequent inventories after the initial inventory has been submitted.[xv] Developing countries have no requirements to calculate emissions for the intervening years between submissions of their national communications to the UNFCCC.

The inventories prepared by Non-Annex 1 countries also follow the IPCC guidelines, although there is no *Common Reporting Format* nor a requirement to disaggregate extensively within categories. Overall, countries are encouraged but not required to provide a similar level of detail to that expected from Annex 1 countries. National communications by non-Annex 1 Parties are compiled by the Climate Change Secretariat, but not subjected to the same in-depth review that is applied to Annex 1 Parties. There is however, a *Consultative Group of Experts on National Communications from Parties* not included in Annex I to the Convention (CGE), that assists parties in preparing their national communications through feedback and capacity building.[52]

GHG Inventory Process in China

Similar to many developing countries, China does not have a permanent institutional structure for carrying out inventories of greenhouse gas emissions, and GHG emissions data are not yet collected at regular intervals. However, in 2010, China committed to report its national GHG emissions by sources and uptake by sinks on a biennial basis (i.e., every two years).

The National Development Reform Commission (NDRC), which reports to the State Council of China, is the lead agency of the National Leading Group to Address Climate Change, a consortium of 20 agencies.[53] The NDRC has the task of estimating China's aggregate energy-related GHG emissions for the year 2005 as an input to China's *Second National Communication to the UNFCCC*. The NDRC's estimate will be based on the data provided by the National Bureau of Statistics (NBS). As part of this effort, China is establishing a GHG inventory information management system that will bring together five sub-sectoral inventories in a greenhouse gas emissions database, and will define the procedures, data structures and standards for the specific government departments that will carry out the data gathering for subsequent inventories.[54] One such department is the Ministry of Environmental Protection (MEP), which monitors energy-related air pollution, collects data on ambient air quality for criteria pollutants, and may become involved in direct CO_2 monitoring.

Data Collection by the National Bureau of Statistics

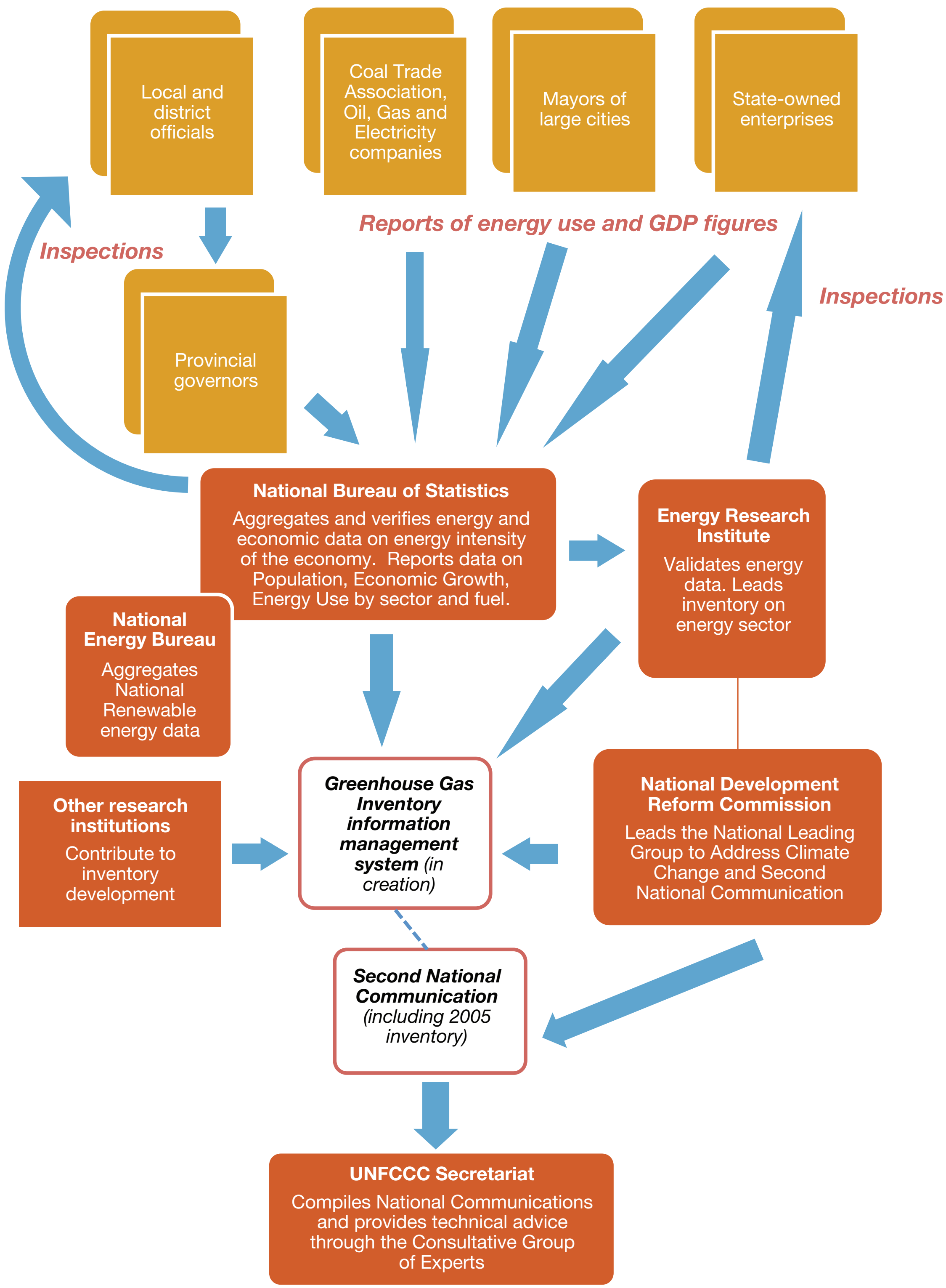
In China, the principal responsibility for collecting and analyzing data on energy supply and use falls with the NBS, with some functions also being given to the recently formed National Energy Bureau. The NBS publishes these data annually in the *Energy Statistics Yearbook*, which provides energy supply data by region and sector at the national and provincial level.

Figure 3 illustrates the institutional structure of the system used in China for collecting, aggregating, and analyzing energy data to produce the GHG inventory for the *Second National Communication* to the UNFCCC.

The NBS collects and aggregates energy supply data by fuel type from the large, mostly state-owned companies that dominate the Chinese commercial markets for oil, natural gas, and electricity. For example, the crude oil consumption is calculated from a monthly production report, seasonal energy consumption report and a customs imports and exports report.[55] These data are relatively easy to collect as they are easily tracked through pipe shipments and port records, and because there are a limited number of enterprises that control the Chinese market in the oil, natural gas, and electricity sectors.

[xv] The Convention specifies that the initial inventory must be submitted within three years of entry into force of the Convention for each Party

Figure 3 – Energy data collection and GHG inventory system in China



Coal supply data is more complicated. Large, state-owned companies provide about one-third of coal supplied to the Chinese domestic market. Another third is marketed by companies operating largely at provincial scale. The remainder is provided by many small, local and private companies. The China Coal Trade & Development Association reports regional coal sales; NBS acquires consumption data from the national and provincial level companies, but production by the large number of small and local companies remains harder to track. In the last few years, the Chinese government has been implementing an aggressive policy to close down small, illegal mines and to consolidate operations in the coal industry, which has led to a dramatic reduction in the number of producing facilities and to an improvement in the completeness of coal-industry data. Nonetheless, some amount of local coal consumption is unaccounted for as coal shortages sometimes cause a surge of coal sales in the informal sector. Unfortunately, there are no good statistics on the use of coal in the informal sector, which includes many rural individuals, families, and local industries that purchase coal on the local, informal market. However, the bulk of China's coal use occurs in the formal sector of the economy, burned for electricity generation and other industrial end-uses.

Although the NBS has a high degree of confidence in this reporting system, it nonetheless annually sends out teams of experts to sit with the staff of selected local bureaus of statistics or other data suppliers to cross-check their records for inconsistencies or errors. Concerns about the energy data from China go back to a period between 1998 and 2001 when the NBS appeared to have mis-reported energy consumption due to an under-reporting of coal production.[56] The NBS subsequently corrected the energy consumption data for various years. Today, data quality analysis and revision is carried out several times each year.[57]

The NBS is also in charge of collecting statistics on transportation, transportation energy consumption, and residential energy consumption. This last quantity is estimated from spot checks and reported yearly. Other entities that contribute to reporting are the Ministry of Railways, the Civil Aviation Administration of China and the Ministry of Housing and Urban-Rural Development.[58] Overall, energy consumption data are less complete and less accurate than energy supply data, especially for the manufacturing sector, the residential sector, and small enterprises.

