GREENHOUSE GAS EMISSIONS:
ESTIMATION AND REDUCTION

Asian Productivity Organization

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ABBREVIATIONS AND ACRONYMS

AGO – Australia Greenhouse Office

APO – Asian Productivity Organization

BEE – Bureau of Energy Efficiency (India)

CDM – Clean Development Mechanism

EC – Energy Conservation

EE – Energy Efficiency

EU – European Union

GHG – Greenhouse Gas

GTZ – *Deutsche Gesellschaft für Technische Zusammenarbeit* (German Technical Cooperation)

GWP – Global Warming Potential

IEA – International Energy Association

IPCC – Intergovernmental Panel on Climate Change

LPG – Liquefied Petroleum Gas

NPC – National Productivity Council of India

NCPC – National Cleaner Production Centre of India

R&D – Research & Development

RE – Renewable Energy

SAR – Staff Appraisal Report

SME – Small and Medium Enterprise

SMME – Small, Medium, and Micro Enterprise

UNEP – United Nations Environment Program

UNFCCC – United Nations Framework on Climate Change Convention

WEC – World Energy Council

WRI – World Resource Institute

FOREWORD

Global warming is now universally accepted as being the greatest environmental threat to mankind in the current century. The impacts are staggering. Antarctic ice is thinning at increasingly rapid rates, with correspondingly massive influxes of fresh water into the world's oceans. Siberia has warmed 3°C as compared to 1960.

All these changes are due mostly to human activities, particularly in raising the levels of CO_2, a major greenhouse gas (GHG). Atmospheric concentrations of CO_2 have risen 35% since the Industrial Revolution. This increase is primarily due to anthropogenic activities such as the burning of fossil fuels and deforestation. Reducing the rate of GHG emissions will be an enormous challenge for everyone throughout the world which must be fought on many fronts.

To create awareness among APO member countries, a workshop was organized in November 2008 in the Republic of China on Reduction of Greenhouse Gas Emissions. During the workshop, the participants expressed the need for comprehensive guidelines for the estimation and reduction of GHG emissions. This manual has been prepared to help APO member countries estimate their GHG emissions from business establishments; residential, commercial, and institutional buildings; and transport sectors, which are the major GHG contributors, and develop appropriate action plans for their mitigation.

Dr. Thomas Fuller, an 18-century British physician, said: "Get the facts, or the facts will get you. And when you get them, get them right, or they will get you wrong." The APO hopes that this manual will help in striking a balance between development and the environment in APO member countries and elsewhere.

Shigeo Takenaka
Secretary-General
Tokyo
December, 2009

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Our special thanks go to UNEP, UNFCCC, IPCC, World Resources Institute, World Energy Council, International Energy Agency, European Commission, Australian Greenhouse Office, National Productivity Council of India, Bureau of Energy Efficiency (Ministry of Power, Government of India), GERIAP, GTZ, USEPA, and many other organizations and individual experts in the field of climate change science, whose valuable input has made this manual useful not only for APO member countries, but also for society in general.

Last but not least, we would like to thank all those who have been involved directly or indirectly in preparing this manual.

CHAPTER 1:
ESTIMATING AND REDUCING GHG EMISSIONS

BACKGROUND

Climate change is one of the most critical global environmental, social, and economic challenges of the century that the entire world is facing. The Earth's average surface temperature has risen by three-quarters of a degree Celsius since 1850. The latest events have clearly demonstrated our growing vulnerability to climate change. Climate change is not only an environmental problem but also a developmental problem. Its adverse impacts will disproportionately affect developing countries with their most vulnerable populations and their least adaptive capacity. In other words, those who have contributed the least so far to this problem and also do not have the financial and technological resources to deal with it will be the most affected. Within developing countries, as well, the poorest citizens living on marginal land and who are most reliant on their direct natural environment will be the ones most at the receiving end of climate change impacts such as droughts and floods.

According to the United Nations Framework Convention on Climate Change, "without further action to reduce greenhouse gas (GHG) emissions, the global average surface temperature is likely to increase by a further 1.8–4.0 deg C this century." [1] This report further projects that at least the lower end of this range would be almost a certainty since pre-industrial times it has risen above 2 deg C, the threshold beyond which is irreversible and possibly catastrophic changes become far more likely. Unmitigated climate change beyond 2 deg C will lead to accelerated, irreversible, and largely unpredictable climate changes. [2]

Most of the changes in our climate have been brought about by anthropogenic activities; that is, they have been caused by human influences. The activities of people that contribute to climate change include, in particular, the burning of fossil fuels, agricultural practices, and land use modifications such as deforestation brought about by the spread of ever-increasing populations. These activities result in the emission of carbon dioxide (CO_2), a major greenhouse gas and the main gas responsible for climate change, as well as other "greenhouse" gases (i.e., gases that trap heat in the atmosphere). In order to bring climate change to a halt and save our planet, it is imperative to reduce greenhouse gas emissions significantly.

In 2005, the European emissions trading scheme commenced while in 2006 the Kyoto Protocol came into effect, with Russia joining. At the same time, rising oil prices due to the impending "oil peak" provided financial incentives for alternative fuels.

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[1] United Nations Framework Convention on Climate Change, 4th Assessment Report of the Intergovernmental Panel on Climate Change, 2 February, 2007.

[2] Report on "Climate Change and International Security," Council of the European Union, Brussels, 3 March, 2008.

WORLD SCENARIO ON GHG EMISSIONS

GHG emissions have risen steadily since pre-industrial times – by 70% between 1970 and 2004 (IPCC, 2007). The largest growth has been observed in the energy supply sector (an increase of 145%) followed by the transport sector at 120% within this period.

Many analyses of GHG emissions trends and projections focus solely on CO_2, as CO_2 is the largest source of GHG, accounting for 77% of all such emissions. The next most important GHG directly emitted through anthropogenic processes are methane and nitrous oxide. Further, future projections and trends are based on CO_2 emissions in view of the accuracy of data on CO_2 emissions from the use of fossil fuels. According to the IPCC, carbon dioxide concentration has achieved unprecedented levels in the atmosphere greater than any time in the last 650,000 years. Thus it has become a major and the fastest-growing factor in climate change (IPCC, 2007).

According to the Energy Information Administration of the U.S. Department of Energy (EIA, 2007), global carbon dioxide emissions have been projected to rise from 26.9 billion tons in 2004 to 33.9 billion tons in 2015, and 42.9 billion tons in 2030, at an average growth rate of 1.8% per year.

CARBON DIOXIDE AND THE GLOBAL GHG EMISSIONS SCENARIO

Current Emissions by Country

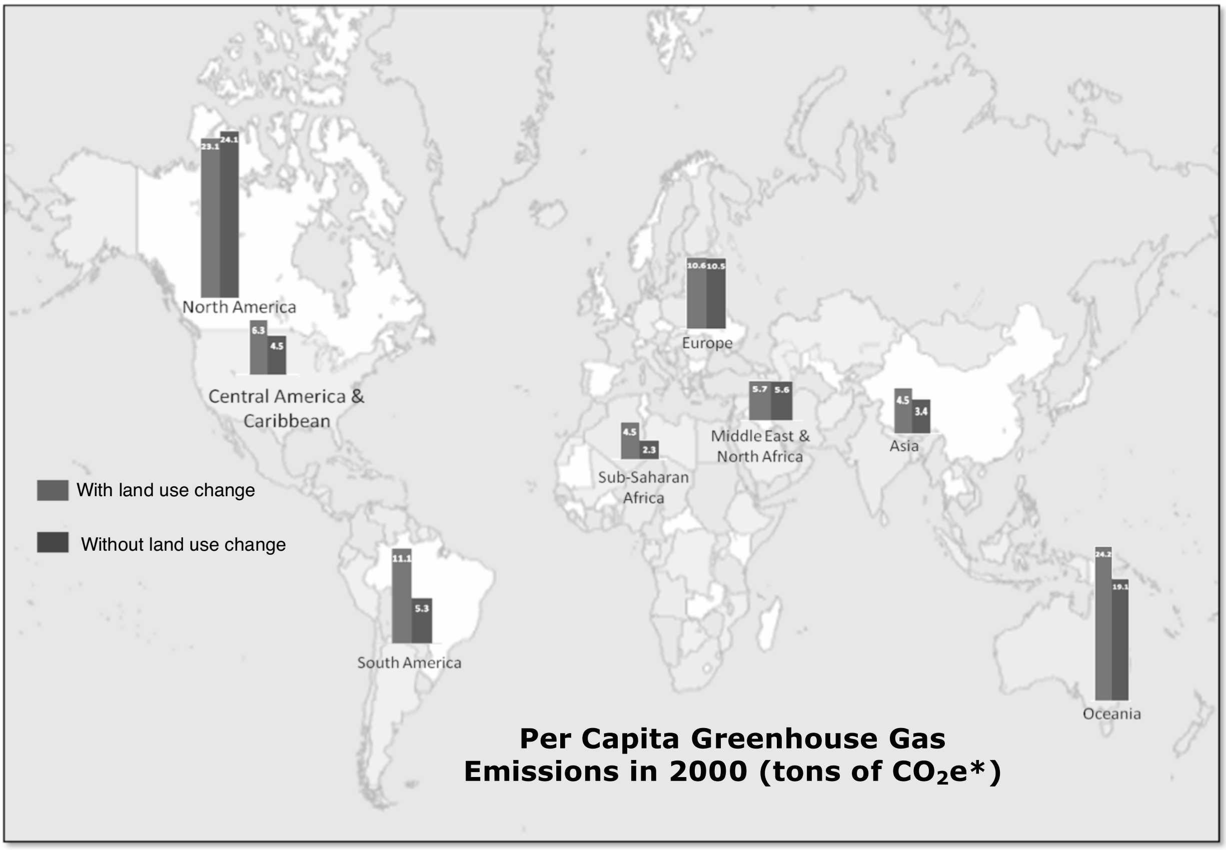
A relatively small number of countries produce a large majority of global GHG emissions. Many also rank among the most populous countries and have the largest economies. The major emitters include almost an equal number of developed and developing countries, as well as some transition economies of the former Soviet Union. For implementation of adequate GHG mitigation measures, the international climate regime has to establish incentives and/or obligations within its political framework. These measures can be achieved through domestic initiatives, international agreements, or both. In the absence of such initiatives, any mitigation measures will fail environmentally.

Emission Projections by Country

Emission projections at the national level are highly uncertain. Uncertainties are especially acute in developing country economies, which tend to be more volatile and vulnerable to external shocks. Furthermore, past projections are also questionable in respect to their accuracy. This has made it difficult to develop policies that are based on such projections. For instance, fixed emission caps (such as Kyoto Protocol-style targets) are less likely to be viable in developing countries than in industrialized countries.

Per Capita Emissions

Only a handful of countries with the largest total emissions rank among those with the highest per capita emissions. For some, per capita emissions vary significantly when CO_2 from land use and non-CO_2 gases are taken into account. Although per capita emissions are generally higher in wealthier countries, there are notable and diverse exceptions. Some developing countries with a rising middle class, for instance, have per capita emission levels similar to those of richer industrialized economies. Accordingly, international agreements predicated on equal per capita emission entitlements will face difficulty in arriving at a consensus because of the diverse national conditions facing countries with similar per capita emission profiles. The per capita GHG emissions from various regions across the globe are shown in Figure 1-1.



*CO_2e: CO_2 equivalent

Source: Adapted from *List of Countries by Greenhouse Gas Emissions Per Capita*. Wikipedia.

Figure 1-1. Per capita greenhouse gas emissions in 2000 (tons of CO_2e)

Sustainable Level of Per Capita GHG Emissions

The sustainable equitable level of GHG emissions per person can be estimated by dividing the IPCC* figure of 11.5 billion tons of CO_2 – the amount the biosphere can theoretically assimilate – by the world's population (IPCC, 2001). This amount equals 11.5/6. The sustainable level of greenhouse gas emissions (GHG) is less than 2 tons CO_2e per person per year.

* Intergovernmental Panel on Climate Change: The IPCC is a scientific intergovernmental body set up by the World Meteorological Organization (WMO) and by the United Nations Environment Program (UNEP).

Cumulative Emissions

Most of the largest *current* emitters also rank among the largest *historic* emitters, with developed countries generally contributing a larger share compared to developing countries' smaller share of cumulative CO_2 emissions summed over time. A country's historic contribution may differ substantially depending on the time period assessed and whether CO_2 from land-use change is included in the calculation. Policy proposals prepared before 1990 that rely on historical emissions face considerable barriers related to data quality and availability.

As can be seen from Figure 1-1, cumulative emissions are higher from the Oceanic and North American regions compared to Europe and South America. We can also see that the emissions are almost on par in Asia, the Middle East, North Africa, Sub-Saharan Africa, and Central America and the Caribbean countries.

Emissions from APO Member Countries

Most APO member countries have transition economies. Only a few have developed economies, such as Japan, Taiwan, Korea, Singapore, and Malaysia. Hence GHG emissions from APO countries vary widely. The levels of per capita GHG emissions from APO member countries are presented in Table 1-1 and visualized in Figure 1-2.

Table 1-1. Per capita greenhouse gas emissions and ranking of APO member countries (year 2000)

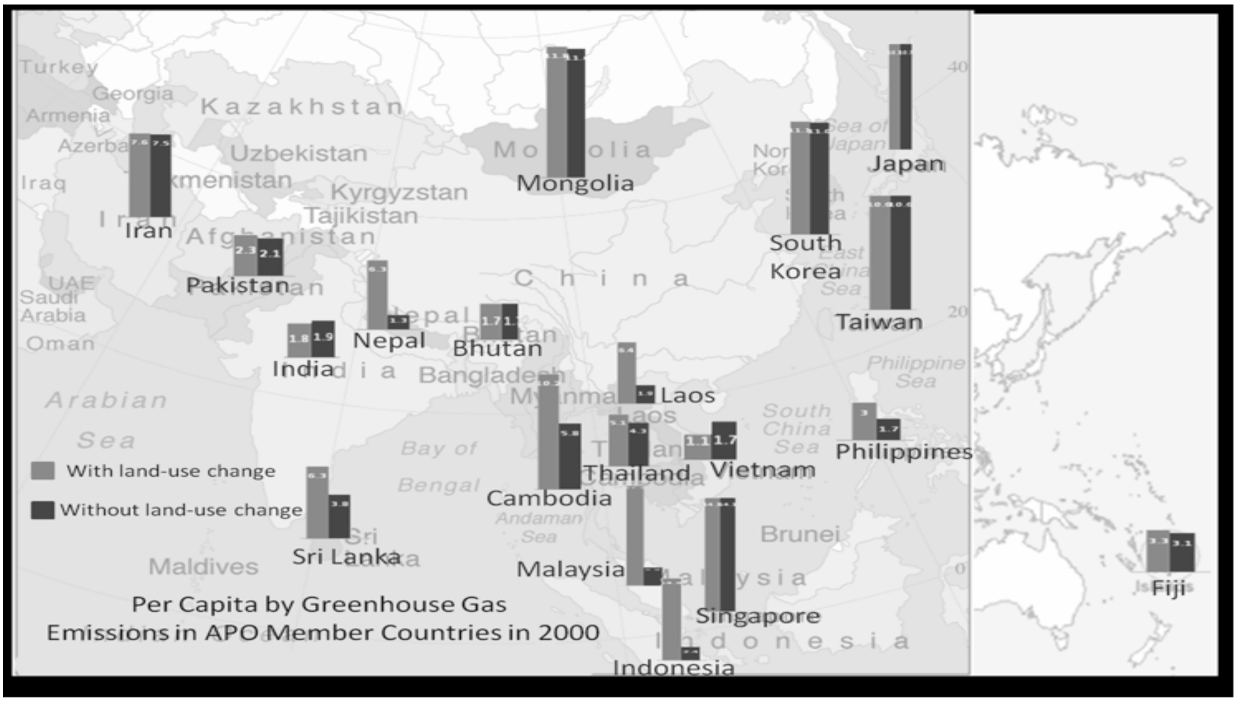
Rank with land-use change	Rank without land-use change	Country	Tons of CO_2e with land-use change	Tons of CO_2e without land-use change
4	64	Malaysia	37.2	6.8
24	123	Indonesia	14.9	2.4
29	18	Singapore	14.1	14.1
41	30	Mongolia	11.8	11.6
45	32	South Korea	11.1	11.0
52	37	Taiwan	10.6	10.6
55	73	Cambodia	10.2	5.8
74	57	Iran	7.6	7.5
91	142	Laos	6.4	1.9
93	164	Nepal	6.3	1.3
94	100	Colombia	6.3	3.8
112	93	Thailand	5.1	4.3
126	110	Fiji	3.3	3.1
132	152	Philippines	3	1.7
136	165	Sri Lanka	2.8	1.3
149	135	Pakistan	2.3	2.1
162	146	India	1.8	1.9
164	150	Bhutan	1.7	1.7
175	153	Vietnam	1.1	1.7
182	177	Bangladesh	0.9	0.9
50	35	Japan	10.7	10.7

Source: *List of Countries by Greenhouse Gas Emissions Per Capita.* Wikipedia.