Discrepancies between national level estimates and provincial estimates arise with some regularity in China. Most experts agree that national level data are more reliable than the disaggregated provincial or sectoral data, as there are fewer cross-checks on the provincial and sectoral data. There is a general consensus among the experts surveyed for this report that these discrepancies are far smaller now than before. Similarly, 3-year average annual data are more reliable than quarterly data. As in the United States, the NBS sources data from different entities to perform cross checks and revises its own datasets with new information. The NBS sends energy data reports to the National People's Congress, which could, in principle, perform checks on the reliability of the data.

Reporting of Energy Intensity, Carbon Intensity and Renewable Energy

Although the emissions inventory for the Second National Communication is one driver for collection of activity data concerning energy and industry in China, the primary demand for this data is largely driven by the overall goals established in the 11th Five-Year Plan (2006-2010), and more specifically, by the *National Climate Change Program* of 2007. The following goals are related to the energy and industrial sectors:[59]

- Reduce energy intensity (energy consumption per unit of GDP) by 20% in 2010 compared to 2005 levels and reduce emissions of main pollutants by 10%.
- Increase the use of renewable energy to 10% of primary energy consumption by 2010.
- A target for commercial nuclear power to reach 5% of installed capacity by 2020.
- Maintain N_2O emissions stable in 2010 relative to 2005 levels.

The pledges by China in Copenhagen represent both a reaffirmation and a more ambitious commitment of the targets stated above. The target for reductions in carbon intensity of 40 to 45% by 2020 replaces China's previous target for energy intensity. The target to increase the share of non-fossil fuels in primary energy consumption to 15% by 2020 is a reaffirmation of the 10% target for renewable energy and 5% target for nuclear power for 2020.

A wide range of policies, programs and regulations has been instituted by the Chinese government to meet these goals. Each program has data collection

Policies and programs to meet climate and energy related goals of the 11th Five-Year Plan (2006-2010)[60, 61]

- Energy intensity targets for major industrial processes, like aluminum, steel, cement and ethylene production; and also targets allocated to provinces, localities and State-owned enterprises.
- Renewable energy portfolio standard, with targets allocated to power companies and provinces (with emphasis on wind, solar, biomass, geothermal and hydropower supplies);
- A national target to improve power sector efficiency by decommissioning small, inefficient power stations and accelerating deployment of improved coal combustion technologies.
- A vigorous program for exploiting coal-bed methane, including the installation of 10 coal-bed methane pipelines by the end of 2010.
- A target for energy savings by China's largest enterprises of approximately 100 million tons of coal-equivalent to be saved during 2006-2010 through the Thousand Enterprise Program, which negotiates commitments of energy efficiency and best practices between companies and the government.
- A program to apply National Building Codes and building energy efficiency programs to all new buildings and to impose higher standards on buildings in major cities (e.g., Beijing, Shanghai, etc.).
- New energy performance standards and labeling requirements for consumer appliances.
- Fuel economy standards and taxes for motor vehicles and for gasoline consumption.
- Expansion of the railway system to 100,000 km in 2020, up from 78,000 km in 2007

demands for performance assessment that contribute to the overall collection of energy data in China.

Energy intensity

With the energy intensity targets, China expanded the systems for collecting and reporting data on energy supply and use at the provincial, municipal, and village or district levels. Governors, mayors, and other local political officials collect these data from local bureaus of statistics operating at the provincial and municipal level, and then transfer these data to the NBS. Many of the provincial officials sign annual contracts with the central government that contain targets for economic growth and development of their respective territories and must report energy, GDP, and other data under the terms of their contracts. In 2009-2010, new performance targets were added that focus on specific goals for reducing energy intensity in China's provinces and large cities. Since future promotions to more attractive jobs for local officials depend on fulfillment of these contracts, these officials will have a strong incentive to meet their targets and to ensure "good reports" from their local bureaus of statistics to the National Bureau of Statistics in Beijing. One might imagine that these 'incentives' could lead to over-reporting of intensity reductions. However, there are significant penalties for misreporting, falsification or concealment, including removal from one's job.[62]

Each spring, experts from the central government, including from NDRC's Energy Research Institute, are sent to visit the provinces. Their assignments are to review and validate the energy data prepared by the local statistical bureaus, and to conduct on-site inspections and spot-checks of major energy-using facilities.[63] Enterprises participating in the *Thousand Enterprise Program*, which have annual targets for energy intensity, go through detailed inspections of their performance and they are rated on that performance. These inspections can reach more than 10% of key enterprises annually. In the future, the inspections could include carbon accounting at the enterprise level.[64] These are valuable quality control procedures, given that the imperative to meet targets could be an incentive to local officials to underreport energy consumption and overreport production, among others. Recent analyses suggest that local governments and companies are indeed held accountable when they fail to achieve their targets.[65]

Energy intensity measures require annual economic output data in terms of Gross Domestic Product (GDP). The NBS is responsible for calculating GDP data and issues a national estimate, but there are also provincial estimates reported upstream. Although GDP statistics have a longer history in China, there are persistent sources of errors. A number of China specialists question the accuracy of historical GDP estimates, especially with respect to the valuation of transactions in the services sector of the economy.

Given the incentives-based policy architecture in China, there is a tendency to over-report GDP at the provincial level. The estimate of economic activity at the national level undergoes iterative corrections as the NBS revises its annual GDP data four times.

It is unclear if the energy intensity measures are revised simultaneously. Recently, the 2008 energy consumption and 2007 GDP data were revised following the *Second National Economic Census* for that same year. Though questions remain about historical GDP estimates, most Chinese experts expressed increasing confidence in the most recent revisions and a willingness to work with their American counterparts to further improve the reporting of economic data and analyses.

Renewable energy

The proportion of renewable energy in China's energy matrix is tracked in reports sent by power companies and provinces referring to the targets they each assume. The National Energy Bureau aggregates this data at the national level.[66] Renewable energy capacity data are more readily available but they have proved to be a less reliable metric than generation data. The Chinese government has already identified this problem and has reportedly changed the indicators to be measured.

It is easier to evaluate compliance with the renewable energy target than to determine the impact of these targets on GHG emissions, because the latter depends on the quantity and type of fuel that is displaced. However, by making some reasonable assumptions about the fuel supply mix that would likely have existed in the absence of these targets, the emissions impact can be estimated.

Carbon intensity

The transition from energy intensity to carbon intensity data is not a difficult task in the energy and industrial sector if the activity data are accurate and the emission factors are adequately defined. This task is now being carried out for the *Second National Communication*. In addition, China is reportedly considering direct CO_2 measurement at some facilities and is reportedly looking at the EPA reporting rule as a model for this. Another alternative under consideration might involve the use of a continuous emission-monitoring (CEM) system at coal-fired power plants.[67]

The baseline for China's carbon intensity target is still missing, pending its 2005 emissions inventory. If China achieves its target, the impact of the carbon intensity target on absolute carbon emissions will depend upon the patterns of economic growth. The reduction in emissions from a Business-As-Usual scenario will be larger if economic growth is smaller, given that lower absolute emissions will be needed to achieve the target.

China's *Initial National Communication on Climate Change*

China submitted its *Initial National Communication on Climate Change* in October 2004.[68] It was prepared by the National Coordination Committee on Climate Change, working under the NDRC with a broad range of officials, experts, scientists, and other academicians. This *Initial National Communication* was approved by the State Council and then submitted to the UNFCCC Secretariat. The estimates of GHG emissions contained in this inventory were based on data for 1994 and covered anthropogenic emissions from the energy, industrial, agricultural, waste, and Land Use, Land use Change and Forestry (LULUCF) sectors. The U.S. government provided some assistance to China in this process.

The principal emissions covered in China's *Initial National Communication* were carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). This report followed the IPCC *Revised 1996 Guidelines*[69] and the *IPCC Good Practice Guidance on Uncertainty*.[70] In 1994, CO_2 represented 73.1% of total Chinese emissions. Methane (CH_4) emissions accounted for a significant 19.7%, and nitrous oxide (N_2O) for 7.2% in CO_2 equivalent terms. Non-CO_2 emissions were proportionally more significant than in the U.S.[71] China's total net emissions in 1994 were estimated to be approximately 3.7 billion tons of CO_2-equivalent emissions.

Table 4 - 1994 net GHG emissions in China (Extracted from Initial National Communication)[72]

Gas	Emissions ($MTCO_2e$)
CO_2	2665.9
CH_4	720.0
N_2O	263.5
Total	**3649.5**

The 1994 inventory used both reference and sectoral approaches (See Appendix 1) for estimating CO_2 emissions from fuel combustion. However, the details of the two approaches were not provided. Depending on the availability of data and emission factors, China used Tier 1, Tier 2, or Tier 3 methods to estimate emissions from different sources. (See Appendix 1 for definitions of these Tiers.) For example, Tier 3 methods were used for the emission estimates of key state-owned coal mines, whereas Tier 2 was employed for the rest of the mines. The emission factors for industrial processes were derived from knowledge of particular factors of production in China, such as the impact of magnesium oxide content in clinker production for cement. For this purpose, the agencies preparing the inventories conducted many sample surveys, measurements and experiments. Among others, there were surveys of industrial boilers, coal quality analysis, methane emissions from mines, clinker sample measurements and surveys of cement, adipic acid and lime enterprises.[73]

Table 5 summarizes China's GHG emissions by sector in 1994. Emissions in the energy sector accounted for 82.4% of total emissions, whereas industrial process emissions accounted for 7.7%.