As can be seen from the table, per capita CO_2e emissions by Malaysia increased from 6.8 to 37.2 tons after land-use change, which is the most emissions among all APO member countries, while Bangladesh had the least at 0.9 tons. However, there is virtually no difference from "without" to "with" land-use change in per capita GHG emissions by developed APO member countries such as Singapore, South Korea, Taiwan, and Japan.

Some Facts About GHG Emissions:

- GHG emissions have risen by 70% between 1970–2004 since the pre-industrial era.
- CO_2 emissions are projected to be 42.9 billion tons in 2030.
- Earth's average surface temperatures has increased by 0.76°C since 1850.
- Global average surface temperature is likely to increase by a further 1.8 to 4.0°C this century.
- CO_2 is the largest source of GHG accounting for 77% of total emissions.
- Sustainable level of GHG emissions is less than 2 tons CO_2e per capita per year.
- Per capita GHG emissions were the lowest from Bangladesh at 0.9 tons of CO_2e in 2000 among APO member countries.
- Energy sector is the major contributor of GHG emissions accounting for 90% of the total CO_2 emissions globally, resulting from fossil fuel combustion.
- Power plants (electricity generation) without heat recovery account for over 70% of GHG emissions globally.



Source: Adapted from *List of Countries by Greenhouse Gas Emissions Per Capita*. Wikipedia.

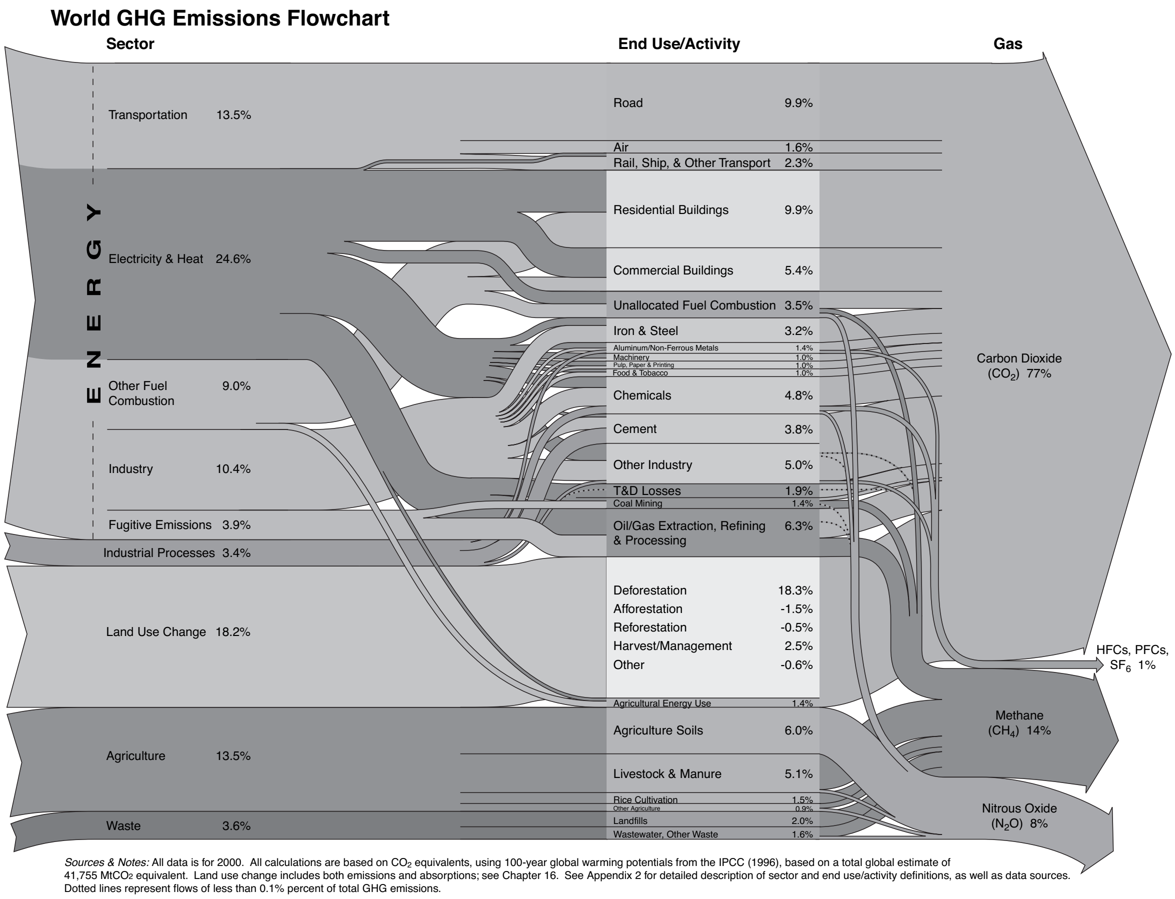
Figure 1-2. Greenhouse gas emissions in APO member countries in 2000 (per capita)

GLOBAL GHG EMISSIONS FLOW BY SECTOR AND ACTIVITY

We have seen that fossil fuel use in the energy sector is the main cause of CO_2 emissions, with a smaller contribution stemming from changes in land use patterns. Narrowing this still further, industry, residential and commercial buildings, and transportation are the major sectors of the economy that use the most energy, and that use varies widely in different parts of the world. The contributions from different sectors to global GHG emissions are summarized in Figure 1-3.

The chart illustrates the use of fossil fuel as the primary source of energy (coal, oil, and gas) and how it differs between sectors using primary energy, i.e., mainly transportation, the manufacturing and construction sectors, and the production of electricity and heat, and secondary consumers (end use/activity), i.e., mainly electricity and heat generation. At the end use/activity level, energy use can be divided as:

- Transport sector – road, air, rail, shipping, and other;
- Industry – different industrial end users (among which are energy-intensive sectors including iron and steel, cement, and chemicals); and,
- Others – mainly residential and commercial sectors.



Source: *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy – Part II.* World Resources Institute, 2005.

Figure 1-3. World emissions flowchart of fossil fuel use (World Resources Institute)

The guide allows visualizing where electricity and heat produced by the electric and cogeneration industry are used as secondary energy by end users, therefore producing indirect emissions, thus making a distinction between direct emissions (emissions from the use of primary energy) and indirect emissions (emissions from the use of secondary energy). Such distinction is important in order to avoid the double counting of emissions. The figure also includes other sectors such as agriculture and waste, which contribute mostly to non-CO_2 emissions not covered over the last 250 years (IPCC, 2007).

It is important to note that the release of carbon dioxide is directly proportional to the efficiency of fossil fuel conversion into energy. At present, the best available coal and natural gas technologies have efficiencies of 45% and 52%, respectively. Assuming typical efficiency of a new coal-fired thermal power plant, equipped with a scrubbing system for sulfur and nitrogen oxide, a 1% increase in efficiency would result in a 2.5% reduction in carbon dioxide emissions.

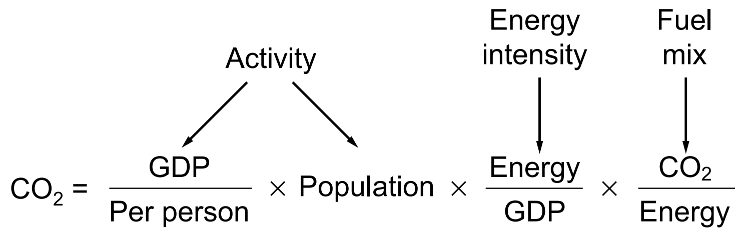
KEY DRIVERS OF EMISSIONS FROM ENERGY USE

The key drivers of emissions from energy use are:

- activities such as total population growth, urbanization, building and vehicle stock, commodity production;
- economic factors such as total GDP, income, and price elasticity;
- energy intensity trends, e.g., energy intensity of energy-using equipment, appliances, and vehicles; and,
- carbon intensity trends; i.e., the amount of carbon released per unit of energy use. (This indicator depends on fuel mix and emission reductions derived from fuel switching.)

These factors are, in turn, driven by changes in consumer preferences, energy and technology costs, demand for goods, settlement and infrastructure patterns, technical development, and the overall economic scenario of the nation (IPCC, 2000).

Energy use produces emissions depending on how assumptions relating to the four main factors vary, that is, activity level, structure, energy intensity, and fuel mix. Altering any of these factors, alone or in combination, can influence emission levels. A simple model can be used for representing the interactions between these four factors and their impact on CO_2 emissions: the farther one drives a car (activity), the more CO_2 emissions will result. However, fewer emissions will result if the car is more energy efficient (energy intensity), and emissions might be avoided entirely if the car is operating on a zero-carbon fuel such as hydrogen (fuel mix). Alternatively, one might choose to ride the bus instead of driving (changing the structure of the activity), which would also alter the CO_2 emissions (Pew Center, 2004). The relationship between various key drivers and emissions is presented in Figure 1-4.



Source: *An Overview of Global Greenhouse Gas Emissions and Emission Reduction Scenarios for the Future.* Institute for European Environmental Policy (IEEP), Brussels. February, 2008

Figure 1-4. Emissions projections — simple model representing key factors driving CO_2 emissions from energy use (Pew Center, 2004)

CO_2 EMISSIONS FROM SELECTED SECTORS

We have understood that GHGs are emitted through natural and anthropogenic sources, and carbon dioxide is the major greenhouse gas contributing to global warming. Most CO_2 emissions derive from fossil fuels used in the energy sector and a smaller portion from change in land-use patterns. Key sectors of the economy that use energy are industry, residential and commercial buildings, and transportation. Contributions from these sectors vary widely between areas of the world depending upon the developmental activities.

As can be seen from Figure 1-3, the major source of CO_2 emissions is the combustion of fossil fuels, which accounts for more than 90% of the total contribution of these emissions globally. Within the energy sector, electricity and heat is the main category, and accounts for over 70% globally from electricity generation without heat recovery, followed by the transport, manufacturing, and construction sub-sectors. In transportation, road transport accounts for nearly three-quarters of all transportation emissions while aviation and marine transport account for most of the remainder (rail and other modes are themselves relatively insignificant). The trends and projections of CO_2 emissions from the various sectors are presented in Table 1-2.

Among the largest-emitting regions (Asia, Europe, and North America) some differences can be seen from Figure 1-5. Heat and electricity in each of these three regions have a very large share ranging from 42.5% (Europe) and 45.4% (Asia). Manufacturing and construction is the next-largest sub-sector for Asia accounting for nearly a quarter, but much less for Europe, and less still for North America.

However, in the case of the transportation sector, this pattern is reversed, with North America producing over 30% of its emissions from all forms of transport, contrasted to under 13% for Asia, with Europe falling in between the two. Industrial process emissions are a fairly small share in both Europe and North America, but more prominent in Asia. Sector-wise CO_2 emissions from the use of energy in various regions are shown in Figure 1-5.

Table 1-2. Trends and projections for CO_2 emissions from various sectors of the economy

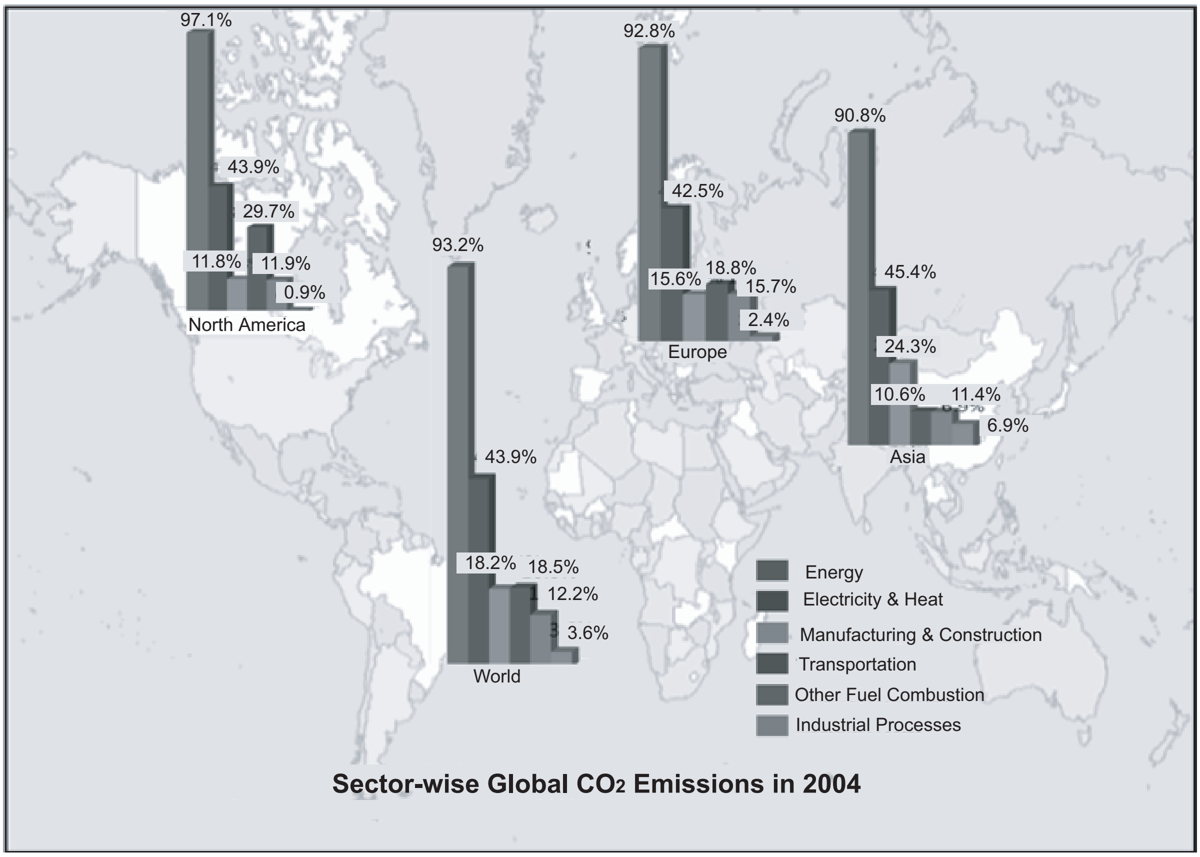
No.	Sector	1990	2010	2020	2050
1.	Industrial	2.8 Gt C	3.2 – 4.9 Gt C	3.5 – 6.2 Gt C	3.7 – 8.8 Gt C
2.	Transport	1.3 Gt C	1.3 – 2.1 Gt C	1.4 – 2.7 Gt C	1.8 – 5.7 Gt C
3.	Infrastructure	1.9 Gt C/yr	2.9 Gt C/yr	3.3 Gt C/yr	5.3 Gt C/yr

Source: IPCC Technical Paper – 1, 1996.

According to the IPCC, the carbon dioxide emissions from Annex I countries are projected to remain either constant, rather than decline by 33%, or increase 76% by 2050.

In view of fast-changing production technology and incorporated energy conservation measures coupled with virtual saturation in demand of developed nations, it is further projected that the share of Annex I countries would decrease to about 60–70% by 2020. Also, it is expected that road and air transportation would increase its share of emissions in most scenarios.

It is estimated that 75% of 1990 emissions are attributable to energy use in Annex I countries while by 2050 only 50% of buildings-related emissions globally are expected to be from Annex I countries.



Source: *Navigating the Numbers: Greenhouse Gas Data & International Climate Policy – Part II.* World Resources Institute, 2005.

Figure 1-5. Sector-wise global CO_2 emissions in 2004

Another important sector that is assuming importance particularly in developing countries is solid waste and wastewater disposal. In most of these countries, solid waste and wastewater management systems are not adequate thus result in release of GHG emissions in the form of methane gas. According to the World Resources Institute (WRI), it is estimated that about 50–80 Mt of methane gas (290–460 MtC) was emitted in 1990 by solid waste disposal facilities (landfills and open dumps) and wastewater treatment facilities in developing countries.

ENERGY SUPPLY SECTOR

It is evident from the above that energy is the primary source of GHG emissions that are being generated during the combustion of fossil fuel. Hence, the energy sector is one of the most important of all sectors as far as GHG emissions are concerned. It has been estimated that in 1990 about 6 GtC was released from energy consumption. Out of this, about 72% was delivered to end users, accounting for 3.7 GtC while the remaining 28%, amounting to 2.3 GtC, was used in energy conversion and distribution.