China indicated that it chose the key emission sources for this inventory based on UNFCCC guidelines. As a result, some industrial and energy sources were absent from the emission tables: CO_2 emissions from the non-energy uses of fossil fuels in ammonia production and urea consumption, and in aluminum production; N_2O emissions from nitric acid production; CH_4 from petroleum systems; HFCs, PFCs and SF_6 emissions.[75]

China's *Second National Communication*

The preparation of China's *Second National Communication* involves a multi-ministry effort led by the Department of Climate Change within the NDRC. International support for this effort comes from the National Communications Support Programme of the Global Environment Facility (GEF), and is delivered through the United Nations Development Programme.[76] The U.S. EPA signed a Memorandum of Cooperation with the NDRC in order to help China

Table 5: 1994 emissions by sector in China, in $MTCO_2e$ (Adapted from Initial National Communication)[74]

Source and Sink Categories	CO_2	CH_4	N_2O
All energy	**2795.5**	**196.8**	**15.5**
Fossil fuel combustion	2795.5		15.5
– Energy and transformation industries	*961.7*		*15.5*
– Industry	*1223.0*		
– Transport	*165.6*		
– Commercial and Institutional	*76.6*		
– Residential	*271.7*		
– Others (building industry & Agriculture)	*96.9*		
Biomass burned for energy		45.1	
Fugitive Fuel Emissions		151.7	
– Oil and natural gas systems		*2.6*	
– Coal mining		*149.1*	
Industrial processes[xvi]	**278.0**		**4.7**
Agriculture		**361.1**	**243.7**
Others (Waste disposal)		**162.1**	
Land use change and forestry (sinks)	-407.5		
Total (Net emissions per year)	**2666.0**	**720.0**	**263.5**

[xvi] Emissions from the production of cement, lime, iron and steel, and calcium carbide, as well as N_2O emissions associated with the production of adipic acid and nylon manufacturing.

build the capacity needed to prepare the inventory.[77] China's *Second National Communication* will develop a more comprehensive GHG inventory than was possible for the *Initial National Communication*.[78] In addition, the geographic coverage of the inventory will extend to the Hong Kong and Macao Special Administrative Regions (SAR), which were not included in the first assessment.[79]

The Inventory for the *Second National Communication* includes several subprojects led by different institutions. The Energy Research Institute of NDRC is responsible for the inventory of emissions from the energy sector, as well as the GHG inventory database and the GHG emission forecast methodology. The inventory of GHG emissions from industrial processes is the responsibility of the Low Carbon Research Center of Tsinghua University.[80] The NDRC is also working with experts from the International Energy Agency, and the Lawrence Berkeley National Laboratory, among other institutions.

A substantial amount of research on energy-related emissions is being undertaken as part of the inventory. One research sub-project involves the construction of an energy balance for the entire country, with data collected from production, supply, and consumption of all energy sources in China. Data on the non-energy use of fossil fuels will be included, filling a gap in the previous inventory. Another sub-project will develop improved emission factors for various types of coal produced and used in China, especially for boilers used in utilities and industries, and for N_2O and CH_4 emissions from fuel combustion. The inventory will also include calculations of emission factors and surveys of fugitive emissions of methane from coal mining as well as from oil and natural gas supply and distribution systems.[81] The inventory for the *Second National Communication* will also benefit from emissions estimates for three additional gases not covered in the 1994 inventory, i.e., HFCs, PFCs, and SF_6, as well as from new activity data and emission factors for various industrial processes.[82]

With these additions, the 2005 inventory will be much more comprehensive and thus more comparable to inventories from Annex 1 countries. By providing a much more precise estimate of China's GHG emissions in 2005, this new inventory will reduce the uncertainties and help to fill in the large gap in official emissions data since 1994.

With support at the highest political levels and substantial resources being devoted to this task, China anticipates completion of its *Second National Communication* at the end of 2011.[83] Nonetheless, many challenges remain. Developing complete statistical data sets that will cover scores of industries and thousands of factories remains a difficult task. The data limitations make it particularly hard to complete the inventory of emissions from industrial processes. In addition, the calculation and validation of appropriate emissions factors is complicated by significant differences in industrial practices, resource quality, and end-user behaviors, which vary widely from region-to-region and sector-to-sector. The GEF reported that the inventory was 25-50% complete as of October 2009.[84]

At the moment, there are no preliminary results available for the inventory. Official sources are reticent to release preliminary data as the results are considered highly political, and carbon intensity targets will most likely be embedded into the upcoming 12th Five-Year Plan.

4. UNCERTAINTY IN EMISSIONS INVENTORIES

It is not possible to calculate the annual GHG emissions of an entire country with 100% accuracy. Uncertainties are unavoidable in national GHG inventories. Despite the best efforts of national experts to apply internationally agreed methodologies with diligence and care, national GHG inventories may under-report or over-estimate actual levels of GHG emissions. To address this situation, the international community relies on *analyses of uncertainty* to gauge the credibility and accuracy of national GHG inventories and to identify aspects of the inventory in need of improvement.[85] The sources of uncertainty should be identified and the magnitudes of uncertainty surrounding each type of emissions calculation are estimated as part of the uncertainty analysis. The results of an uncertainty analysis describe the boundaries of a statistical confidence interval around the estimated level of GHG emissions. These boundaries are typically expressed as a range or a percentage of the estimated value.[xvii] Alternatively, if the characteristics of the underlying probability distribution are known to the analyst, uncertainty may be expressed in terms of the standard deviation (often referred to as the *sigma*) of that underlying distribution.

Annex 1 countries are already required to submit uncertainty analyses to the UN Climate Change Secretariat as part of their national GHG inventories; these types of analyses are not currently required for Non-Annex 1 Parties to the Climate Convention (i.e., developing countries). But implementing enhanced analyses of uncertainty could be very useful for increasing the value of the inventory process in both industrialized and developing countries.

In a recent study, the U.S. National Research Council indicated that typical uncertainties in annual estimates of CO_2 emissions from fuel consumption in Annex 1 countries are in the range -5% to +5%. The uncertainty in CO_2 emissions estimates from fuel consumption in developing countries can be even larger, typically from -10% to +10%.[86] This reflects the fact that developing countries often have less experience with GHG emissions inventories, as well as more limited institutional capacity to measure energy use and calculate emissions, compared to their industrialized country counterparts. However, the quality of emissions inventories in some key developing countries could be improved dramatically with a relatively small investment.[87] To reduce uncertainty in assessing emission reduction claims, Matthias Jonas, et al.[88] suggest assessing emission reductions over a series of years and not only during one year periods. In addition, Jonas et al., suggest that it is important identify emissions sources with low uncertainty but substantial magnitude, in order to focus policy attention on opportunities to achieve significant emissions reductions.

Uncertainty can be introduced into national inventories in many sectors and from a number of directions. Energy-related emissions of CO_2, have a relatively low uncertainty range compared to the uncertainty in estimates for emissions arising in other sectors, including the industrial process, agriculture, waste and forestry sectors.[89] However, in the case of CO_2 emissions from fossil fuel use, where the quantity of CO_2 emitted from combustion is calculated as a function of the amount of fuel consumed, the fraction of the fuel that is oxidized, and the carbon content of the fuel that is burned, the primary source of uncertainty lies in the quality of estimates used for the amount of each fuel that is burned. Secondary sources of uncertainty may arise from regional variability in the carbon content of coal, oil, natural gas and other fuels along with variations in the combustion efficiency of different energy end-use technologies.

In the case of GHG emissions calculations that extrapolate from direct measurements of combustion processes, these estimates are subject to instrumental "drift" and to errors introduced by the data-recording equipment. Calculations that are based on end-user or supplier surveys are subject to biases in survey design as well as to "skew" or distortion in the selection of the survey sample that could lead to an unrepresentative sample of the underlying population of energy consumers. To add a further complication, in some cases economic incentives or the perception of personal and professional risks may encourage under- or over-reporting.

[xvii] For example, the analyst might conclude with 95% confidence that annual energy-related emissions of CO_2 in Country X were 100 metric tonnes in 2005, with an error margin of, say, -2% to +5%. This would mean that the analyst thought there was a 95% probability that the actual CO_2 emissions of Country X in 2005 were between 98 metric tonnes of CO_2 and 105 metric tonnes of CO_2.