In order to focus on major GHG emission sources, this manual pays particular attention on the estimation of GHG emissions from the industrial, infrastructure, and transport sectors. The energy sector is common in all, as energy is an essential component of every activity.

Since small and medium enterprises (SMEs) in Southeast Asian countries contribute the most to GHG emissions, focus has also been laid to discussing the technologies for GHG emission reduction particularly in the SME sector. This manual therefore presents examples of GHG emissions estimation and case studies on GHG emission reduction technologies.

SMEs AND GHG EMISSIONS

SMEs are an important sector serving as the engine of growth in virtually all developing nations. They are the main driver for industrialization and a key channel for absorbing most of the country's labor. SME expansion boosts employment more than large firms as they are more labor intensive. SMEs enhance competition and entrepreneurship and thus have external benefits to economy-wide efficiency, innovation, and aggregate productivity growth. They contribute, in general, to around 30–60% of East Asian region GDP and up to 70% of the region's total employment. In India, the MSME (micro, small, and medium enterprises) sector accounts for 40% of exports, 45% of industrial production, and 8% of total GDP (SME Times, May, 2008). At the same time, Indian SMEs are more responsible for causing global warming or pollution due to a lack of basic infrastructure, accessibility, and affordability of high tech production technologies and hampered by inefficient mechanisms to safely discharge effluents. Of course, SMEs are important in providing a flexible skilled production base that attracts foreign direct investment (FDI) to boost the economy of the nation.

Despite their positive aspects, SMEs consume more resources per unit of product and generate more pollution compared to large industries, thus contribute to environmental pollution to a great extent. Generally, SMEs put about 65% of the total pollution load on the environment. This has been attributed to low skill levels, technological status that is typically just conventional, financial constraints, weak entrepreneurship, etc. Though the quantity of waste generation from a single SME may be less compared to large enterprises, the cumulative environmental impact of a number of SMEs is very high in view of their presence in clusters in a given region. This clearly indicates that SMEs consume more resources as compared to large enterprises, but they also have great potential for resource optimization and conservation. In order to assist SMEs in developing countries, a mechanism has been developed to reduce GHG emissions called "emission trading" under the Kyoto Protocol. Using this mechanism, Annex 1 countries are permitted to purchase allowances for carbon produced by their industries through technological improvements.

KYOTO PROTOCOL AND GHG EMISSIONS REDUCTION

The Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in Kyoto, Japan, in December 1997 and entered into force on 16 February 2005. The rules and requirements for implementation of the Kyoto Protocol were further elaborated in a package of decisions called the Marrakesh Accords. The Marrakesh Accords were formally adopted by COP/MOP at its first session in Montreal, Canada, in December 2005.

The Kyoto Protocol shares the ultimate objective of UNFCCC to stabilize atmospheric concentrations of greenhouse gases at a level that will prevent dangerous interference with the world climate. In pursuit of this objective, the Kyoto Protocol builds upon and enhances many of the commitments already in place under the Convention:

- Each Annex I Party must undertake domestic policies and measures to reduce GHG emissions and to enhance removals by sinks.
- In implementing these policies and measures, each Annex I Party must strive to minimize any adverse impact of these policies and measures on other Parties, particularly developing country Parties.
- Annex I Parties must provide additional financial resources to advance the implementation of commitments by developing countries.
- Both Annex I and non-Annex I Parties must cooperate in the areas of:
  - Development, application, and diffusion of climate-friendly technologies;
  - Research on and systematic observation of the climate system;
  - Education, training, and public awareness of climate change;
  - Improvement of methodologies and data for greenhouse gas missions; and,
  - Gas inventories.

However, the Kyoto Protocol's most notable elements are its binding commitments on Annex I Parties to limit or reduce greenhouse gas emissions, and its innovative mechanisms to facilitate compliance with these commitments.

EMISSIONS TRADING

Under emissions trading, an Annex I Party may transfer Kyoto Protocol units to, or acquire units from, another Annex I Party. A Party may acquire an unlimited number of units under Article 17. However, the number of units that a Party may transfer is limited by the Party's commitment period reserve (CPR). The CPR is the minimum level of units that a Party must hold in its national registry at all times. The requirement for each Party to maintain a CPR prevents a Party from overtransferring units, and thus impairing its ability to meet its Article 3, paragraph 1, commitment.

Annex I Parties may choose to implement domestic or regional (e.g., with a group of Parties) systems for entity-level emissions trading, under their authority and responsibility. Although the Kyoto Protocol does not address domestic or regional emissions trading, Kyoto emissions trading forms an umbrella under which national and regional trading systems operate, in that the entity-level trading uses Kyoto Protocol units and needs to be reflected in the Kyoto Protocol accounting. Any transfer of units between entities in different Parties under domestic or regional trading systems is also subject to Kyoto Protocol rules. The emissions trading scheme (ETS) of the European Union is one example of a regional trading system, operating under the Kyoto Protocol umbrella.

This manual can help the industries, community, and local bodies estimate their GHG emissions and obtain the carbon credits from Annex 1 countries through CDM under the Kyoto Protocol.

CHAPTER 2:
ESTIMATING GHG EMISSIONS

GHG EMISSIONS ESTIMATION AND INVENTORY

It is important to estimate the greenhouse gas emissions from any source in order to develop policies on mitigation measures. The GHG emission inventory identifies the most significant emission sources and trends, helping enterprises, local bodies, and nations develop action plans to mitigate them. The action plans are generally developed in order to reduce GHG emissions without disrupting economic growth and development. The inventory also helps to prioritize the sectors and take corrective measures.

GHG INVENTORY CONCEPTS AND OBJECTIVES

The preparation of inventories relies on a few key concepts with a common understanding. This helps to ensure comparable inventories, avoid double counting or omissions, and to confirm the time series reflects actual changes in emissions. In order to have a uniform and undisputed inventory, one should have understanding about greenhouse gases, their emissions, and global warming potential (GWP). The global warming potential of major gases is presented in the following table.

Table 2-1. Global warming potential of major GHGs

No.	GHGs	GWP (100-year time horizon)	
		SAR*	TAR*
1	Carbon dioxide (CO_2)	1	1
2	Methane (CH_4)	21	23
3	Nitrous oxide (N_2O)	31	296
4	HFCs	140–11,700	120–12,000
5	CFCs	6,500–9,200	5,700–11,900
6	SF	23,900	22,200

*SAR, TAR: Second Assessment Report, Third Assessment Report

Source: *Report on Climate Change and International Security*. Council of European Union, Brussels, 3 March, 2008.

The objectives of making a GHG inventory are two-fold. The first objective is to estimate the GHG emissions from various sources and develop a national database for reporting at the national and international level. The second is for assessing GHG emission reductions for emission trading under CDM. In both cases, one has to develop and upgrade the GHG emissions sources and potentials on a regular basis. Such an inventory creates a database of the principal sources of emissions to prioritize mitigation measures to curtail emissions.

Any baseline emission inventory requires inputs including, but not limited to, energy consumption in the industrial, commercial, residential, and transport sectors.

In transportation, the usual inputs pertain to the type of vehicle, average miles traveled per vehicle, and the type and amount of fuel used. The baseline emission calculators apply emission coefficients/factors to energy consumption to compute greenhouse gas emissions. Methane generation potential from wastes, etc. is also estimated.

The important sectors and sub-sectors that contribute to GHG emissions are energy, industrial processes and product use, infrastructure, transport, waste, etc. IPCC has set out methodologies to estimate GHG emissions and total emissions are calculated by summing up all the sources. A national total is calculated by summing up the emissions and removals for each gas. The emissions resulting from use of fuel in ships and aircrafts are not included in the national total but are reported separately.

In order to calculate a national inventory, it is necessary to select an approach to include harvested wood products (HWP).

PREPARATION OF NATIONAL INVENTORY

Before starting a national inventory, one should first determine whether it will meet IPCC standards. A decision tree is presented in the following diagram for preparing a national inventory as per the IPCC Guidelines. This diagram explains the stages needed to make sure it complies with the IPCC standards. The flow diagram illustrates how the different types of users (working at different levels of inventory detail) can utilize the various volumes of the IPCC Guidelines for preparing an inventory. One should recognize that reality is more complex than this simple explanatory chart. Some countries may have portions of the inventory complete at a high level of detail but may only be getting started on other parts. It is quite likely that some users will need to do several iterations of the thinking process reflected in the diagram with regard to different aspects of their inventory.

The stages outlined in the flow diagram are:

Question 1

Do you already have a detailed national inventory?

Answer: *Yes*

If your country already has a complete national inventory, you should convert the data it contains into a form suitable for use by IPCC. This means converting it into a standardized format. In order to do this, refer to Volume 1 of the IPCC Guidelines, Reporting Instructions. This explains how the data should be documented and reported.

Answer: *No*

You should start to plan your inventory and assemble the data you will need to complete the worksheets of the IPCC Guidelines. Refer to the "Getting Started" section of the workbook.

Question 2

Do you want to use the inventory software available from IPCC?

Answer: *Yes*

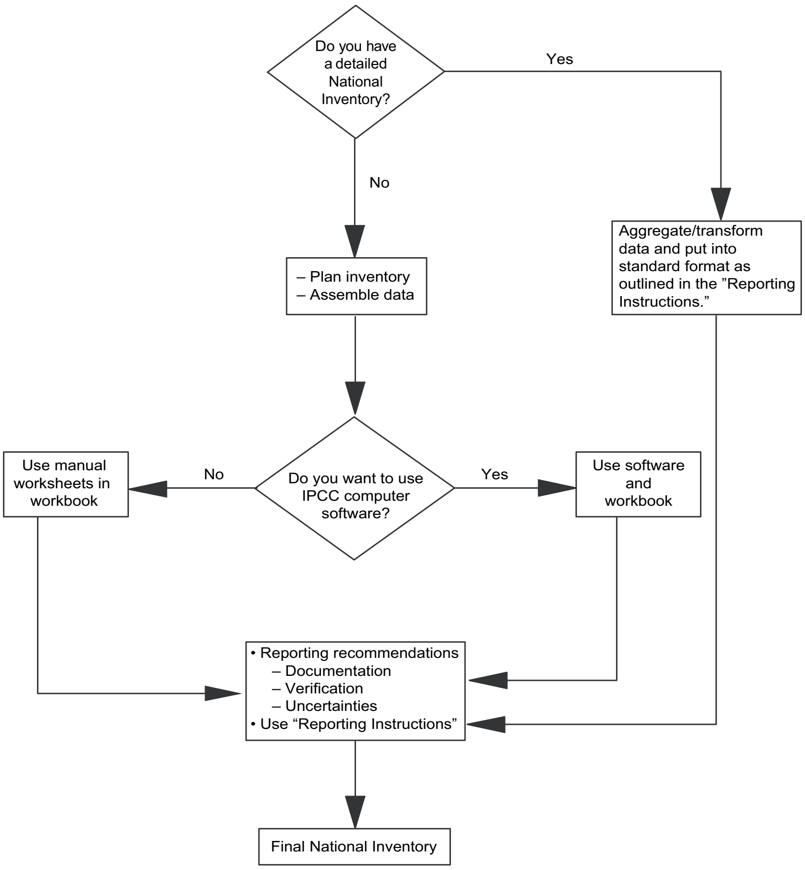
If you want to use the IPCC software, you will still need to follow the instructions included in the workbook to prepare and assemble the data you have collected. To enter data you will use the software instead of the printed worksheets.

Answer: *No*

If you do not use the IPCC software, use the workbook and the worksheets it contains to assemble your collected data into an inventory.

Finally...

Inventory data should be returned to IPCC in the form recommended in the Reporting Instructions. It is important that, when you have used a methodology other than the IPCC default methodology, it is properly documented. This will ensure that national inventories can be aggregated and compared in a systematic way in order to produce a coherent regional and global picture.



AVAILABILITY / USE OF COMPUTER SOFTWARE

IPCC computer software is available with the IPCC Guidelines. The software includes the same simple default methods as presented in the Workbook and the Sectoral and Summary Tables for reporting inventories, as presented in the Reporting Instructions. It is available in English only. This version of the software is being produced in Excel 5.0.

If you would like to receive a copy of the software, send a letter or fax to:

IPCC UNIT FOR GHG INVENTORIES
Pollution Prevention and Control Division
OECD, Environment Directorate
2, Rue André-Pascal
75775 PARIS CEDEX 16, FRANCE
FAX: (33-1) 45 24 78 76

Source: *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories.* Task Force on National Greenhouse Gas Inventories, IPCC.

Figure 2-1. Decision tree for preparation of GHG emission inventory

In order to simplify this manual, special attention is paid to methods for estimating GHG emissions from major sectors such as industrial processes and products, and the residential, commercial/institutional, and transport sectors.

Methodology for Inventorizing GHG
Making an inventory of greenhouse gases is a systematic step-by-step process. Before undertaking estimates of emissions and removals from specific categories, an inventory compiler should become familiar with the material. A six-step, 16-task methodology has been developed based on the IPCC Guidelines on GHG Emissions and is presented below.