Table 6: Uncertainty in U.S. GHG emissions 1990-2008 (95% confidence interval)[90]

Gas	2008 emissions estimate ($MTCO_2e$)	Lower bound of uncertainty range	Upper bound of uncertainty range
CO_2	5920.8	-2%	5%
CH_4	567.1	-11%	17%
N_2O	314.3	-11%	46%
PFC, HFC & SF_6	146.7	-2%	11%
Total	**6949.0**	**-1% (6887.2)**	**6% (7117.5)**
Net emissions (sources and sinks)	**6008.6**	**-2% (5898.9)**	**7% (6174.1)**

In order to understand and minimize uncertainty in of national GHG emissions inventories, it would be beneficial for each country to implement or increase spot-checks, and audits of reporting entities and cross-checks of data to ensure data quality. Implementing such procedures can help to identify those elements of the emissions estimation process that are in need of strengthening or improved design.

Uncertainty in U.S. GHG Inventories

The EPA calculated the uncertainty of its 2008 national GHG inventory, applying the IPCC Tier 2 methodology.[91] The Agency estimated with 95% confidence that annual U.S. net GHG emissions in 2008 were 6008.6 $MTCO_2e$, with an overall uncertainty of -2% to +7%.[xviii] When uncertainty is asymmetrical, as in this example, that indicates the actual value could be underestimated by as much as 7%, but is unlikely to be more than 2% below the stated or expected value. In the U.S. case for 2008, this suggests that there is a 95% probability that actual U.S. net GHG emissions in 2008 were greater than 5888 $MTCO_2e$ and less than 6429 $MTCO_2e$ (See Table 6) Gregg et al., applying a different statistical approach to an earlier U.S. GHG inventory, estimated that the two sigma uncertainty range was narrower, approximately 3 to 5% of total emissions.[92]

National GHG emissions inventories are complex; many kinds of activities and entities contribute to the uncertainty in estimated emissions. The EPA strives to be as comprehensive as possible but notes that not all sources of GHG emissions could be included in the *U.S. 2008 Greenhouse Gas Inventory*. Some identified sources of GHG emissions were ignored because of limitations in the available data and others were left out because these sources were not fully characterized.[xix] Ignoring these emissions and leaving them out of the uncertainty analysis constrains the value of this analysis. However, the Agency believes that these factors, in aggregate, have a relatively small effect on the total and do not materially alter the outcome.[93]

In addition, a statistically significant uncertainty surrounds certain aspects of estimated U.S. methane (CH_4) emissions. This uncertainty mainly arises from (1) unmonitored emissions of coal-bed methane from surface mining of coal; (2) methane emissions from post-mining activities and (3) fugitive emissions of methane from pipelines and gate stations in the natural gas distribution systems.[94] In many older U.S. cities, aging distribution manifolds allow small but significant amounts of methane leakage to occur; this leakage is not currently accounted for in the U.S. national GHG inventory.

Furthermore, disparities in data collection among regions across the United States continue to occur. In particular, the United States does not collect energy data with the same degree of detail concerning energy use in U.S. territories as it does in U.S. states.[95]

The UNFCCC commissioned an expert review of the *U.S. National Greenhouse Gas Inventory 1990-*

[xviii] This total is slightly lower from the one in Table 1 because some emission sources were not assessed for uncertainty.

[xix] The excluded sources were: CO_2 from burning in coal deposits and waste piles, enhanced oil recovery, natural gas processing, "unaccounted for" natural gas, shale oil production, graphite consumption in ferroalloy and steel production, metal production and non-hazardous industrial waste combustion; CH_4 from calcium carbide and silicon carbide production, production of carbides other than silicon carbide, and petroleum coke production; N_2O from caprolactam production and acrylonitrile production; SF_6 from aluminum fluxing and degassing, production/leakage/breakage of soundproofed double-glazed windows, production/leakage/dismantling of radar, tracer and night vision equipment, applications in sports shoes, tires, and tennis balls, applications to trace leakage of pressure vessels and used as a tracer gas in open air, and miscellaneous SF_6 uses.

2007[96] as it does with all Annex 1 inventories.[97] This review concluded that the U.S. inventory has improved significantly in terms of transparency and that it generally follows the UNFCCC *Reporting Guidelines*. However, it found that the U.S. GHG inventory continued to use a somewhat dated set of approaches and emissions factors for fossil fuels. The factors used for estimating CO_2 emissions from coal were found to be in need of updating. In addition, the U.S. continued to use lower-tier methods for estimating emissions from stationary sources, instead of the more reliable, higher-tier methods recommended by the IPCC. The estimated uncertainty in the multi-year trend for total GHG emissions during the period from 1990 to 2005 was found to be fairly high, in the range of -12 to +23%.[98] The UNFCCC Expert Review team recommended that the United States make the achievement of consistency in reported time-series data a topic to be addressed in future inventories, along with a focus on sources of persistent uncertainty.[99]

In preparing the most recent U.S. national GHG inventory, the EPA observed that uncertainties in activity data, carbon content of fuels and products, as well as the efficiency of oxidation of carbon, have a relatively small impact on emission estimates. There is more uncertainty in the allocation of fuels to different sectors, due to the deregulation of natural gas and electricity markets, the limited data collection in U.S. territories, the allocation of International Bunker Fuels and discrepancies in estimates of fuel consumption by vehicle type in the transportation sector.[100]

Uncertainty in China's GHG Inventories

Similarly, there are many recognized sources of uncertainty in China's national GHG inventory. Many of the emissions calculations in the GHG inventory that were incorporated into China's *Initial National Communication* were implemented using the generic default values for emissions factors from the Tier 1 methodologies of the IPCC *Revised 1996 Guidelines*. In an effort to increase accuracy and minimize uncertainty, the Chinese team preparing the *Initial National Communication* supplemented official government statistics with sample surveys of energy use and with on-site interviews of government officials. Some parts of the activity data for 1994 were derived from expert judgment, however, rather than from direct measurement or from statistical surveys. Even with these additions, the 1994 inventory failed to account for some important energy-related emissions. For example, China is known to have had substantial underground coal-seam fires for many years. Such fires can generate substantial emissions of CO_2 and CH_4.[xx, 101] However, only fugitive CH_4 emissions from

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[xx] These emissions are estimated to amount to 54 $MTCO_2e$ per year.

coal mining were reported in the 1994 inventory. As a consequence, China's aggregate emissions for 1994 may have been under-reported.

Despite steps taken in the past to improve emissions reporting, significant uncertainty in China's national GHG inventory persists today. This is largely due to difficulties in getting the data for some key activities as well as insufficient time span and coverage of the sample surveys needed to produce a fully representative sample of the underlying distributions.[102] For example, it remains unclear how emissions from underground coal fires are being measured today, and whether these emissions will be reported comprehensively in the 2005 national GHG inventory that is currently being prepared as part of China's *Second National Communication*.

Several studies have attempted to quantify the uncertainty in China's estimated GHG emissions. Gregg et al. reviewed emissions data by sector and by region for both China and the United States.[103] They analyzed the emissions data published by both governments and compared official data with monthly time series data derived from proprietary data collected in each country. Their analysis suggested that the two sigma uncertainty on total national GHG emissions for China could be as high as 15-20%. Akimoto et al., in an earlier study, noted that it was not possible to independently evaluate the uncertainty in Chinese data on energy-related emissions, although satellite measurements of N_2O suggested an underreporting of coal consumption between 1996 and 2003.[104] (These errors in coal production data were subsequently corrected by the NBS.) Among the experts interviewed for this study, a rough consensus suggests that the uncertainty in estimates of China's coal use could be on the order of 5-10%.

China's *Second National Communication* will include an uncertainty analysis for each of the inventory categories, and will follow the IPCC uncertainty guidelines.[105] For this new inventory, uncertainty should be reduced considerably due to the increased breadth of the inventory, the more detailed survey and analysis of activity data, as well as the use of emission factors that reflect the actual circumstances "on the ground" in China.

Notwithstanding the improvements that have been made in emissions measurement, monitoring, and reporting in both the United States and China, uncertainties will remain in the national GHG inventories of both countries. A number of opportunities are emerging today that suggest ways to enhance technical cooperation between the two nations, drawing on the historical strengths of each one, and offering new ways to improve the overall quality and usefulness of these increasingly important reports.

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5. COMPARISON OF INVENTORY PROCESSES

Strengths and Challenges in the U.S. Inventory Process

The primary approach used in the United States to collect data on energy use and energy-related emissions of greenhouse gases involves the use of statistical surveys. On the supply side, the Energy Information Administration surveys the universe of fuel suppliers and mid-stream consumers, such as refineries. In addition, it conducts a periodic sampling of a representative sub-set of energy end-use consumers in various categories. The principal strengths of the U.S. approach to data collection, aggregation, and reporting lie in the scientific design of these surveys, their coverage of almost 100% of energy suppliers, and the careful design of consumer surveys. Taken together, these surveys provide a generally accurate and representative picture of the behavior of much-larger populations that are never queried.