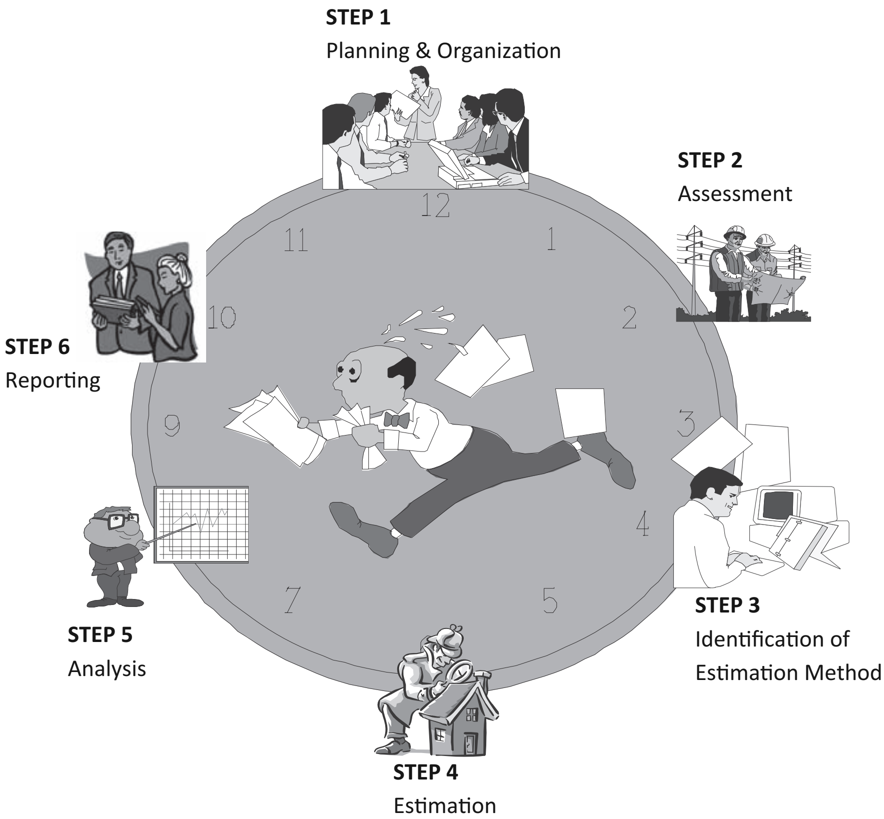


Figure 2-2. Methodology for GHG inventorization

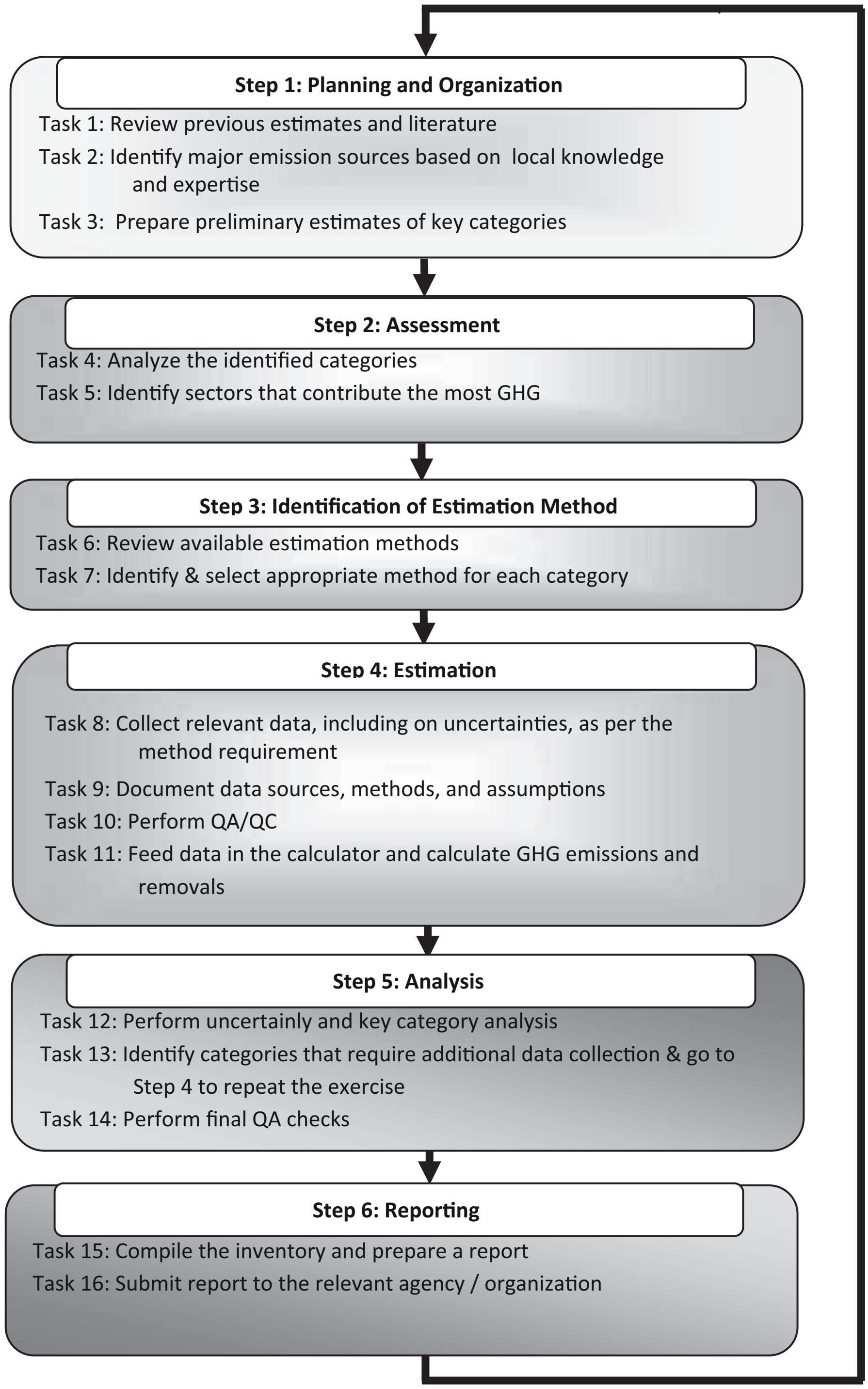
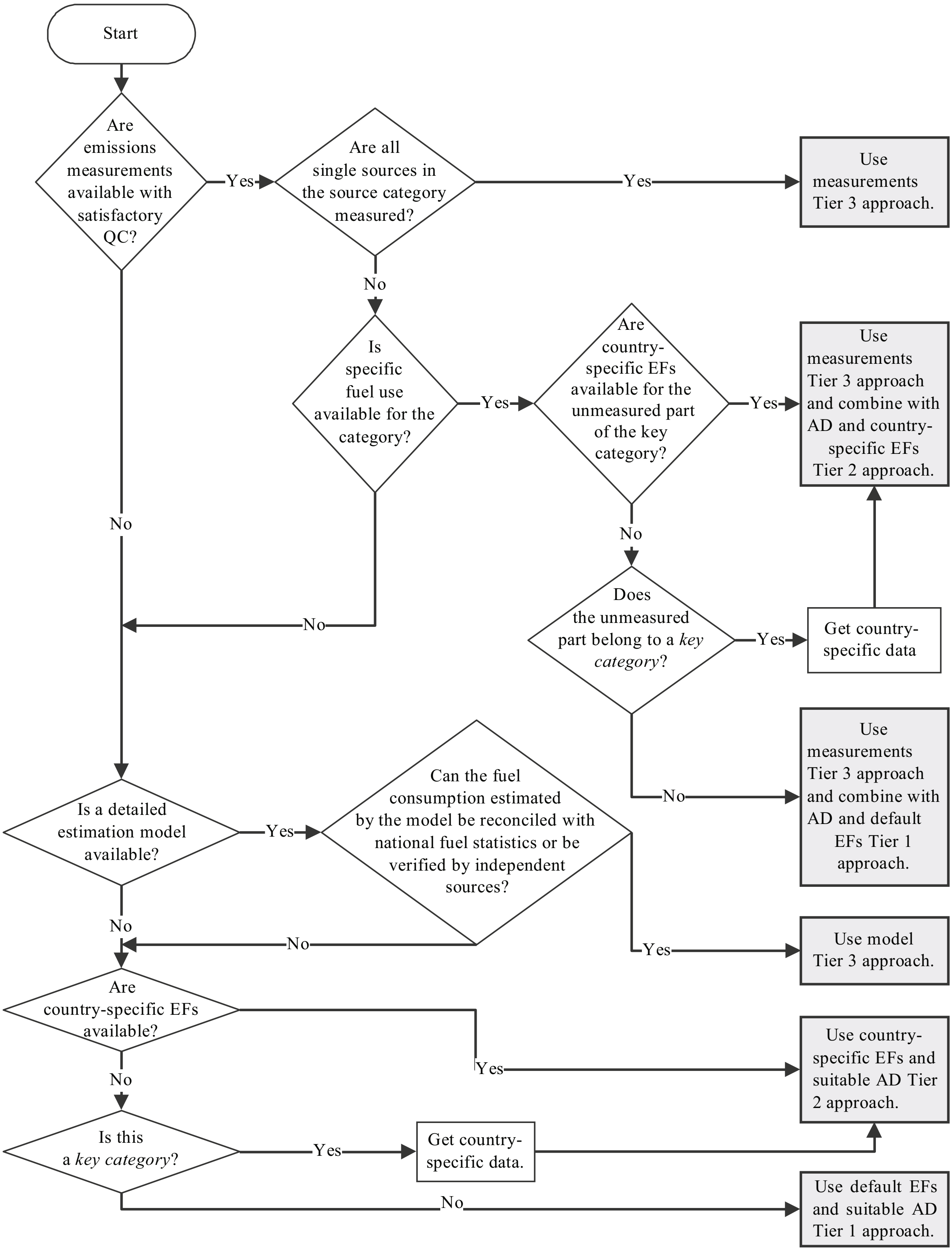


Figure 2-3. Six-step methodology for greenhouse gas (GHG) inventorization



Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Task Force on National Greenhouse Gas Inventories, IPCC.

Figure 2-4. Generalized decision tree for estimating emissions from fuel combustion

The inventory should be based on previous inventories, if available, and should be revised as per the requirements. When a revised inventory is compiled, all estimates by year should be reviewed for consistency and updated integrating any feasible improvements wherever necessary. Thus an iterative process builds on and improves the inventory each time a new inventory is compiled as illustrated in Figure 2-4. A tier or level approach has been followed to inventorize GHG emission estimations. The tier approach is explained below.

Tier 1
The Tier 1 inventory method is fuel-based, since emissions from all sources of combustion can be estimated on the basis of the quantities of fuel combusted (usually from national energy statistics) and average emission factors. Tier 1 emission factors are available for all relevant direct greenhouse gases.

Tier 2
In the Tier 2 inventory method for energy, emissions from combustion are estimated based on country-specific emission factors in place of the Tier 1 defaults. Since available country-specific emission factors might differ for different specific fuels, combustion technologies or even individual industrial plants, activity data could be further disaggregated to properly reflect such disaggregated sources.

If an inventory compiler has well documented measurements of the amount of carbon emitted in non-CO_2 gases or otherwise not oxidized, it can be taken into account in this tier in the country-specific emission factors.

Tier 3
In the Tier 3 inventory method for energy, either detailed emission models or measurements and data at the individual plant level are used where appropriate. Properly applied, these models and measurements should provide better estimates primarily for non-CO_2 greenhouse gases, though at the cost of more detailed information and effort.

ESTIMATION OF GHG EMISSIONS FROM INDUSTRIAL PROCESSES AND PRODUCT USE

GHG emissions are produced from a wide variety of industrial activities. The main emission sources are releases from industrial processes that chemically or physically transform materials (for example, a blast furnace in the iron and steel industry, ammonia and other chemical products manufactured from fossil fuels used as chemical feedstock, and the cement industry are notable examples of industrial processes that release significant amounts of CO_2). During these processes, many different greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs), can be produced.

In addition, chemical compounds that may escape as greenhouse gases often are used in products such as refrigerators, foams, and aerosol cans. For example, HFCs are used as alternatives to ozone-depleting substances (ODS) in various types of product applications. Similarly, sulfur hexafluoride (SF_6) and N_2O are utilized in a number of products with industrial applications (e.g., SF_6 used in electrical equipment and N_2O used as a propellant in aerosol products primarily in the food industry) or by end-consumers (e.g., SF_6 used in running shoes and N_2O used for surgical or dental anesthesia). A notable feature of these product uses is that, in almost all cases, significant time can elapse between the manufacture of the product and the ultimate release of the damaging greenhouse gas. The delay can vary from a few weeks (e.g., aerosol sprays) to several decades as in the case of rigid foams. In some applications (e.g., refrigeration) a portion of the greenhouse gases used in the products can be recovered at the end of the product life and either recycled, sequestered, or destroyed. In addition, several other fluorinated greenhouse gases may be used in special processes, for example in semiconductor manufacture, such as:

- nitrogen trifluoride (NF_3)
- trifluoromethyl sulphur pentafluoride (SF_5CF_3)
- halogenated ethers ($C_4F_9OC_2H_5$, $CHF_2OCF_2OC_2F_4OCHF_2$, $CHF_2OCF_2OCHF_2$)

and other halocarbons not covered by the Montreal Protocol including CF_3I, CH_2Br_2, $CHCl_3$, CH_3Cl, and CH_2Cl_2. *IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines, Volume 3*) also provides estimation methods for halogenated greenhouse gases that are not covered by the Montreal Protocol.

The following Table 2-2 provides possible greenhouse gases from various industrial processes, which can be used as a reference and can serve as a guide to identify emission sources.

Although the climate changes naturally on its own, humans contribute heavily to pollution of the environment. More and more people are wondering how they can do their part to help reduce greenhouse gas emission into the atmosphere. While change won't happen overnight, here are steps that you can take against global warming in your own place of business.

Table 2-2. Industrial processes and product use categories and their possible emissions

2 Industrial Processes and Product Use (Note 1, 2)	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases (Note 3)
2A Mineral Industry							
2A1: Cement Production	X	*					
2A2: Lime Production	X	*					
2A3: Glass Production	X	*					
2A4: Other Process Uses of Carbonates							
2A4a: Ceramics	X	*					
2A4b: Other Uses of Soda Ash	X	*					
2A4c: Non Metallurgical Magnesia Production	X	*					
2A4d: Other	X	*					
2A5: Other	X	*	*				
2B Chemical Industry							
2B1: Ammonia Production	X	*	*				
2B2: Nitric Acid Production	*	*	X				
2B3: Adipic Acid Production	*	*	X				
2B4: Caprolactam,Glyoxal, and Glyoxylic Acid Production	*	*	X				
2B5: Carbide Production	X	X	*				
2B6: Titanium Dioxide Production	X	*	*				
2B7: Soda Ash Production	X	*	*				
2B8: Petrochemical and Carbon Black Production							
2B8a: Methanol	X	X	*				
2B8b: Ethylene	X	X	*				
2B8c: Ethylene Dichloride and Vinyl Chloride Monomer	X	X	*				
2B8d: Ethylene Oxide	X	X	*				
2B8e: Acrylonitrile	X	X	*				
2B8f: Carbon Black	X	X	*				
2B9: Fluorochemical Production (Note 4)							
2B9a: By-product Emissions (Note 5)				X	X	X	X
2B9b: Fugitive Emissions (Note 5)				X	X	X	X
2B10: Other	*	*	*	*	*	*	*
2C Metal Industry							
2C1: Iron and Steel Production	X	X	*				
2C2: Ferroalloys Production	X	X	*				
2C3: Aluminium Production	X	*			X		
2C4: Magnesium Production (Note 6)	X			X	X	X	X
2C5: Lead Production	X						
2C6: Zinc Production	X						
2C7: Other	*	*	*	*	*	*	*
2D Non-Energy Products from Fuels and Solvent Use (Note 7)							
2D1: Lubricant Use	X						
2D2: Paraffin Wax Use	X	*	*				
2D3: Solvent Use (Note 8)							
2D4: Other (Note 9)	*	*	*				
2E Electronics Industry							
2E1: Integrated Circuit or Semiconductor (Note 10)	*		*	X	X	X	X
2E2: TFT Flat Panel Display (Note 10)				X	X	X	X
2E3: Photovoltaics (Note 10)				X	X	X	X
2E4: Heat Transfer Fluid (Note 11)							X
2E5: Other	*	*	*	*	*	*	*

Table 2-2. Industrial processes and product use categories and their possible emissions (continued)

2 Industrial Processes and Product Use (Note 1, 2)	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Other halogenated gases (Note 3)
2F Product Uses as Substitutes for Ozone Depleting Substances							
2F1: Refrigeration and Air Conditioning							
2F1a: Refrigeration and Stationary Air Conditioning	*			X	X		*
2F1b: Mobile Air Conditioning	*			X	X		*
2F2: Foam Blowing Agents	*			X	*		*
2F3: Fire Protection	*			X	X		*
2F4: Aerosols				X	X		*
2F5: Solvents (Note 12)				X	X		*
2F6: Other Applications	*	*	*	X	X		*
2G Other Product Manufacture and Use							
2G1: Electrical Equipment							
2G1a: Manufacture of Electrical Equipment (Note 13)					X	X	*
2G1b: Use of Electrical Equipment (Note 13)					X	X	*
2G1c: Disposal of Electrical Equipment (Note 13)					X	X	*
2G2: SF_6 and PFCs from Other Product Uses							
2G2a: Military Applications					*	X	*
2G2b: Accelerators (Note 14)					*	X	*
2G2c: Other					X	X	*
2G3: N_2O from Product Uses							
2G3a: Medical Applications			X				
2G3b: Propellant for Pressure and Aerosol Products			X				
2G3c: Other			X				
2G4: Other	*	*		*			*
2H Other							
2H1: Pulp and Paper Industry (Note 15)	*	*					
2H2: Food and Beverages Industry (Note 15)	*	*					
2H3: Other	*	*	*				

1) "X" denotes gases for which methodological guidance is provided in this volume.
2) "*" denotes gases for which emissions may occur but for which no methodological guidance is provided in this volume.
3) For precursors (NOx, CO, NMVOC, SO_2 and NH_3) see Table 7.1 in Chapter 7 of Volume 1.
4) The Tiers 2 and 3 methodologies are applicable to any of the fluorinated greenhouse gases listed in Tables 6.7 and 6.8 of the Contribution of Working Group I to the Third Assessment Report of the IPCC (IPCC, 2001), comprising HFCs, PFCs, SF_6, fluorinated alcohols, fluorinated ethers, NF_3, SF_5CF_3. In these tiers all estimates are based on measurements, either measured losses from the process or measured emissions, and accommodate process-specific releases. For the Tier 1 methodology, default values are provided for HFC-23 emissions from HCFC-22 manufacture and for process emissions of HFCs, PFCs and SF_6. For the other materials there are too few manufacturers, each with individual technology, to permit the use of general default values.
5) The "Other halogenated gases" are fluorinated alcohols, fluorinated ethers, NF_3, SF_5CF_3.
6) Small amounts of CO_2 used as a diluent for SF_6 and emitted during magnesium processing are considered in significant and are usually counted elsewhere. The "other halogenated gases" here mainly comprise fluorinated ketones.
7) Emissions from feedstock uses in petrochemical industry should be addressed in 2B8 (Petrochemical and Carbon Black Production). Emissions from some product uses should be allocated to each industry source category (e.g., CO_2 from carbon anodes and electrodes – refer to 2C (Metal Industry)).
8) Only NMVOC emissions and no direct greenhouse gases are relevant to this category. Therefore no methodological guidance is provided in this volume. For guidance on NMVOC, see Chapter 7, Volume 1.
9) Emissions from Asphalt Production, Paving of Roads and Roofing are included here. For details, see Section 5.4 of this volume.
10) The "Other halogenated gases" are NF_3, $c\text{-}C_4F_8O$, etc.
11) The "Other halogenated gases" here include $C_4F_9OC_2H_5$ (HFE-7200), $CHF_2OCF_2OC_2F_4OCHF_2$ (H-Galden1040x), $CHF_2OCF_2OCHF_2$ (HG-10), etc.
12) Emissions from use of fluorinated gases as solvent should be reported here. Emissions from aerosols containing solvents should be reported under Category 2F4 rather than under this category. Emissions from other solvent use should be reported under 2D3.
13) At the time of writing of these *Guidelines*, no emissions of "Other halogenated gases" are identified, but it is possible that these gases may be used and emitted in the future.
14) At the time of writing of these *Guidelines*, no emissions of PFCs or "Other halogenated gases" are identified, but it is possible that these gases may be used and emitted in the future.
15) No specific section on these categories is provided in this volume, but methodological guidance on CO_2 emissions from use of carbonates from these industries is provided in Chapter 2, Section 2.5 of this volume.