Each survey has specific validation rules to check for general patterns of consistency in the reported data. The survey designers assume that energy suppliers and consumers have no incentive to under-report or misrepresent the data describing their sales and purchases and will respond accurately if promised individual anonymity. End-use consumer surveys query the consumer about his or her use of fuels and electricity, and may employ a combination of self-reporting questionnaires and in-person interviews. Although there is no parallel system of personal responsibility in the United States that is comparable to that found in the Chinese system, the EIA assumes that fuel and electricity suppliers will respond accurately to the supply-side questionnaires.

Quality assurance, quality control, and uncertainty analysis are embedded in the U.S. inventory process at the EPA. There are several features of these processes that increase the reliability of the resulting emissions estimates, such as detailed and standardized procedures for record keeping, expert review, re-calculations, feedback loops for corrective actions, and coordination among agencies. The track record of inventories since 1997 has shown that the capacity of EPA to conduct the annual GHG inventory is improving steadily.

Despite the best efforts of the EIA, EPA, and other agencies, uncertainties remain concerning some elements of U.S. emissions data. There is persistent uncertainty about non-energy uses of fuels in the industrial sector (e.g., in the manufacture of plastics and fertilizers). There is no longer a survey on the production and use of coal tar. The available data on asphalt production and use are incomplete. Emission factors for coal need refinement. The quantities used and emission factors applied to liquefied petroleum gases are not well characterized and thus remain difficult to estimate; persistent uncertainties remain throughout the supply chain. In addition, the data on leakage in local distribution systems for natural gas are spotty and incomplete. Data on the distribution and disposition of domestic bunker fuels, both in the air transport and in the water transport sectors, is neither complete nor transparent.

The principal strengths of the U.S. approach to data collection, aggregation, and reporting lie in the scientific design of these surveys, their coverage of almost 100% of energy suppliers, and the careful design of consumer surveys.

However, most observers agree that none of these errors is likely to affect the overall trend in annual energy-related GHG emissions to a significant extent. And, even in aggregate, they are unlikely to affect the total of U.S. energy-related GHG emissions by as much as 5%. Efforts are underway to improve the data collection and analysis concerning residential and commercial consumer behavior. In addition, DOE, DOT and EIA are developing improved instruments for collecting data on energy consumption in the transportation sector. Implementation of these measures should improve U.S. data on energy use and energy-related GHG emissions.

As there is no current U.S. policy in place requiring GHG emissions reductions, there has been little incentive to mis-represent emissions data. However, this may change once carbon emissions are regulated through caps, fees, taxes or other instruments. Once emission restrictions are in place, companies would have an incentive to under-report fuel consumption or over-report emission reductions, if doing so would allow them to avoid paying fees or to accumulate more emission allowances. Although there are statistical validation rules to detect “outliers” in the current EIA supply surveys, there are no auditing procedures for survey responses.

Some of these issues will be addressed by the new EPA mandatory reporting rule and the introduction

Table 7 – The U.S. and China GHG emissions inventory systems at a glance

	United States	China
Main strengths	- Deep experience with GHG inventories - Established institutional capacity - Transparency in methods - Almost universal coverage of energy supply surveys - Excellent tools for statistical analysis	- Personal and institutional accountability for sound data reporting - Audits and inspections to verify energy data - Good data collection for oil, gas, and electricity - Data collection driven by energy intensity targets and policy implementation
Main weaknesses	- Lack of auditing procedures and inspections for energy suppliers and emission sources - Lack of integration of data collection with any climate policy. - Reliance on self-reporting	- Low data collection capacity in many provinces - Little experience with emissions inventories - Relatively low transparency concerning metadata as well as data collection and methods of analysis - Lack of official emissions data since 1994
Reporting system on energy use	- Self reporting by energy suppliers. - Survey of sample of end-use consumers	- Reporting on energy use by local officials to provinces to NBS
Data verification systems	- Statistical validation rules for surveys - Trust in lack of incentives to misreport - Internal QA/QC systems - Comparison to EIA inventory - Expert and public review - UNFCCC review	- Audit and inspection process for provinces and enterprises - Data validation and cross checking by NBS - Revision and correction of past data by NBS - Revisions by National People's Congress - No UNFCCC consultation required for developing countries.
Main sources of uncertainty in energy and industrial sector emissions	- Non-energy use of fuels - Coal tar and asphalt - LPGs - Coal emissions factors - Natural Gas systems - Domestic bunker fuels - Methane and nitrous oxide emissions - SF_6 leaks from electrical transmission equipment - U.S. territories data	- Coal from small mines - Loss of coal in transit - Underground coal fires - Small enterprises - Subsistence energy use by rural communities - Sectoral consumption estimates
Overall uncertainty of emissions inventory	- EPA estimate for 2008 (-2 to 7%) - Gregg et al. estimate (3-5% for fossil fuel combustion and cement manufacturing) - UNFCCC multi-year trend analysis (-12 -+23%)	- No comprehensive estimates for all emissions - Gregg et al. (+15 to 20% for fossil fuel combustion and cement manufacturing) - Uncertainty in forthcoming inventory unknown but significant improvements expected
Expected improvements	- EPA Mandatory reporting rule for emissions reporting with EPA data verification will result in disclosure of facility data starting in mid-2011. - Increased use of Continuous Emissions Monitoring systems. - Linkage of GHG inventory with possible federal climate legislation	- 2005 inventory with expected improvements in coverage, emission factors, surveys and activity data - GHG inventory information management system for biennial reporting - Wider implementation of Open Government Information Regulation - Continued closure of small and inefficient coal mines - Expand from focus on energy intensity reporting with the addition of carbon intensity reporting

of requirements to install systems of continuous emissions monitoring (CEM) of CO_2 at some facilities. However, it is unclear if these emissions measurements will be cross-checked against the energy supply data provided to EIA and how these measurements may be used to verify aspects of the national GHG inventories. The EPA has indicated that it will follow the model of the Clean Air Act, validating facility reports but not requiring verification of these reports by an independent third party.[106]

The current 2008 U.S. *National GHG inventory* is a good indicator of greenhouse gas emissions at the national and sectoral level. It provides a good baseline with which to calibrate the U.S. emission reductions pledged in Copenhagen. With the implementation of EPA's new mandatory reporting rule, the U.S. should be able to track emissions from high-emitting enterprises (as the Chinese will do in their *Thousand Enterprise Program*), although the current quality assurance and quality control systems for emissions reporting will need to be improved to prevent misreporting and fraud once the new EPA mandatory reporting rule has gone into effect. Spot-checking, inspections, and cross-checking with other data sources will become much more important, once emissions are regulated and carbon becomes a commodity with a market price.

Strengths and Challenges in China's Inventory Process

The principal strength of China's data collection, aggregation, and reporting process is the focus on personal and institutional accountability. By linking the career prospects of local and provincial officials to their success in fulfilling their annual performance contracts and in reporting the results to the central government, China sends a clear signal to these officials of the importance the government places on its energy intensity targets. In the case of the large state-owned enterprises that dominate the oil, coal, electricity, and natural gas supply sectors, the active intervention of their government owners ensures that these companies will respond to requests for information on the quantities consumed and the pricing of fuels and electricity that they sell. Although the incentives for officials may lead some of them towards skewing the data in favor of meeting their GDP and energy consumption targets, the audit and inspection processes conducted by NBS provide a corrective mechanism to detect these misreporting incidents. China is effective at collecting data from the nation's principal energy-intensive industries (e.g., oil and gas industries, coal-fired power plants, large coal mines and other large industrial enterprises). These are the enterprises where most GHG emissions are produced and where most opportunities for emission reductions lie. The current processes lead to data that are reliable at an aggregate level. Nonetheless, key gaps and uncertainties remain. These concern, for example, emissions from the production and use of coal from small mines in rural areas, the "loss" of coal in transit, underground coal fires, the activities of small- and medium-sized enterprises, and the sectoral allocation of residential, commercial and transportation energy consumption. There is also a gradient of data collection capacity, ranging from high levels of capacity in the Eastern industrialized provinces to less-developed capacities in the Western provinces. Clearly, China faces an enormous data collection challenge, complicated by a large population, a very rapid economic transition, a massive and continuing rural-to-urban migration, and changing energy consumption patterns.