Source: *IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 1, 2006.* Task Force on National Greenhouse Gas Inventories, IPCC.

GHG ESTIMATION METHODS

The first step is to recognize how much your firm or organization may be contributing to the problem of greenhouse gas emissions.

A number of methods are available to calculate GHG emissions. You can choose the one that is most appropriate for your industry or application. However, calculation methods that are in accordance with IPCC guidelines for the preparation of national inventories are encouraged.

Emission Estimation for Facilities

The various methods used to estimate GHG emissions for facilities are presented below.

- **Monitoring and Direct Measurement** – This method is helpful in estimating GHG emissions from continuous sources such as smoke from stacks. This may involve Continuous Emission Monitoring Systems (CEMS) where emissions are recorded continuously over a longer and uninterrupted period. This method can be applied to the industrial establishments that have a fixed emission source as stacks.
- **Mass Balance** – In this method, emissions are determined based on the difference in the input and output of a unit operation where accumulation and depletion of a substance are included in the calculations.
- **Engineering Estimates** – This method may involve estimating emissions from engineering principles and judgment by using knowledge of the chemical and physical processes involved.

Emission Factors

GHG emissions are estimated based on developed emission factors (EFs). An emission factor is the rate at which a pollutant is released into the atmosphere as a result of some process activity or unit throughput. EFs used may be average or general or technology-specific.

In order to estimate GHG emissions from industrial processes, generally two approaches, known as mass-balance and emission factor approach, have been adopted. Both the approaches have specific advantages and disadvantages. The emission factor approach provides an instant solution while the mass-balance approach relies on measurements and monitoring. A comparison of both approaches is presented in the following table.

According to *IPCC Good Practice Guidance Guidelines, 1996,* the most common simple methodological approach to calculate GHG emissions is to combine information on the extent to which a human activity takes place (called activity data or AD) with coefficients that quantify the emissions or removals per unit activity. These are called emission factors (EF). The basic equation is therefore:

$$\text{Emissions} = AD \times EF$$

For example, in the energy sector fuel consumption would constitute activity data, and the mass of carbon dioxide emitted per unit of fuel consumed would be an emission factor, as per the requirement. The basic equation can, in some circumstances, be modified to include estimation parameters other than emission factors.

Example of Electricity Emission Factors

Low-level GHG power projects that supply clean energy to the electricity grid generally estimate reductions from assumptions about the energy source that they are offsetting. While the estimation method of:

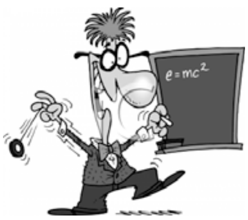
$$a \text{ MWh} * b \text{ tCO}_2\text{e/MWh} = c \text{ tCO}_2\text{e}$$

is straightforward for the project proponent, the justification for the number at *b* is more complex. There are several options for considering EFs for calculating emission reductions from clean or low-emission energy supply to an electricity grid supply that should be understood when making process decisions.

There is no perfect factor that works in every situation and there are a number of factors that can guide the selection of a type of emission factor. While choosing EFs, one should consider the following:

- Are there similar projects / programs already operating with a level of methods consistency?
- Is there a regulatory framework that restricts the choice?
- What are the levels of accuracy / assurance required for the emissions calculation? For example, a project planning to take part in emissions trading will need a more rigorous methodology and calculation than one funded simply as a demonstration of *possible* technologies.
- How regionally specific is the program? Is equity across the country a concern?
- Are available data to do the calculations sufficient and if not, is there enough capacity within the program or proponents to do this work?

Estimation of GHG from the Energy Sector



The energy sector is one of the main contributors to GHG emissions. In most of the economies of the world, energy systems are largely driven by the combustion of fossil fuels. During the combustion process, carbon dioxide and water are produced from the carbon and hydrogen present in the fossil fuel. Thus the chemical energy present in the fuel is released in the form of heat that is generally used either directly or with some conversion losses to produce mechanical energy for the generation of electricity or for transportation.

Categorization of Sources

The energy sector mainly comprises of:

- exploration and exploitation of primary energy sources;
- conversion of primary energy sources into more usable energy forms in refineries and power plants;
- transmission and distribution of fuels; and,
- use of fuels in stationary and mobile applications

Emissions arise from these activities by combustion and as fugitive emissions, or the escape of gases without combustion. For inventory purposes, fuel combustion may be defined as "the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus."

Stationary combustion is usually responsible for about 70% of the greenhouse gas emissions from the energy sector. About half of these emissions are associated with combustion in energy industries, mainly power plants and refineries. Mobile combustion (road and other traffic) causes about one-quarter of the emissions in the energy sector. Typically, only a few percent of the emissions in the energy sector arise as fugitive emissions from extraction, transformation, and transportation of primary energy carriers. Examples are leakage of natural gas and the emissions of methane gas during coal mining and flaring as part of oil/gas extraction and refining. In some cases where countries produce or transport significant quantities of fossil fuels, fugitive emissions can make a much larger contribution to the national total.

GHG CALCULATORS

A number of calculators are available for the estimation of greenhouse gases. Many countries such as Canada, the U.S., Australia, and Europe have developed their own calculators based on the IPCC guidelines. The most popular calculator is the one developed by UNEP. The calculator developed by the Australian Greenhouse Office is also simple and easy to use. This can also be easily utilized by APO member countries for estimation of their GHG emissions. Both of these calculators are discussed in this manual and the member countries can adopt whichever is most suitable for them. Other calculators have also been developed by private companies to help calculate GHG emissions for CDM (clean development mechanism) purpose. One such calculator is presented below.

Table 2-3. GHG emission calculator developed by A1 Future Technologies (India)

Baseline Emissions		GHG	CDM Project Emissions		Net Reduction		GWP[a]		$C0_2$e[b]
0	-	$C0_2$	0	=		x	1	=	
0	-	CH_4	0	=		x	21	=	
0	-	N_20	0	=		x	310	=	
0	-	HFC-23	0	=		x	11700	=	
0	-	HFC-125	0	=		x	2800	=	
0	-	HFC-134a	0	=		x	1300	=	
0	-	HFC-152a	0	=		x	140	=	
0	-	CF_4	0	=		x	6500	=	
0	-	C_2F_6	0	=		x	9200	=	
0	-	SF_6	0	=		x	23900	=	
0		Totals	0						
						Grand Total			

1. Global Warming Potential as related to CO_2.
2. Carbon dioxide equivalent.

Note: All units should be converted to metric tons before being keyed into the calculator. You only need to provide values for the Baseline Emissions and CDM Project Emissions columns (green-colored cells). Indicate 0 (zero) for empty fields. To avoid errors, make sure to hit all the Calculate buttons before hitting Total.

Source: www.carbonmcgroup.com/ghgcalculator.html

UNEP GHG Emissions Calculator

A simplified GHG emissions calculator has been developed by UNEP and given below. This calculator can help make estimations of the reduction in GHG emissions through adopted measures. The spreadsheet used for calculating GHG emissions is shown below. The details can be obtained from GHG calculation tools available at www.ghgprotocol.org/standard/tools.htm.

Table 2-4. Spreadsheet for calculating GHG emissions based on UNEP GHG calculator

INSTRUCTIONS

1. Fill in the cells coloured green, and GHG emissions will be automatically calculated
2. Standard emission factors are provided in yellow cells. You can replace these with company specific emission factors if available
3. Please make sure that you provide data in the correct unit as indicated!! Use conversion factors (separate sheet) to convert from eg m3 to tonnes
4. Please make sure that you save the document under a different name for each plant

GENERAL

Name of organisation:	
Main product:	
Base year of GHG emissions:	

Note: we would prefer GHG emissions to be calculated for 2003 if data are not available (yet) please calculate for 2002

SUMMARY OF GHG EMISSIONS

GHG emission source	Quantity		Unit
	2002 (or 2003)	2004	2002 (or 2003)
1. Fuel combustion	0	0	Tonne CO2
2. Fuel for transport	0	0	Tonne CO2
3. Electricity consumption	0	0	Tonne CO2
4. Process related	0	0	Tonne CO2
Grand total (1, 2, 3 + 4)	**0**	**0**	Tonne CO2
Production			Tonne product
Normalised CO2 emissions			T CO2 / T product

Emission factors by country	
Bangladesh	0.54
China	0.772
India	0.89
Indonesia	0.724
Mongolia	0.724
Philippines	0.724
Sri Lanka	0.205
Thailand	0.618
Vietnam	0.724

1. FUEL COMBUSTION (for production and onsite electricity generation, but excluding fuel as feed for e.g. ammonia production)

Fuel Type	Quantity		Unit	Emission factor	CO2 emissions (tonne)	
	2002 (or 2003)	2004			2002 (or 2003)	2004
Coal			Tonne	2.51	0	0
Natural Gas			Tonne	2.93	0	0
Diesel oil			Kilo liters (1000 litres)	2.68	0	0
Other fuel: ……					0	0
Sub total 1					**0**	**0**

Note: if other fuels are used for the production process, please insert these and use the emission factors from the UNEP GHG Calculator)

2. FUEL FOR TRANSPORT

Fuel Type	Quantity		Unit	Emission factor	CO2 emissions (tonne)	
	2002 (or 2003)	2004			2002 (or 2003)	2004
Petrol			Kilo liters (1000 litres)	2.22	0	0
Diesel			Kilo liters (1000 litres)	2.68	0	0
LPG			Kilo liters (1000 litres)	1.65	0	0
Sub total 2					**0**	**0**

3. ELECTRICITY CONSUMPTION (Excluding onsite generation)

Electricity	Quantity		Unit	Emission factor	CO2 emissions (tonne)	
	2002 (or 2003)	2004		(see right for country factors)	2002 (or 2003)	2004
Electricity purchased from grid			MWh		0	0
Electricity exported			MWh		0	0
Sub total 3					**0**	**0**

Note: please use company specific emission factors or otherwise the default emission factor for your country indicated on the right
Note: emissions from electricity exported are subtracted from electricity purchased from the grid

4. PROCESS RELATED

Process	Process	Quantity		Unit	Emission factor	CO2 (tonne)	
		2002 (or 2003)	2004			2002 (or 2003)	2004
Cement production	Clinker production			Tonnes clinker produced	0.525	0	0
Lime production	Lime production			Tonnes lime produced	0.86	0	0
Phosphate rock production	Dryer			Tonnes phosphate used	0.043	0	0
	Calciner with scrubber			Tonnes phosphate used	0.115	0	0
Nitric acid production (HNO3)	Atmospheric pressure plant			Tonnes HNO	1.395	0	0
	Medium pressure (<6 bar)			Tonnes HNO	2.17		
	High pressure plant (>7 bar)			Tonnes HNO	2.79		
Ammonia/Urea production	Synthetic ammonia production			Tonnes ammonia produced	1.45	0	0
	Urea prod. from natural gas			Tonnes feed	1.6	0	0
Iron & steel production	Iron & steel (primary)			Tonnes steel produced	2.48	0	0
	Iron & steel (secondary)			Tonnes steel produced	0.44	0	0
	Electric arc furnace			Tonnes steel produced	0.0044	0	0
	Ferroalloy production			Tonnes ferroalloy produced	4.3	0	0
Pulp production	Pulp mill make up CaCO3			Tonnes CaCO3	0.44	0	0
	Pulp mill make up Na2 CO3			Tonnes Na2CO3	0.415	0	0
Sub total 4						**0**	**0**

Note: Process specific GHG calculation tools are available on: http://www.ghgprotocol.org/standard/tools.htm

Household Greenhouse Gas Emissions Calculator

To better understand your own contribution of greenhouse gas emissions to the atmosphere, you can use the following calculator. This calculator was developed by the Australian government to help that nation's residents calculate and reduce their GHG emissions. This calculator can be used as a reference.

Use this calculator to estimate your household's greenhouse gas emissions from everyday activities. Don't worry if you can't work out the exact numbers – a rough indication is better than nothing. In Australia, an average-size household generates around 14 tons of greenhouse gases each year, but a bigger household will be more.

Table 2-5. Calculator for estimating GHG emissions released by households

Activity	Unit	Factor	GHG emissions
Household energy	Enter whole numbers only		
Natural gas or LPG	Megajoules only	x 0.07 =	0 Kilograms
Or for LPG if you buy it by the liter	Liters	x 1.7 =	0 Kilograms
Or natural gas (units in 3.6 megajoules)	Units	x 0.24 =	0 Kilograms
Electricity	Kilowatt-hours	x 1 =	0 Kilograms
Oil or kerosene	Liters	x 3 =	0 Kilograms
Wood (used in slow combustion heater)	Kilograms	x 0.23 =	0 Kilograms
Wood (used in open fireplace)	Kilograms	x 5 =	0 Kilograms
TOTAL GREENHOUSE GAS EMISSIONS FROM HOUSEHOLD ENERGY			0 Kilograms
TRANSPORT			
For gasoline/petrol	Liters	x 2.6 =	0 Kilograms
For LPG	Liters	x 1.8 =	0 Kilograms
For diesel fuel	Liters	x 3.0 =	0 Kilograms
Air travel (domestic)	Km	x 0.129 =	0 Kilograms
TOTAL GREENHOUSE GAS EMISSIONS FROM TRANSPORT			0 Kilograms
HOUSEHOLD WASTE			
Food and garden waste	Kilograms	x 1 =	0 Kilograms
	TOTAL GREENHOUSE GAS EMISSIONS		0 Kilograms

Special note: This calculator is based on indicators and factors developed for Australian households, and can also serve as a guide for APO member countries.

Household Energy:

- For each energy source, you need to find out how many units of energy you used in the past year.
- For electricity and gas, many suppliers include a bar graph on each bill showing how much energy per day you used for each billing period over the past year.
- Calculate the amount of energy used in each billing period by multiplying your daily use by the number of days in the billing period (usually 60 or 90 days).
- You should also be able to get this information by ringing your energy supplier and quoting your details.

Transportation:

- Many people don't know how much fuel they use each year, so you may have to make an estimate.
- Several approaches can be used to calculate how many liters of fuel you use. If you know your average weekly amount of money spent on fuel, and the cost per liter, calculate annual liters using: (weekly $) / (cost per liter) x 52 for a few weeks, record how much fuel you buy each week (in liters) and then estimate annual liters using (number of liters bought) / number of weeks x 52.
- Look up www.greenvehicle guide.gov.au to find out your car's fuel consumption. Remember most cars use more than the standard test results, but this gives an indication. Then calculate annual liters: number of kilometers / 100 x fuel consumption (liters / 100 km)

Source: *Global Warming Cool It: A Home Guide to Reducing Energy Costs and Greenhouse Gases*. Australian Greenhouse Office, Department of Environment and Water Resources, 2007.

GHG-Energy Calculator Developed by Australian Greenhouse Office

A comprehensive and simple GHG calculator has been developed in Australia known as "GHG-Energy Calc" which is a stand-alone calculator that can be accessed from www.wacollaboration.org.au or www.carbonneutral.com.au and used without additional supporting software. The current version is written in the Delphi program. Users only have to fill in their data once to see both energy and emissions results. It takes only a minute or two to download and gives instant results for any audit or "what if" scenario figures entered by the user.

The calculator has been designed to run simple audits and budgets of greenhouse gas emissions for the infrastructure sector (households, commercial, and institutional) and small businesses, from the direct consumption of fuel, electricity, food, and goods but not services. It may be noted that GHG-Energy Calc is not intended to provide the accurate and detailed audit outputs that may be required, for example, by local bodies or industry groups. However it is useful for the purpose of domestic energy and emissions budgeting, or as indicative estimates preliminary to more detailed audits. GHG emissions estimation, through this calculator, can provide a good indication of potential areas for emissions reduction.

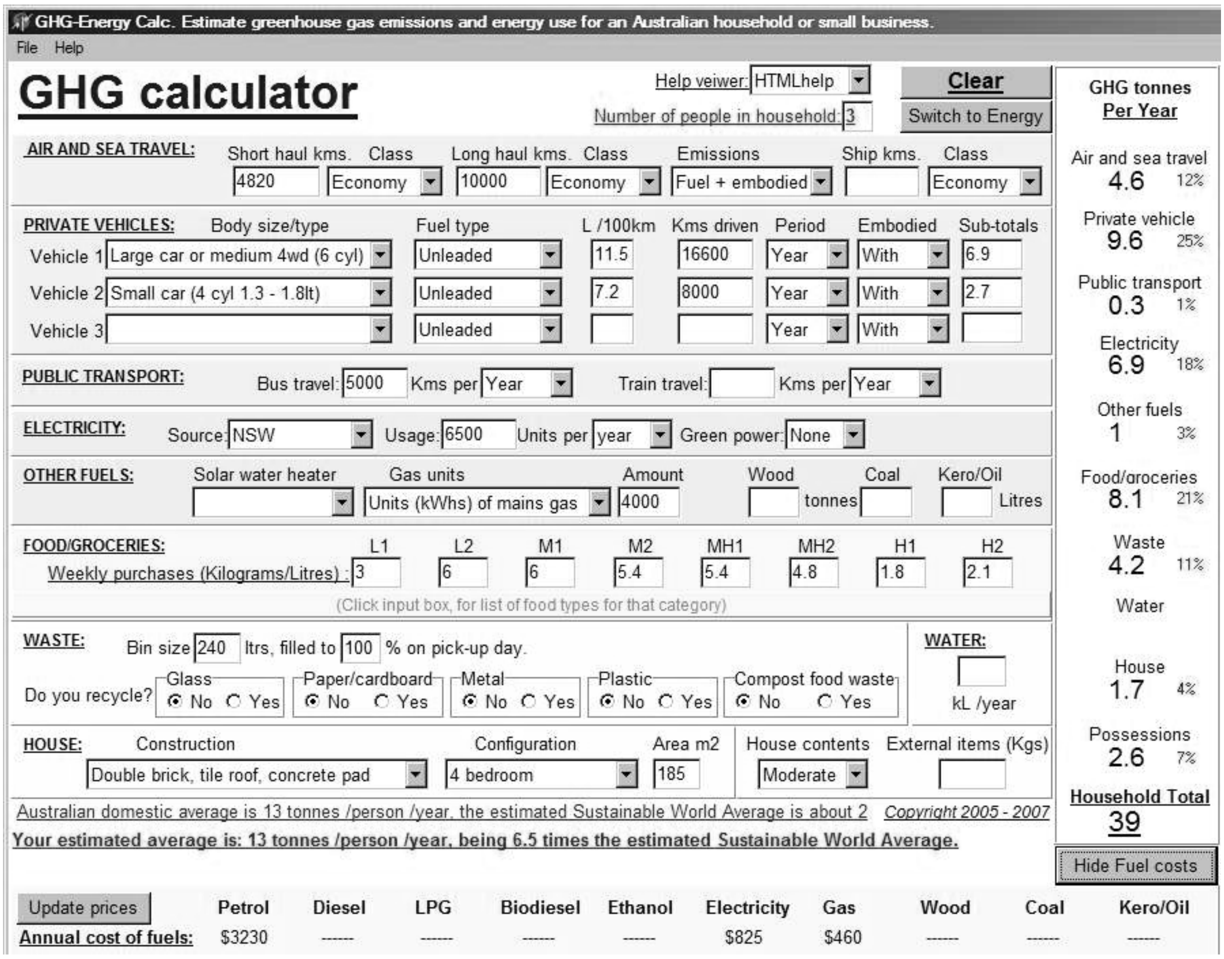
The calculator has been designed based on normal fuel-based (coal and/or oil) technology used to generate electricity. However this calculator has to be modified to reflect the change of technology and shift of energy sources away from predominantly coal to gas and "renewable," as this will have a direct impact on the emission factors.

The calculator has been designed to encourage self-auditing of energy use and emissions by households and small businesses. It estimates all energy and emissions resulting from the consumption of energy and goods:

- Direct energy and emissions from fuel and electricity used.
- Upstream energy and emissions from the extraction / refining of the fuels and generation of the electricity that is used (1+2 = full cycle energy and emissions)
- Embodied energy and emissions from the production and manufacture of:
  - Food, groceries, and water that we consume and municipal solid waste
  - Vehicles and other transport modes, housing, and other possessions

The following Table 2-6 gives an example of GHG emission calculation for a family of three in Australia. The details of this calculator can be seen at www.wacollaboration.org.au or www.carbonneutral.com.au.

Table 2-6. GHG-Energy Calc 4, showing emissions for a typical Australian family of three



Source: www.carbonneutral.com.au

EMBODIED ENERGY AND EMISSIONS FACTORS

Meaning of Embodied Energy

For the purposes of this manual and GHG-Energy Calculator:

- *Embodied energy* is defined as the energy used in the production, manufacturing, packaging, and transport of foods and consumer goods. In Australia, over 95% of this energy comes from fossil fuels. The same is true for APO member countries where energy is primarily derived from fossil fuels such as coal and oil.
- *Embodied emissions* is defined as the sum of the greenhouse gases emitted in the combustion of fossil fuels as part of all aspects of production, including electricity, upstream fuel emissions, and machinery depreciation, together with other GHGs such as methane and nitrous oxide that may be emitted as a result of production processes.

In the GHG-Energy Calculator only primary emission sources, i.e., direct energy use and the consumption of goods and transport, have been included over which the consumer can exercise direct choice.

It must be noted that in the GHG-Energy Calculator, embodied energy and emissions provide estimates that are only indicative, rather than precise, because a single, estimated emission factor is used for each of the goods categories. As well, these estimates may vary widely depending upon the types of material used and the categories into which they fall. The embodied energy for various items is presented in Annex 4.

Emission Factor: CO_2 Emission Factors

(From 2006 IPCC Guidelines for National Greenhouse Gas Inventories)

Carbon dioxide is released from the combustion of fuel. In order to reduce the emission of CO_2 and maximize the amount of energy per unit of fuel consumed, one has to optimize the combustion process. Efficient combustion of fuel ensures oxidation of the maximum amount of carbon present in the fuel. CO_2 emission factors for fuel combustion are therefore relatively insensitive to the combustion process itself; rather, they are primarily dependent on the carbon content of the fuel only. The carbon content of various fuels is presented in Annex 5, Table A5-4, and Annex 10. The carbon content may vary considerably both among and within primary fuel types on a per mass or per volume basis, as follows:

- The carbon content for natural gas depends on the composition of the gas which, in its delivered state, is primarily methane, but can include small quantities of ethane, propane, butane, and heavier hydrocarbons. Natural gas flared at the production site will usually contain far larger amounts of non-methane hydrocarbons. The carbon content will be correspondingly different.
- Light refined petroleum products such as gasoline usually have less carbon content per unit of energy than heavier products such as residual fuel oil.
- The carbon emissions per ton vary considerably for coal deposits, depending on the composition of carbon, hydrogen, sulfur, ash, oxygen, and nitrogen.

Such variability can be reduced by converting to energy units.

Generally, a small portion of the carbon from fuel escapes oxidation during the combustion process. This fraction is usually small (up to 1% of carbon). The default emission factors presented in Annex 11 are derived assuming the fraction of carbon oxidized is "1" in deriving the default CO_2 emission factors.

The carbon content of fuels from which emission factors on a full molecular weight basis can be calculated (Annex 11) is presented in Annex 10. These emission factors are default values that may be used only if country-specific factors are not available. More detailed and up-to-date emission factors may be available at the IPCC EFDB (Emission Factor Database).

Other Greenhouse Gases

Emission factors for non-CO_2 gases from fuel combustion are strongly dependent on the technology used. Since the set of technologies applied in each sector varies considerably, so do the emission factors. Therefore it is not particularly useful to provide default emission factors for these gases on the basis of fuels only. Tier 1 default emission factors are therefore provided in the subsequent chapters for each sub-sector separately.

Table 2-7 shows the emission factors for various sectors and sub-sectors as developed by the Australian Greenhouse Office to be used in GHG Energy Calculator. In view of similar regional conditions in most APO member countries, these factors may be considered for GHG emissions calculations.

Table 2-7. Emission factors for GHG calculation developed by the Australian Greenhouse Office

No.	Sector	Emission factor
1	Automobiles manufactured and serviced in Australia	0.158 g CO_2e/MJ
2	Food	0.095 kg CO_2e/ MJ
3	Residential buildings	/MJ
4	Transport	
a	Long-haul aircraft	0.245 + 0.01+ 0.0 = 0.264 kg/ passenger km, economy
b	Short-haul aircraft	0.38 + 0.01 + 0.01 = 0.407 kg/ passenger km, economy
c	Long-haul aircraft	1.28 + 0.03 + 0.04 = 1.35 MJ/ passenger km, economy
d	Short-haul aircraft	2.0 + 0.03 + 0.07 = 2.1 MJ/ passenger km, economy
5	Marine	
a	Ocean liner transport, economy class	0.39 kg CO_2e/ passenger km
b		4.99 MJ/passenger km
6	Surface	
a	Manufacture and servicing of motor vehicle	1.2 tons CO_2e / ton vehicle weight / year
b	Bicycle	0.02 kg per passenger km
c	Bus	0.06 kgCO_2e/ passenger km
d	Diesel train	0.03 kgCO_2e/ passenger km
e	Electric train	0.03 kgCO_2e/ passenger km
f	Taxi (carrying two passengers)	0.26 kgCO_2e/ passenger km
7	Wood heater	0.034 kgCO_2e/MJ
8	Food / groceries	0.095 g CO_2e /MJ
9	Municipal solid waste	2.7 kg CO_2e/ kg MSW
10	Renewable energy	0.03 kgCO_2e/MJ

NOTES:
- For business class, economy passenger emissions are multiplied by 2.
- For premium economy, economy passenger emissions are multiplied by 1.2.
- For first class, economy passenger emissions are multiplied by 3.
- Emissions from wood heating used in GHG-Energy Calc were derived from Houck, et al. = 0.55 kg CO_2e/ kg fuel = 0.034 kgCO_2e/MJ

Source: *Global Warming Cool It: A Home Guide to Reducing Energy Costs and Greenhouse Gases.* Australian Greenhouse Office, Department of Environment and Water Resources, 2007 (www.carbonneutral.com.au).

Emissions per passenger km for premium economy, business, and first class seats were estimated proportionally to typical seat area (www.seatguru.com).

Embodied emissions (EE) of an aircraft are less than one-tenth the EE per passenger km of a driver-only car, due mainly to the huge distances – over 30 million km – flown by jet aircraft in their lifetime. This is about 120 times the 250,000 km traveled by a typical car in its lifetime.

Depending on the situation and conditions, the APO member countries may select any of the emission factors presented in this manual.

Emission Factor Estimation from Municipal Solid Waste (MSW)

Domestic solid waste comprises a variety of wastes that have greenhouse gas emission potential such as paper and its byproducts, food products, and garden wastes. Such wastes generate methane upon degradation which has higher GWP (global warming potential) compared to CO_2. However, in terms of reporting, it is calculated in relation to carbon dioxide equivalent. The U.S. Environmental Protection

Agency has estimated CO_2e of various domestic waste products, presented below, that can be used for calculation of GHG emissions.

Table 2-8. Methane yield from selected landfill solid waste components

Material	Selected methane yield – tons of carbon equivalent (CO_2e) / wet ton
Newspaper	0.285
Office paper	1.328
Corrugated cardboard	0.591
Coated paper	0.323
Food scraps	0.369
Grass	0.235
Leaves	0.183
Branches	0.187
Methane emissions from landfill = 0.24 kg CO_2e/kg MSW	

Source: U.S. Environmental Protection Agency, 1998.

- Total embodied emissions factor for MSW was estimated by adding embodied energy emissions and methane emissions = 2.45 + 0.24 = 2.7
- Estimated embodied emissions of MSW = 2.7 kg CO_2e/kg

UNCERTAINTIES OVER INVENTORY ESTIMATES

A general treatment of uncertainties in emission inventories is provided in Chapter 3 of Volume 1 of the 2006 IPCC Guidelines. A quantitative analysis of the uncertainties in the inventory requires quantitative input values for both activity data and emission factors. The following table presents uncertainties for activity data and emission factors that will be useful in GHG emission estimation.

Table 2-9. Uncertainties due to emission factors and activity data

1	2	3	4	5
Gas	**Source category**	**Emission factor** U_E	**Activity data** U_A	**Overall uncertainty** U_T
CO_2	Energy	7%	7%	10%
CO_2	Industrial Processes	7%	7%	10%
CO_2	Land Use Change and Forestry	33%	50%	60%
CH_4	Biomass Burning	50%	50%	100%
CH_4	Oil and Natural Gas Activities	55%	20%	60%
CH_4	Coal Mining and Handling Activities	55%	20%	60%
CH_4	Rice Cultivation	$^3/_4$	$^1/_4$	1
CH_4	Waste	$^2/_3$	$^1/_3$	1
CH_4	Animals	25%	10%	25%
CH_4	Animal Waste	20%	10%	20%
N_2O	Industrial Processes	35%	35%	50%
N_2O	Agricultural Soils			2 orders of magnitude
N_2O	Biomass Burning			100%

Note: Individual uncertainties that appear to be greater than ±60% are not shown. Instead, judgment as to the relative importance of emission factor and activity data uncertainties are shown as fractions which sum to one.

Source: *IPCC Guidelines on National Inventory, 2006*. Task Force on National Greenhouse Gas Inventories, IPCC.

CHAPTER 3: GHG EMISSION REDUCTION TECHNOLOGIES

INTRODUCTION

As we have seen, GHG emissions are mainly the result of the use of fossil fuels to generate energy. The main greenhouse gas is carbon dioxide emitted when fossil fuels are burned. It is directly proportional to both energy consumption and economic development. Alarmingly, GHG emissions globally have reached such a critical situation that warrants immediate attention by everyone to adopt mitigation measures to contain the ever-increasing carbon dioxide levels in the atmosphere. The major sectors that contribute to GHG emissions are industry, transportation, and residential, institutional, and commercial buildings.

Most countries have made efforts to improve the energy efficiency of their systems and reduce energy consumption. However, in the absence of widespread, determined, and effective steps to curtail demand growth – by dramatic efficiency improvements and technological developments – primary energy demand is likely to expand two to two-and-a-half fold by 2050 (World Energy Council).

GHG REDUCTION TECHNOLOGIES

The technologies to reduce GHG emissions revolve around reducing or eliminating carbon dioxide emissions and these may be achieved through the following techniques and technologies:

- Use of renewable energies such as solar, wind, biomass, etc.
- Small, mini- and micro-hydro power plants
- Waste-to-energy (WTE)
- Alternative fuels technology
- Fuel substitution
- Fuel cells (transportation and stationary)
- Methane capture from landfill sites
- Green productivity tools and techniques

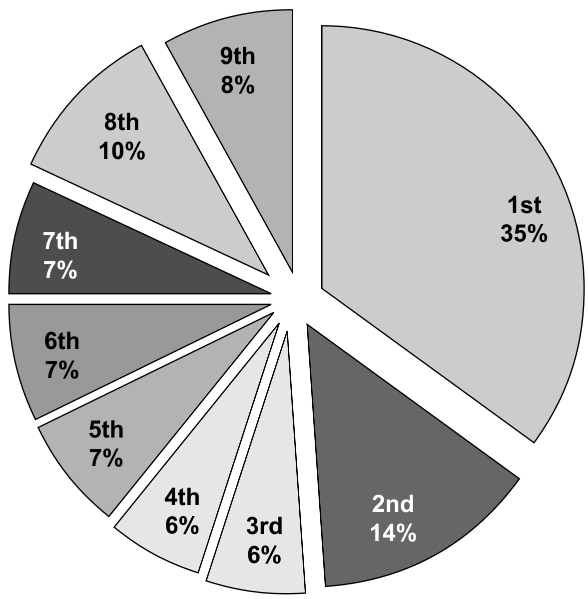
Above all, however, is the energy efficiency that plays such an important role cutting across all existing technologies. Selection of technological options is highly important for mitigating GHG emissions. Before selecting any mitigation technology one has to carry out a detailed needs assessment, with the selection based on the following factors:

- GHG reduction potential
- Assessment of investments required
- Specific cost of GHG reduction, \$/t CO_2
- Correspondence to national and sectoral development goals

How Energy Efficiency Can Lead to CO_2 Reduction

Energy efficiency is the most important factor in mitigating GHG emissions. About 35% in GHG emissions reduction in the energy sector can be brought about by energy efficiency alone and the balance can be achieved by a number of emerging technologies, as listed below.

- Energy efficiency
- Scrubbing CO_2 at power stations
- Afforestation
- Utilization of waste
- New transport fuels
- Renewable energy
- Nuclear power
- Fuel substitution, coal-to-gas combined cycle



Source: *Climate Change.* Ed. Brooks, Cole Publishing, 2001.