> *The principal strength of China's data collection, aggregation, and reporting process is the focus on personal and institutional accountability. By linking the career prospects of local and provincial officials to their success in fulfilling their annual performance contracts and in reporting the results to the central government, China sends a clear signal to these officials of the importance the government places on its energy intensity targets.*

Despite these gaps and uncertainties, virtually all analysts queried for this study agree that the accuracy and completeness of China's energy data has improved markedly in the last decade and the degree of uncertainty has declined significantly. This trend toward continuous improvement is likely to continue in the years to come. Although any given year of data or individual figure for sectoral emissions may turn out to be reported in error for a brief period of time, the clear consensus among the interviewed experts was that the error would be found and corrected quickly; it would not be allowed to persist over a multi-year period, as was the case with the reported sudden drop in coal production in the late 1990s and early 2000s. In recent years, China has openly recognized the occasions when the country has failed to meet its energy intensity targets, acknowledging their shortcomings in achieving national targets.[107]

There remain significant issues in the minds of some of the analysts interviewed for this study concerning China's strictly limited publication of primary data on energy supply and use. Several experts expressed particular concern about the lack of information regarding the specific regional and sectoral origin of energy data, as well as about the methodologies and assumptions employed in data collection and analysis. Furthermore, many data are provided only in aggregate form and the procedures for aggregation are not clearly disclosed. This lack of transparency hinders independent statistical analyses by scientists. Increased transparency and sharing of information would be very beneficial to international understanding of China's situation.

In 2008 China published its first national regulation on freedom of information, called the *Open Government Information regulations (OGI)*. With this guidance, the Ministry of Environmental Protection has issued "measures for environmental information disclosure" that are applicable to various enterprises and departments.[108] These regulations have been implemented mostly to enforce pollution control measures and to force disclosure of pollution incidents, but could plausibly be extended in the future to disclosure of GHG emissions. The central government is already disclosing the performance of provinces in relation to their energy-intensity targets in order to promote competition among them. These encouraging signs indicate that transparency and public access to information are viewed by many at the most senior levels within the Chinese government as effective tools for advancing national economic and environmental goals. Even greater progress could be possible if the government would promote public reporting of the underlying provincial and local data on energy, economic activity, and GHG emissions.

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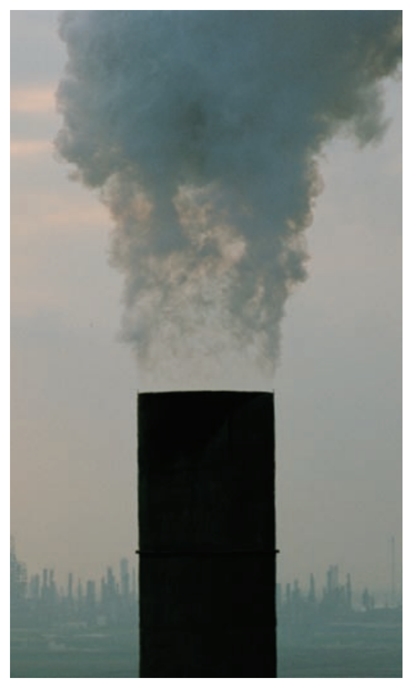

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6. INDEPENDENT ASSESSMENT OF NATIONAL GHG EMISSIONS

Alternative Sources of Emissions Data

In addition to the data that are forwarded to the UNFCCC through the National Communications submitted by Parties to the Convention, there are a number of additional resources of data that can be used to characterize global GHG emissions by sources and uptake by sinks. Two of the most prominent institutions that produce annual estimates of CO_2 emissions by countries are the International Energy Agency (IEA), an energy research organization operated under the auspices of the Organization for Economic Cooperation and Development (OECD), and the Carbon Dioxide Information and Analysis Center (CDIAC), a research center operated by the U.S. Department of Energy. These organizations primarily rely on the same set of nationally reported statistics. Although some international energy companies provide supplemental information to the IEA, these are not comprehensive datasets.

Differences in the assumptions, definitions and methods of calculation used by each institution are the source of the small discrepancies[xxi] in their resulting CO_2 emissions estimates.[109] For instance, the IEA 1994 estimate of CO_2 emissions from fuel combustion by China based on the "sectoral approach" was 0.5% lower than the official 1994 estimate included in China's *Initial National Communication*. For the U.S., there was a discrepancy of 0.2% between the higher IEA estimates and the values reported in the U.S. national GHG inventory for 2007.[110]

In the United States, the Energy Information Administration conducts a separate Greenhouse Gas Inventory for the United States every year. The agency received this mandate with the Energy Policy Act of 1992. (The official U.S. inventory that is transmitted to the UNFCCC is produced by the EPA.[xxii]) The EIA inventories are released earlier (in December for the emissions from the prior year) while the EPA inventories are released in April of the following year; this provides an initial estimate of emissions for each year.[111] Although this process represents a duplication of effort, the EIA's GHG inventory helps detect potential errors in the official U.S. national GHG inventory. Furthermore, the EIA also provides CO_2 emission estimates for other countries while the EPA makes estimates for non-CO_2 emissions worldwide.[112]

In addition, a number of promising approaches to estimating GHG emissions are being developed at various institutions. Researchers at Purdue University[113] have mapped fossil fuel CO_2 emissions in the contiguous United States for 2002 based on emissions from point sources (power plants, airports, industries), and mobile source emissions. The EDGAR project of the European Union[114] has done something similar at a coarser resolution (0.1° longitude by 0.1° latitude) on a global scale, using a geographic database of the locations of power plant and industrial facilities, road networks, shipping routes, human and animal population density, and agricultural land use, in combination with multiple sources of emissions data. These approaches give numbers that are only illustrative today but may have the potential to have practical applications in the future.

Also, many U.S. states have undertaken their own statewide inventories of greenhouse gases. As of August 2009, 46 states had each completed their inventory or had one in progress. The EPA indicates that there are slight discrepancies between state inventories and the U.S. national inventory because of small methodological differences and the difficulty of allocating some emissions at the state level.[115]

In China, there are no independent, comprehensive sources of data on energy supply and use outside of the official Chinese government sources described above. Some international energy companies as well as some trade associations have proprietary emissions data, but all datasets are limited in scope.

China is the country with the largest number of projects by the Clean Development Mechanism of

[xxi] Even though the discrepancies in CO_2 emissions estimates between IEA and the Government of China are small, differences in how each handles the conversion of fossil, nuclear, and renewable sources of energy (including hydro) into electricity leads to large differences in estimates of overall energy production and consumption. However, these differences bear no impact on the emissions calculations.

[xxii] It is important to clarify that the EPA estimates of U.S. energy-related emissions are based on energy data provided by the EIA, and that EPA does not use the direct emission estimates incorporated in the EIA inventory. Although the emissions estimation processes of the two agencies are similar, there are some significant methodological differences. One important difference is that EIA uses the latest Global Warming Potential (GWP) values from the IPCC's *Fourth Assessment Report*, whereas the EPA uses the GWP values published in the IPCC's *Second Assessment Report* as per UNFCCC guidance.

the Kyoto Protocol,[xxiii] 48.7% of the global total.[116] The issuance of certified emission reduction units (CERs) requires independent third-party verification to ensure that the claimed reductions are real, measurable, and lasting. Although the accounting for GHG emissions reductions from these projects follows a different methodology compared to that used in creating a national emissions inventory, these projects have helped to build national capacity in China related to the accounting for GHG emissions from industrial processes and renewable energy projects.

Corroboration of Emission Inventories through Atmospheric Measurements, Satellites and Models

The concentrations of CO_2 in the atmosphere worldwide are well established and are monitored closely with a network of surface monitoring stations, aircraft, balloons, and satellites. As of early 2010, the global mean CO_2 concentration was 388 parts per million, increasing on average 1.93 parts per million by volume (ppmv) every year between 1998 and 2008.[117,118] Although there are currently various satellites that measure carbon dioxide concentrations in the atmosphere,[xxiv] there is currently no reliable way to directly "see" the sources of the CO_2 emissions increases in the atmosphere as they are being released, and no way to verify in real time the magnitude of the fossil fuel emission sources from different areas of the world. The rapid mixing of CO_2 in the atmosphere and the difficulty of detecting the small increments of man-made emissions are some of the difficulties encountered in trying to link changes in atmospheric concentrations to emissions in a specific geographic area or nation.