Figure 3-1. GHG reduction potential of various technologies

Barrier Analysis

One of the important aspects one should look into is the barriers faced in adopting and/or implementing any technologies. Barrier analysis is highly important particularly in developing economies. Depending upon local conditions, these barriers will vary from country to country; however, generalized obstacles have been listed below to provide a guide to analyzing barriers in specific situations.

Barriers to Energy Efficiency:

- The availability of efficient appliances and production devices;
- The availability of good information for consumers about such equipment and devices; and,
- The availability of technical, commercial, and financial services when necessary.

- Legal
- Organizational, institutional
- Technological
- Financial
- Informational
- Personal/human – attitudinal

After conducting barrier analysis, one should identify enabling measures to overcome these barriers for successful implementation of mitigation programs.

Energy Efficiency

Energy efficiency is an important tool to overcome climate change problems. The Kyoto Protocol objectives, and more recently concerns about energy security, have enhanced the importance of energy efficiency policies. The emissions of carbon dioxide are directly linked with the energy efficiency of the system. As per the World Energy Council (http://www.worldenergy.org/wec-geis), energy efficiency (EE) encompasses all changes that result in a reduction in the energy used for a given energy service such as lighting, heating, etc., or in the level of activity. This reduction in energy consumption is not necessarily associated with technical changes, since it can also result from better organization and management as well as improved economic efficiency in the sector.

According to economists, energy efficiency is defined as encompassing all changes that result in decreased amounts of energy used to produce one unit of economic activity (e.g., the energy used per unit of GDP or value added). Energy efficiency is associated with economic efficiency and includes technological, behavioral, and economic changes (World Energy Council, 2008).

In developing economies as well as developed nations, energy efficiency is also an important issue, however, normally with different driving forces depending upon socio-economic and political considerations. In developing

Some Facts:

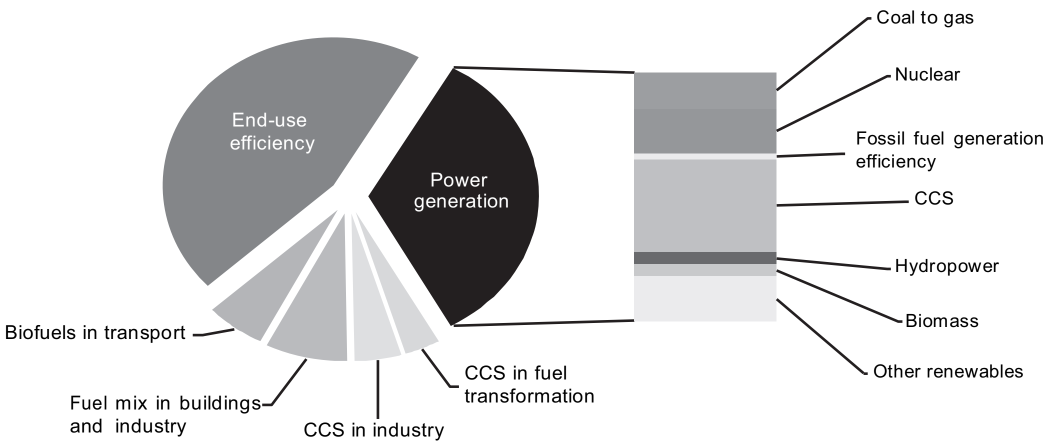
- About 20% of end-use efficiency improvements are offset by higher conversion losses.
- The electricity produced is converted to energy units (toe) on the basis of their average efficiency, which varies from 33% for nuclear power plants to 100% for hydro plants, and to 30% to 40% for thermal power plants.
- Energy efficiency of thermal power generation has improved by only 2% since 1990 at the world level from 32% in 1990 to 34% in 2005.
- At the world level, households and industry account for two-thirds of the reduction of the energy intensity (35 and 30%, respectively).
- Changes in economic structure also influence final energy intensities: services require six times less energy inputs per unit of value added than industry.
- Estimated mitigation potential during Kyoto Period
    - Renewable energy technologies (23 MT)
    - Energy efficiency (77 MT)
    - Electricity T&D (18 MT)
    - Methane mitigation technologies (20 MT)

countries, the need to reduce GHG emissions and local pollution has relatively less priority. However, other related issues such as reducing the financial burden of oil imports, reducing investment on energy infrastructure, and making the best use of existing supply capacities in order to improve access to energy are among the more important driving forces. Further, the problem has been accentuated following the steep increase in oil prices since 2003, which has increased the cost of oil imports drastically, with severe consequences for economic growth especially in the poorest countries. In this regard, any efficiency improvement in oil-consuming sectors will not only result in direct economic benefits to oil importing countries but also will serve more consumers.

Improvement in EE in energy-intensive sectors, by reducing the amount of energy input without changing the quality or quantity of end-use services rendered, makes the path for economic development less expensive and more sustainable. EE improvements yield direct benefits, such as reduced burdens on investment for energy infrastructure projects, lowered levels of crude oil imports, greater affordability, improved access to modern energy sources through more-affordable energy services, reduced local air pollution, and the global benefits of reduced greenhouse gas emissions.

Improved EE also yields economic and social benefits, including enhanced energy security, reduced impact on consumers from energy price increases, and employment generation through development of domestic EE industries. Although the role of EE in mitigating climate change is well understood, large gaps remain between industrialized and developing countries in terms of EE potential and investments. According to the International Energy Agency (IEA), more than 65% of GHG reductions through 2030 could come from EE measures in developing and transition countries.

Improved EE in buildings, industry, and transport alone could lead to a one-third reduction in energy use by 2050. Figures 3-1 and 3-2 illustrate that existing and emerging energy conservation alternatives and improved end-use efficiency are the most important contributors to reduced GHG emissions. Improving EE – by obtaining more light, heat, mobility, or other services from less primary energy input – is also one of the least expensive means of GHG emission reductions. As with other climate change mitigation projects, if investment on EE is cost-effective, then the GHG emissions savings will essentially be free.



Source: *An Analytical Compendium of Institutional Frame Works for Energy Efficiency Implementation.* Energy Sector Management Assistance Program. Formal Report 331/08. ESMAP, The International Bank for Reconstruction & Development/The World Bank Group, October 2008.

Figure 3-2. GHG emissions reductions through 2050, by consuming sector

Table 3-1. Opportunities for EE improvements by consuming sector

Sector	EE Improvement Opportunities
Buildings	Building design and measures such as better insulation, advanced windows, EE lighting, space conditioning, water heating, and refrigeration technologies
Industry	Industrial processes, cogeneration, waste heat recovery, preheating, efficient drives
Cities and municipalities	District heating systems, combined heat and power, efficient street lighting, efficient water supply, pumping, and sewage removal systems
Agriculture	Efficient irrigation pumping and efficient water use, such as drip irrigation
Power systems	*New thermal power plants:* Combined cycle, supercritical boilers, integrated gasification combined cycle (IGCC), etc. *Existing generation facilities:* Refurbishment and repowering, improved O&M practices, and better resource utilization (higher plant load factors and availability) *Reduced transmission and distribution losses:* High voltage lines, insulated conductors, capacitors, low-loss transformers, and improved metering systems
Transport	Efficient vehicles, urban mass transport systems, modal shifts to inter- and intra-city rail and water transport, CNG vehicles, traffic demand management
Households	Lighting, appliance efficiency, improved cook stoves

Source: *An Analytical Compendium of Institutional Frame Works for Energy Efficiency Implementation.* Energy Sector Management Assistance Program. Formal Report 331/08. ESMAP, The International Bank for Reconstruction & Development/The World Bank Group, October 2008.

Energy efficiency is, in fact, a matter of individual behavior and also reflects the natural behavior of energy consumers. Avoiding unnecessary consumption of energy or choosing the most appropriate equipment to reduce the cost of the energy helps not only to decrease individual energy consumption without decreasing individual welfare but also gives economic gains.

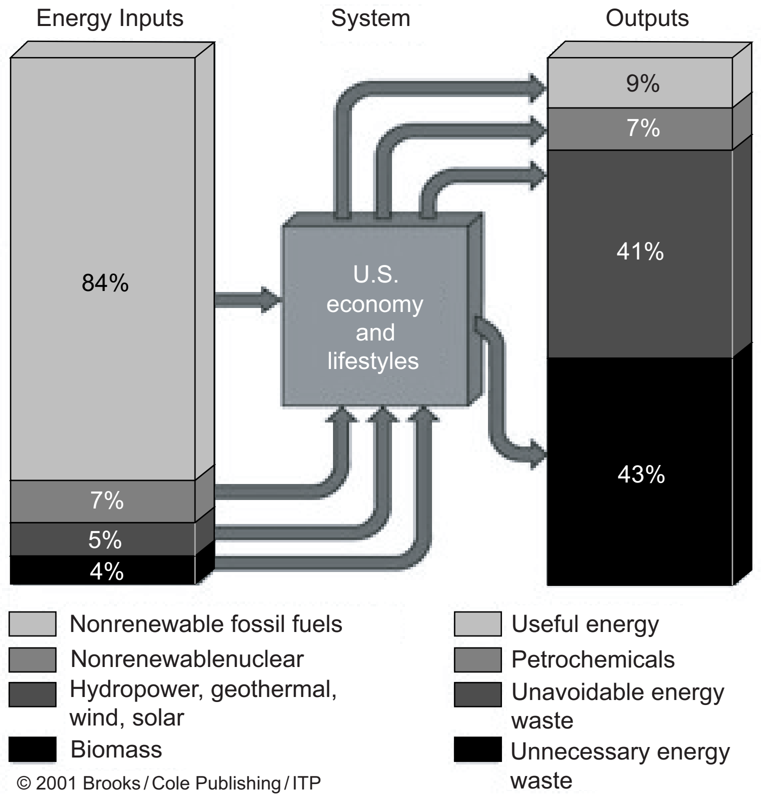
Energy efficient technologies normally represent upgradation in service through improved performance. A wide range of energy efficient technologies have ancillary benefits from improved quality of life such as advanced windows that not only save on heating and cooling expense, but also make the home or workplace more comfortable. Similarly, more efficient vehicles not only save on fuel costs, but also emit less pollutants. Thus, improving the general environment

Benefits of Energy Efficiency:

- Energy saved is energy produced.
- Supply more consumers with the same electricity production capacity, which is often the main constraint in many countries of Southeast Asia.
- Reduced electricity demand, and reduced investment needed for expansion of the electricity sector.
- Reduced GHG and other emissions.
- Maintains a sustainable environment.
- Improved energy security.
- Increased profits.
- Reduced energy bills.
- Reduced energy imports.

improves health directly and saves on health costs both to the individual and to society indirectly. However, adoption of energy efficient technologies and energy management practices varies widely with nations as per their respective policies. Energy efficiency provides a tremendous cost-effective opportunity to reduce the need for new power generation and GHG emissions. The EE opportunities in energy-intensive sectors are presented in Table 3-1.

The following figure shows the relationship between the U.S. economy and lifestyle with respect to energy use. If we look into this critically, about 43% of expended energy is wasted unnecessarily while only 9% is useful energy.



Source: *Climate Change.* Ed. Brooks, Cole Publishing, 2001.

Figure 3-3. Showing relationship between economy & lifestyle for energy use

GHG REDUCTION TECHNOLOGIES FOR INDUSTRIES

Among the industrial sectors, energy-intensive sectors such as iron and steel, pulp and paper, oil and gas extraction, and thermal power plants are the main GHG contributors. Large industries, however, can improve energy efficiency in their production processes and thus reduce overall energy demand. The bulk of GHG reduction technology expenditures are made in these energy-intensive sectors.

In addition to energy-related GHG emissions, the industrial sector also emits GHGs from various processes. These include:

- CO_2 from the calcination process in lime and cement production; steel (production of coke and pig iron); production of aluminum and ammonia
- Refrigerants, aerosols, CFCs, HCFCs, HFCs, etc.

- Methane from miscellaneous industrial processes such as oil refining, coal mining, etc.
- N_2O from nitric acid and nylon production, perfluorocarbons such as carbon tetrafluoride, and hexafluroethylene from aluminum production through electrolysis

International Barriers in GHG Reduction Technologies:

- Disagreements over intellectual property rights
- Lack of available finances
- Lack of capacity and basic environmental legislations and institutional factors in host countries
- Legal and treaty impediments to implement cooperative actions among firms to reduce GHGs
- Within WTO, there is concern about environmental protection as a potential restraint on free trade

The total energy share of the industrial sector for OECD Annex I countries in 1988 was typically 25–30% of total energy used; however, the amount for non-Annex I countries averaged 35–45%, and was as high as 60% in China. It is evident that different countries have followed different fossil fuel trajectories to arrive at their present economic status. This variation in industry energy share among different countries not only indicates differences in energy intensity but also the more rapid industrial growth of non-Annex I countries (IPCC Technical Paper 1, 1996).

During the early 1990s, carbon emissions from industrial sectors in the European Union and U.S. remained below their peak levels of 10–15 years earlier, while Japan's emissions remained relatively constant. However, the CO_2 emissions from the industrial sectors of non-Annex I countries continue to grow with rapid industrialization.

The past two decades have seen huge improvement in the efficiency of industrial processes due to introduction of cleaner technologies. However, energy efficiency remains the major area for reducing CO_2 emissions.

There is a direct correlation between energy use and levels of GHG emissions, so activities related to GHG emission reduction are closely tied to energy conservation and energy efficiency strategies.

Industries invest in various GHG reduction technologies including applications on solar energy, cogeneration, alternative fuels, and waste-to-energy. Currently, the major expenditure on GHG reduction is related to operating, repairing, and maintaining cogeneration facilities, waste-to-energy, and fuel substitution technologies. The investment on GHG reduction technologies may not have substantial impact on the reduction of energy consumption in the short term but instead may be spread over several years.

Case Studies on Energy Efficiency in SMEs

In the face of increasing fuel prices and limited resources, the industrial sector, particularly small and medium industries in countries with transition economies, has undertaken a number of initiatives to improve the energy efficiency of industrial processes. Some examples of energy efficiency approaches adopted by Indian industries are highlighted below. In view of the similar conditions in most APO member countries, the examples presented here may be considered to be widely applicable.

Iron and Steel Sector – Small Steel Re-rolling Mill (NPC, India 2005)

Baseline data

• Re-rolling mill furnace capacity	10 tons/hr
• Mill operation per day	10 hrs
• Operating days per year	250
• Production during 2004	14,721 tons
• Specific oil consumption	
• (Heat-up time + production)	115 liters/ton
• Cost of oil	60 USD/kL
• Specific power consumption	111.65 kWh/ton
• Cost of power	0.13 USD/kWh
• Total cost of energy	
– Oil	101,575 USD
– Electricity	213,668 USD
Total	315,243 USD

Energy efficiency measures

In order to reduce energy cost, the combustion efficiency of the furnace was improved by providing the appropriate quantity of oxygen along with the adoption of a heat recovery system from the flue gas. These measures resulted not only in economic gains but also a reduction in GHG emissions, as given below.

I. Oil savings

• Specific oil consumption before implementation	115 liters/ton
• Specific oil consumption after implementation	77.8 liters/ton
• Reduction in oil consumption	37.2 liters/ton (32.3% down)
• Annual reduction in oil consumption	37.2 x 14,721 = 547.6 kL
• Annual monetary savings	547.6 x 60 USD = 19,714 USD
• Annual reduction in GHG emissions	16,42.8 tons

II. Power savings

• Specific power consumption before implementation	111.65 kWh/ton
• Specific power consumption after implementation	76.17 kWh/ton
• Reduction in power consumption	111.65 – 76.17 = 35.48 kWh/ton
• Annual power savings	35.48 x 14721 = 0.522 million kWh
• Annual monetary savings	67,860 USD

III. Annual savings due to increased yield

• Average yield before	91.986%
• Average yield after	95.039%
• Increase in yield percentage	3.053%
• Average production during 2004	14,721 tons
• Extra production from improved yield	449.4 tons
• Cost of finished product	600 USD/ton
• Monetary benefit	449.4 x 600 269,640 USD

Total annual monetary gain after implementing GP-EE measures:
19,714 + 67,860 + 269,640 = 355,214 USD

Case Studies on GHG Reduction Through Energy Efficiency in Indian Industries (Table 3-2)

Indian industries have taken a number of initiatives to improve their energy efficiency not only on their own but also through regulatory approaches. The Bureau of Energy Efficiency, under the Indian Ministry of Power, has taken several initiatives to help SMEs by providing technical assistance.