However, the question remains whether there is an independent way to verify national emissions inventories by measuring atmospheric emissions with satellites and atmospheric measurements, identifying the geographic source of carbon dioxide emissions. One type of mathematical tool under development today that could potentially be used for this purpose in the future is called a *tracer-transport inverse* model. This type of model attempts to simulate mathematically the movement of air masses and currents throughout different regions of the world, based on observations of regional wind speeds and atmospheric measurements of CO_2 concentrations and other "tracer" compounds.[119, xxv]

In principle, by "inverting" the mathematical model, the modeler can "back-cast" the movement of emissions and trace back these emissions to their source. Currently available tracer-transport models contain large structural uncertainty and have great difficulty resolving the sources of emissions to regions on the scale of individual countries. The NRC report concludes that "although, in principle, tracer-transport inversion models could provide independent estimates of anthropogenic emissions from individual countries for timescales of several days to a year, uncertainties using state-of- the-art models are too high for this purpose."[120] Nonetheless, the NRC report suggests that, with more and better Earth-orbiting satellites taking a larger number of measurements, and with improved and expanded atmospheric data, the margin of error in estimates made with these models could be dramatically reduced. The NRC goes on to say that these improvements will rely on strategic investments in research, satellites to monitor CO_2,[xxvi] as well as an expansion of the global atmospheric sampling network,[xxvii] enhanced mapping of global land use change, and more detailed, spatially gridded estimates of emissions.

[xxiii] China has been issued 197,128,089 Certified Emission Reductions (CERs) from 812 projects as of April 27, 2010

[xxiv] GOSAT = Greenhouse gases Observing Satellite; IASI = Infrared Atmospheric Sounding Interferometer; SCIAMACHY = Scanning Imaging Absorption Spectrometer for Atmospheric Chartography; AIRS = Atmospheric Infrared Sounder

[xxv] The presence or absence of the radioactive carbon isotope ^{14}C in atmospheric samples allows scientists to distinguish between carbon derived from fossil-fuel combustion and carbon that is of biological origin.

[xxvi] The Orbiting Carbon Observatory (OCO), a NASA satellite which intended to measure carbon dioxide concentrations with higher resolution and accuracy (1-2 ppm), failed in its launch on February 2009. President Obama has allocated budget for a new satellite.

[xxvii] Particularly in high emission zones and underrepresented areas of the world

7. RECOMMENDATIONS

Based on this study, WWF recommends that the following steps be taken by the United States, China, and the international community at large:

A. Enhance bilateral cooperation on energy data and GHG inventories

The United States and China have a history of cooperation in the energy sector, dating to the early 1990s. This record of cooperation should be reinforced and expanded in the realm of GHG inventories to reinforce mutual trust about each country's systems and data.

- The United States has significant historical experience with the use of energy consumption surveys and the analysis of time-series data on sectoral energy use, applying sophisticated tools of statistical analysis. Sharing the design of these surveys and their results with the Chinese side could help China to improve the statistical basis of its data on energy consumption and strengthen the foundations of its greenhouse gas inventories. In this way, the U.S. could provide practical assistance with China's efforts to institutionalize its new system for conducting GHG inventories every two years.

- China has extensive experience in validation and "ground-truthing" of reports on energy usage as well as auditing procedures that can be applied to enterprises and their claims of emissions reductions. Sharing this experience could help the United States strengthen spot-checks and auditing procedures.

- There are opportunities for technology cooperation and transfer in both countries that could lead to improved monitoring of local emissions, especially fugitive emissions. For example, China has developed measuring devices for CO_2 from smokestacks that could be useful for scaling up emissions monitoring in the United States, as they are considerably less expensive than the ones currently in use for this purpose in the U.S.

- The U.S.-China cooperation on this front should be part of a wider cooperation agenda to promote the low carbon economy on both sides of the Pacific.

B. Establish auditing procedures for energy surveys and emissions data reporting in the U.S.

Currently, the process of self-reporting energy data is adequate for carrying out the U.S. national greenhouse gas inventory. However, carbon emissions need to be regulated in the future. The regulatory system needs to be prepared to address this by introducing auditing procedures to ensure consistently high accuracy in reporting energy use and GHG emissions. This is particularly important to maintain integrity in any carbon trading system.

- The U.S. Environmental Protection Agency should assess how best to strengthen the current self-reporting model for collection of GHG emissions data. Auditing procedures should be introduced for energy data reporting, as this data will continue to be the foundation for all estimates of energy-related GHG emissions in the United States.

- It is particularly important to include robust auditing procedures in the implementation plan for the new EPA mandatory reporting rule on large stationary sources of greenhouse gases.

C. Expand publication of primary data related to China's GHG emissions inventory for 2005

China's *Second National Communication on Climate Change*, which will include its 2005 GHG emissions inventory, is scheduled for completion in 2011. This eagerly-awaited document will illustrate some of the massive transformations that China has undergone since 1994, the last year of official GHG emissions reporting. It will also set the baseline for the country's CO_2 intensity target.

- Like the United States, China should strive to reduce uncertainty and increase transparency in the reporting of its GHG emissions. Special attention should continue to be paid to such high emitting sectors as electricity generation, steel manufacturing, and cement production.

- To reinforce confidence among the international community, China, where appropriate, should consider expanding publication of primary energy and emissions data, as well as the documentation on methodologies, sources of data and the uncertainty analysis that was applied to these data. This would facilitate further research and analysis by scientists and agencies in China and abroad.

D. The U.S. Congress should quickly pass comprehensive energy and climate legislation

While China is already moving rapidly to implement the pledges it made in Copenhagen, the world is still waiting for the U.S. to make good on the promises made in Copenhagen that were contingent on passing climate legislation.

- Passing climate legislation in the U.S. Congress would create positive momentum for the creation of transparent and accurate emissions inventories worldwide. Through this process, the U.S. should create a domestic carbon market that can be linked with the European Emissions Trading System (ETS) and trading systems in other regions. In doing so, the U.S. would create incentives for emerging economies to improve their national GHG inventories so that they might be able to join these markets eventually.

E. China should swiftly incorporate its Copenhagen targets into the 12th Five-Year Plan (2011-2015)

China made considerable advances during the term of its 11th Five Year Plan in the implementation of its climate and energy targets. As the next Five-Year Plan is being drafted, it is important to maintain this momentum.

- It is important that China embed its new targets for carbon intensity, non-fossil energy, and forest cover and stock pledges as announced in Copenhagen into its next Five-Year plan, prorating the 2020 targets appropriately to 2015.

F. Strengthen capacities and enhance GHG emission inventories in developing countries

During the last fifteen years, the extensive reporting requirements placed on Annex 1 countries by the UNFCCC have resulted in major progress on data collection and enhancement of national institutional capacity to prepare GHG inventories. In Non-Annex 1 countries, inventories and national communications typically have been prepared with external assistance as one-time exercises. This has slowed improvement in the institutional capacities needed to conduct regular GHG inventories.[121] Copenhagen produced a "breakthrough," eliciting agreements from some Non-Annex 1 Parties to report their mitigation actions every two years. This welcome development represents a significant step forward in the accounting for global GHG emissions.

- Increased investment in China's GHG Inventory Management System will be necessary in order for China to build the domestic capacity needed to successfully conduct its GHG inventories every two years.

- China and the U.S. should work together to seek agreement on the details of biennial reporting of national GHG inventories by Non-Annex 1 countries and should cooperate to ensure adequacy of international financial support as well as respect for national sovereignty in the production of GHG inventories. Supporting biennial inventories would require relatively small investments from the international community, compared to the much larger needs of international climate finance to support mitigation and adaptation activities in developing countries.

- The United States and China should join in efforts to strengthen the capacities of other countries to develop sound inventory mechanisms, focusing on the major sources of emissions.

- Non-Annex 1 parties could request the UNFCCC's *Consultative Group of Experts on National Communications from Non-Annex 1 Parties* to act as a vehicle for international consultations on individual national GHG inventories.

G. Recognize inventory uncertainties in emission reduction pledges

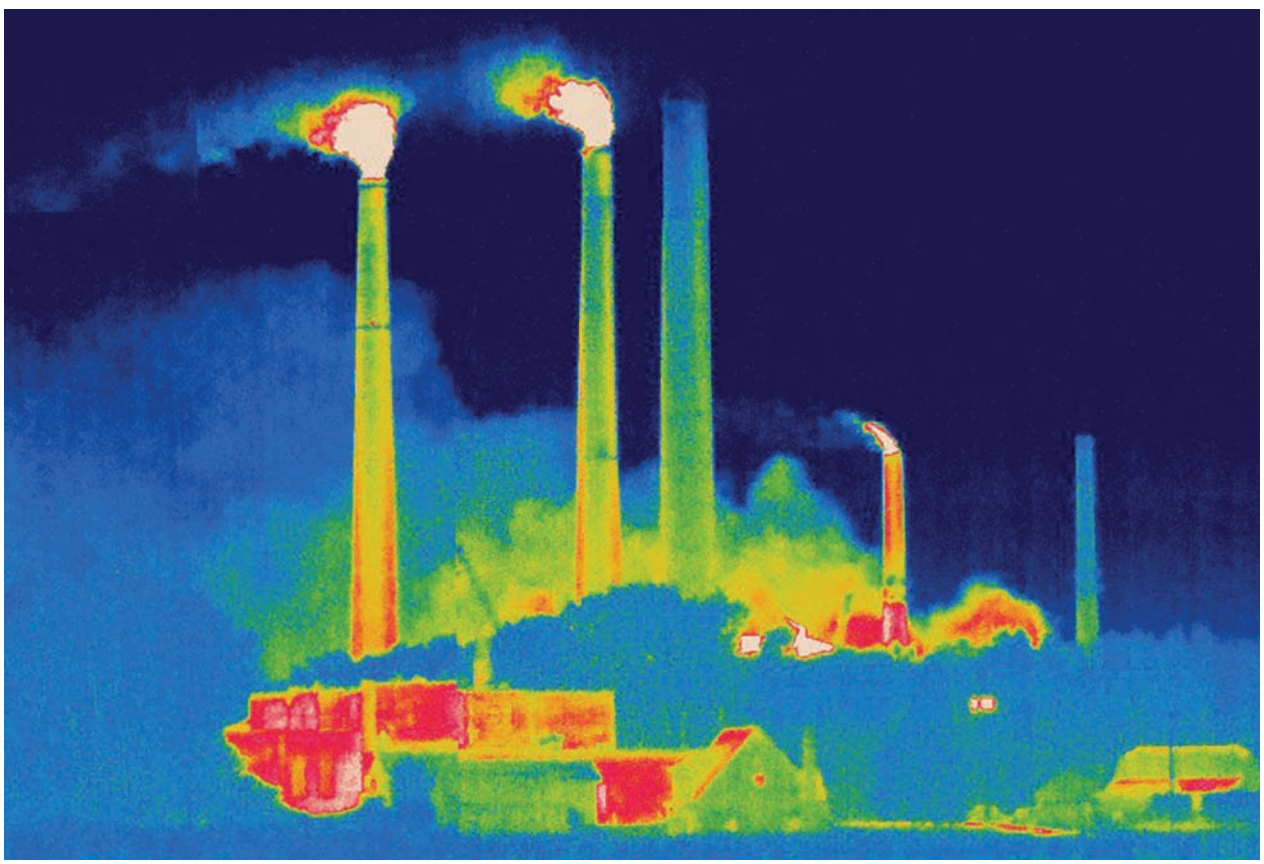
GHG inventories have an embedded uncertainty which can be reduced but not eliminated. However, given the drastic needs for emission cuts from now to 2050, uncertainty may be less of a problem because the level of cuts needed is much larger than the uncertainty levels over a multi-year period.

- Emissions reductions should be monitored carefully over time so that the magnitude of emissions reduction trends are clearly identified and lie outside the margin of measurement error. This implies that all countries should work to shrink the margin of measurement and estimation error so that emission reduction trends over a multi-year period (e.g., 3 years) are clearly revealed beyond the range of uncertainty. The emission reduction commitments by the U.S., China, and other countries should include recognition and documentation of the inherent measurement and estimation uncertainty.

H. Expand cooperation and investment in atmospheric measurements, Earth Observing Systems as well as Earth Systems Science.

International scrutiny of domestic energy statistics is a sensitive issue for many countries, who see international inspections as an infringement of national sovereignty. Nonetheless, in order to manage the risks of climate change, the international community must improve the ability to monitor fundamental changes in the Earth's conditions and to understand the implications of these changes.

- As a report by the U.S. National Research Council has indicated, satellite and atmospheric measurements could, in the future, assist in the monitoring of CO_2 and other GHG emissions and comparison with inventory data, provided there are strategic investments in monitoring and sampling stations along with new satellite systems. Just as the international community has come to value global climate models built by various universities and research centers that use international meteorological data, it can capture similar value concerning emissions of CO_2 and other greenhouse gases by investing in a worldwide network of monitoring stations combined with satellite measurements and modeling capabilities. In this regard, it is worth highlighting the role of public entities like NASA and the UK Met Office, which continue to supply climate science information to the entire world. At a time when China is developing its own space exploration capabilities, there is a great opportunity for U.S.-China collaboration on this frontier.



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8. CONCLUSIONS

The results of this study suggest that the existing systems in both the United States and China are adequate to assess progress toward the pledges made by each country at COP-15 in Copenhagen. The U.S. emissions inventories are highly reliable and robust, with detailed documentation regarding data collection and sources of uncertainty. With fourteen inventories completed so far, the EPA, EIA and other contributing agencies have accumulated a wealth of experience in conducting GHG inventories and in upgrading data collection practices, surveys and methods. Nonetheless, the U.S. has not used the inventory for regulatory processes, so neither EPA nor EIA have instituted auditing and spot-checking procedures that go beyond statistical data checks to verify self-reporting from companies. The new EPA mandatory reporting rule will likely lead to more systematic verification of emissions reduction claims. However, the United States needs to take the further steps of direct measurement and regular auditing in order to ensure accuracy and reliability in its emissions monitoring systems. These next steps will be extremely valuable as the U.S. begins to implement GHG regulations and to put a price on GHG emissions.

As a developing country with a huge population and relatively little experience in reporting GHG emissions, China's statistical challenges are enormous. Its data collection systems rely on personal and institutional responsibility and are bolstered by regular audits and inspections. With the recent implementation of more rigorous energy intensity targets, the government has increased its efforts at data collection and reporting, dramatically improving its energy statistics. This should facilitate upcoming emissions inventories and reduce uncertainty. The system of direct measurements, regular audits and personal responsibility for government officials will continue to increase confidence in China's GHG emissions reduction reports.

In summary, while the U.S. has extensive capacities in the area of statistical analysis and survey data collection capacity, China has greater experience in the implementation of mandatory targets. China also has extensive experience with spot-checks and audits for verification of national targets. All these capabilities will become even more important once carbon emissions are regulated in both countries.

The complementary historical experiences of China and the United States create many opportunities for bilateral cooperation to improve inventories, data collection, and emissions monitoring, including through the use of satellites and atmospheric measurements.

Implementing low-emissions development strategies in China and the United States demands a rigorous accounting for GHG emissions. Thus, China has to endeavor to build a robust statistical and data collection capacity, while the U.S. needs to link the national GHG emissions inventory into Federal policy and regulation of greenhouse gases. With accurate monitoring and reporting of GHG emissions and increased commitments to clean energy by the U.S. and China, the two countries can lead the world in advancing towards a low-carbon future.

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APPENDIX 1 - IPCC Guidelines for Greenhouse Gas Inventories

The Intergovernmental Panel on Climate Change (IPCC) developed the *1996 IPCC Guidelines for National Greenhouse Gas Inventories*, which are the reference methodology for GHG inventories by countries[122]. The guidelines were updated in 2006 but this edition has not been endorsed yet by the COP.[123] In addition, the IPCC issued guidance on uncertainty management in 2000[124] and separate guidance for Land Use, Land Use Change and Forestry in 2003.[125]

The IPCC Guidelines include methods for direct estimation of emissions as well as generic *emissions factors* (the conversion multiplier to derive emissions per unit of fuel or of *activity data* — e.g., sales or consumption of fuels, or clinker production for the cement sector).

In preparing the inventory, countries calculate emissions by compiling activity data on a national basis for each of the sectors categorized by the IPCC (Energy, Industrial Process, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry, Waste, and Other). Activity data can vary from fuel consumption to amount of raw material processed to vehicle-miles-traveled, depending on the sector. This inventory procedure is called the "Sectoral Approach." The activity data is then converted into emissions by multiplying the activity level by *emission factors* specific for each type of fuel or activity.

There are three tiers of methods for the inventory, each with increasing complexity. For emissions from fuel combustion, **Tier 1** inventory methods involve the simplest approaches and rely on the quantity of fuel combusted and average emissions factors for each fuel. **Tier 2** methods estimate emissions with the same fuel consumption statistics but employ country-specific emission factors accounting for differences in carbon content of fuels and combustion technologies available in each country. **Tier 3** methods incorporate detailed emission models, important for CH_4 and N_2O emissions, or actual emission measurements at power plants. In general, the calculation of CO_2 emissions from fuel combustion doesn't require Tier 3 approaches. Industrial processes in general require Tier 2 and Tier 3 approaches.

As a methodology to verify the "Sectoral Approach", countries are asked to carry out a national estimate of CO_2 emissions (not of the other GHGs) through a top-down assessment of fuel combustion at a national level, simply by adding national fossil fuel production and imports, and subtracting exports and changes in stocks, and then multiplying by the corresponding emission factors for each type of fuel. This top-level calculation of CO_2 emissions is called the "Reference Approach."

The IPCC Uncertainty Guidelines[126] have two tiers of methods for depicting uncertainty. **Tier 1** methods combine uncertainties of emission factors, activity data and other inputs to estimate overall uncertainties using an error propagation equation, whereas **Tier 2** methods employ Monte Carlo Stochastic Simulation, which is able to analyze asymmetrical uncertainties.

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