Table 3-2. Case studies of GHG reduction through energy efficiency in Indian industries

No.	Industry/ Sector	Implemented	Measures adopted	1st year energy savings (USD)	1st year electricity /fuel savings	1st year CO_2 mitigated (tons)	Assumed sustainability (years)	Expected CO_2 emissions mitigated across entire life cycle (tons)
1	Hindalco Ind. Ltd., Renukoot, UP (Aluminum)	2003–4	• Use of slotted anode in pot smelter • Optimization of anode dimensions and metal pad	4,161,325 2,670,000	146,725 MWh 77,265 MWh	146,725 77,265	10 10	1,467,250 772,650
2	Tata Motors, Jamshedpur (Automobile)	2004	Intermediate controllers for compressed air system	27,720	1005 MWh	1005	10	10,050
3	Technical Stampings Automotive Ltd., TN (Automobile)	2004–5	Installation of energy savor coil (energy efficient transformer)	14,730	128 MWh	128	10	1280
4	Birla Super Cement, Sholapur, Maharashtra (Cement)	2003–4	• Reduction of power by process modification • Process modification in ball mill	58,925 60,450	673 MWh 722 MWh	673 722	10 10	6,730 7,230
5	Shree Cement Ltd., Beawar, Rajasthan (Cement)	2005	Closed circuiting of cement mill	207,500	10,661 MWh	10,661	10	106,610
6	Dalmia Cement, Dalmiapuram, TN (Cement)	2005	Dry fly ash storage and handling system	410,000	100 MWh	5,780	10	57,800
7	Tuticorin Alkali Chemicals and Fertilizers Ltd., TN (Chemical)	2005	Installation of gasifier	187,500	604 MWh	9,681	10	96,810
8	Gharda Chemicals Ltd. (Chemical)	2003–4	Installation of high efficiency impellers in batch reactors	125,000	1,200 MWh	1,200	10	12,100
9	Polyplex Corp. Ltd., Uttaranchal (Chemical)	2005	Replacing steam jet ejectors with vacuum pumps	297,500	660 kL oil	1,986	10	19,860
10	Rashtriya Chemicals and Fertilizers Ltd., Trombey, Maharashtra (Chemical)	2005	Flare gas utilization	10,750	1,479,090 cu.m gas	4,120	10	41,200

Table 3-2. Case studies of GHG reduction through energy efficiency in Indian industries (continued)

No.	Industry/ Sector	Implemented	Measures adopted	1st year energy savings (USD)	1st year electricity /fuel savings	1st year CO_2 mitigated (tons)	Assumed sustainability (years)	Expected CO_2 emissions mitigated across entire life cycle (tons)
11	Siel Chemical Complex, Rajpura, Punjab (Chemical)	2005–6	Membrane cells refurbishment to reduce voltage drop and power consumption	829,775	7,951 MWh	7,951	10	79,510
12	Mahanand Dairy, Maharashtra (Dairy)	1990	Use of solar water heater for boiler feed water pre-heating, etc.	6,400	70 kL oil	211	10	2,110
13	Hindustan Lates Ltd., Karnataka (Pharmaceuti-cal)	2005	Replacement of steam traps and heat recovery from steam condensate	82,450	11,162 kL oil	33,665	10	330,650
14	IPCA Laboratories, Ratlam, MP	2006	Installation of energy savers	61,875	1,734 MWh	1,734	10	17,734
15	National Fertilizers Ltd., Vijaipur (Chemical)	2003–4	Heat recovery from pre-concentrator by installing DM water pre-heater in ammonia plant	1,705,000	6,060 kL naptha	13,298	10	132,980
16	Brakes India Ltd., Vellore, Tamilnadu (Foundry)	2005	Redesigning of furnace coil	144,000	1440 MWh	1440	10	14,400
17	Rashtriya Ispat Nigam Ltd., Vizag Steel (Iron & Steel)	2006–7	Optimization of combustion parameters in coke oven batteries	960,000	951 million cu.m gas	122,854	10	1,225,840
18	Tata Steel Ltd., Jamshedupur, Jharkhand (Iron & Steel)	2006–7	Substitution of coal with by product gas in boilers of power house	1,625,000	201,464 tons coal	286,079	10	2,860,790
19	Nagaon Paper Mill, Assam (Pulp & Paper)	2004	Improvement of power factor by installation of capacitor bank and filter in HT and LT lines	231,325	8,750 tons coal	12,425	10	124,250
20	Sirpur Paper Mills, Andhra Pradesh (Pulp & Paper)	2003–4	Replacing the boiler feed pump motor	26,031	833 MWh	833	10	8,330

Table 3-2. Case studies of GHG reduction through energy efficiency in Indian industries (continued)

No.	Industry/ Sector	Implemented	Measures adopted	1st year energy savings (USD)	1st year electricity /fuel savings	1st year CO_2 mitigated (tons)	Assumed sustainability (years)	Expected CO_2 emissions mitigated across entire life cycle (tons)
21	Ballarpur Industries Ltd, Chandarpur, Maharashtra (Pulp & Paper)	2003–4	Use of activizer "G" with coal in coal fired boiler	267,500	7,259 tons coal	10,307	10	103,070
22	Neyveli Lignite Corporation Ltd., Tamilnadu (Thermal Power)	2004–5, 2005–6	• Replacement of old efficiency water circulating pumps • Replacement of wooden fills with un-bounded PVC fills in cooling tower • Replacement of dyno-drives with variable frequency drives	159,500 512,900 118,925	3,504 MWh 25,472 tons coal 416 MWh	3,504 36,170	10 10	35,040 361,700
23	Manglore Refinery and Petrochemicals Ltd., Karnataka (Refinery)	2006–7	Utilization of waste heat for pre-heating crude	2,047,500	5,623 liters oil	16,960	10	169,600
24	Century Rayon, Maharashtra (Textiles)	2005–6	Energy conservation in compressed air systems	93,750	960 tons coal	1,363	10	13,630
25	Indian Rayon, Veraval (Textiles)	2004–5	Control of water supply by installation of variable frequency drive on cooling water pumps	25,700	187 MWh	187	10	1,870
26	Apollo Tyres Ltd., Pirambra, Kerala (Tires)	2004	Plant lighting	147,500	1,700 MWh	1,700	3	5100
27	J.K. Tyre and Industry Ltd., Rajasthan (Tires)	2006–7	Optimization of energy on cooling towers	162,910	1,512 MWh	1,512	10	15,120
28	Rama Phosphate Ltd., Indore, M.P. (Edible Oil)	2000–2	Waste heat recovery in boiler and installation of FBC boiler	337,500	1,350 tons coal	2,025	10	20,250

Source: Greenhouse Gas Mitigation through Energy Efficiency by Indian Industry 2007 – Compendium Vol. 1; Bureau of Energy Efficiency and Indo-German Energy Program.

Tips for Energy Efficiency in Industries
Based on a study carried out by the National Cleaner Production Center (NCPC) of India during 2002–4 under the GERIAP* project in various industrial sectors of Southeast Asian countries, some important tips were suggested to improve the energy efficiency of various equipment and activities. These EE measures have had great impact on the emission of GHGs.

**Greenhouse Gas Emission Reduction from Industry in Asia and the Pacific*

The project was funded by the Swedish International Development Cooperation Agency and coordinated by United Nations Environment Program and implemented together with national focal points in nine countries: Bangladesh, China, India, Indonesia, Mongolia, the Philippines, Sri Lanka, Thailand, and Vietnam.

Key suggestions included:

- Use variable-speed drives on large boiler combustion air fans with variable flows
- Use boiler blow down to help warm back-up boilers
- Maintain lowest acceptable process steam pressures
- Use waste steam for water heating
- Monitor O_2/CO_2/CO and control excess air to the optimum level in furnaces
- Retrofit furnaces with heat recovery device
- Recover heat from incinerator off-gas
- Use waste heat for fuel oil heating, boiler feedwater heating, outside air heating, etc.
- Use chiller waste heat to preheat hot water
- For compressed air, replace standard v-belts with high-efficiency flat belts as the old v-belts wear out
- Use water-cooled rather than air-cooled chiller condensers
- Shut down spare, idling, or unneeded equipment
- Make sure that all utilities to redundant areas are turned off, including utilities such as compressed air and cooling water

EE "DOs and DON'Ts"
For efficient energy utilization, the following is recommended:

DOs

- Clean burners, nozzles, strainers, etc.
- Inspect oil heaters for proper oil temperature
- Inspect for buildup of soot, fly ash, and slag on the fire side of boiler
- Maintain lowest acceptable process steam pressure
- Preheat boiler feed-water
- Insulate all flanges, valves, and couplings
- Check alignment of motors
- Correct power factor to at least 0.90 under rated load conditions in electric utilities
- Check belt tension regularly and use flat belts as an alternative to v-belts in drives

- Change oil filters regularly in compressors
- Use evaporative cooling in dry climates for heating/ventilation/air conditioning (HVAC)
- Seal leaky HVAC ducts and around coils
- Use water-cooled condensers rather air-cooled condensers in refrigeration systems
- Conduct regular energy audits
- Change exit signs from incandescent to LED illumination
- Turn off all utilities when not needed
- Replace old spray-type nozzles with new square spray ABS virtually non-clogging nozzles

DON'Ts

- Don't waste hot water by disposing in drain
- Don't continue using wet insulation, better to replace it
- Don't run fans when not needed
- Don't overcharge oil in chillers
- Avoid over-sizing refrigeration systems – match the connected load
- Don't assume that the old way is still the best – particularly for energy-intensive low temperature systems for refrigeration

Some EE Facts

Boilers

- A 5% reduction in excess air increases boiler efficiency by 1%, and a 1% reduction of residual oxygen in stack gas increases boiler efficiency by 1% (Limit excess air to less than 10% with clean fuels.)
- A 1 mm-thick scale (deposit) on the water side of a boiler can increase fuel consumption by 5 to 8%.
- A 3 mm-thick soot deposition on the heat transfer surface of a boiler can cause an increase in fuel consumption by 2.5%.

Steam systems

- A 3 mm-dia. hole in a pipeline carrying 7 kg/cm^2 steam wastes 33 kiloliters of fuel oil in one year.
- A 6º C rise in feed water temperature through economizer/condensate recovery in a boiler realizes a 1% savings in fuel consumption.
- A 0.25 mm-thick air film offers the same resistance to heat transfer as a 330 mm-thick copper wall.

Insulation

- A bare steam pipe 150 mm in diameter and 100 m in length, carrying saturated steam at 8 kg/cm^2, would waste 25,000 liters of furnace oil in a single year.
- A 70% reduction in heat loss can be achieved by floating a layer of 45 mm-diameter polypropylene (plastic) balls on the surface of 90ºC hot liquid/condensate.

Motors

- High efficiency motors offer 4–5% higher efficiency compared to standard motors.
- For every 10º C increase in motor operating temperature over the recommended peak, the life of the motor is estimated to cut in half.
- A voltage imbalance can reduce motor input power by 3–5%.
- If rewinding is not properly done, motor efficiency can be reduced by 5–8%.

Compressed air

- Reduction of 1 kg/cm^2 air pressure (8 kg/cm^2 to 7 kg/cm^2) would result in 9% input power savings. This also reduces compressed air leakage rates by 10%.
- A compressed air leak from 1 mm-size hole at 7 kg/cm^2 pressure causes a power loss equivalent to 0.5 kW.
- Each 5°C reduction in intake air temperature results in a 1% reduction in compressor power consumption.

Chillers

- Reducing condensing temperature by 5.5°C results in a 20–25% decrease in compressor power consumption.
- A 1°C increase in evaporator temperature reduces compressor power consumption by 20–25%.

Source: *Energy Efficiency Guide for Industries in Asia.* UNEP, 2002.

RESIDENTIAL, INSTITUTIONAL, AND COMMERCIAL BUILDINGS (INFRASTRUCTURE SECTOR)

Climate change is caused by an increase in greenhouse gases in the Earth's atmosphere. These gases absorb heat leaving the earth and return some of it, making the earth warmer overall. Before the industrial revolution, carbon dioxide levels in the atmosphere were consistently between 260 and 280 parts per million (ppm). In recent times human activities have increased the concentration to 380 ppm — that's an increase of more than a third! The following activities from residential buildings generate greenhouse gases:

- burning fossil fuels – coal, oil, or gas
- using electricity generated by burning fossil fuels

Some Important Tips:

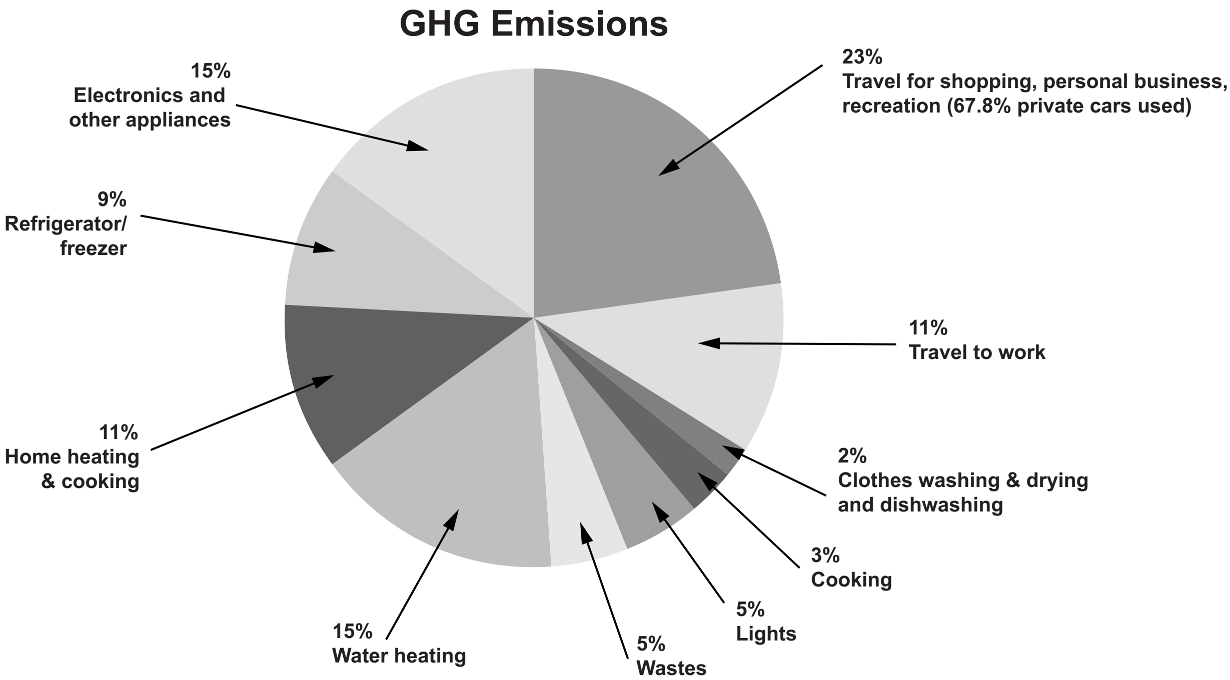
- Add insulation, especially to the roof.
- Change your window glass to double glazing and add outside shades to use in summer.
- Buy an electric bike and use carpool for long trips.
- Consolidate your trips.
- Buy energy-efficient appliances with "Energy Labels."

Some Facts:

- One liter of petrol, diesel and gas emits 0.00222, 0.00268 and 0.00165 kg CO_2
- An 18-Watt CFL emits 20 gm/hr CO_2 as compared to 110 gm/hr from a 100-Watt incandescent lamp.

- several aspects of farming: raising cattle and sheep, using fertilizers, and some crops
- clearing land
- breakdown of food and plant wastes and sewage

The following figure illustrates a generalized percentage contribution of GHG emissions from various sources originating from typical households. It can be observed that maximum GHG emission is contributed by travel activities followed by water heating and electronic and other appliances used inside the home. In view of this, more emphasis should be given to reduce GHG emissions from these major sources.



Source: *Global Warming Cool It: A Home Guide to Reducing Energy Costs and Greenhouse Gases*. Australian Greenhouse Office, Department of Environment and Water Resources, 2007.

Figure 3-4. Showing energy consumption in various areas of a household

Although the climate changes naturally on its own, humans contribute heavily to pollution of the environment. More and more people are wondering how they can do their part to help reduce greenhouse gases emissions into the atmosphere. While change won't happen overnight, here are actions you can take against global warming.

In order to reduce energy consumption and improve the energy efficiency of residential, commercial, and institutional buildings, the Bureau of Energy Efficiency, Ministry of Power, India, has issued guidelines specifying a "U-factor" for roof assembly and an "R-factor" for wall insulation. Examples of these factors are given in the following tables. Calculations using the U- and R-factors are presented in Annex 12.

Table 3-3. Roof assembly U-factor and wall insulation R-factor requirements

Climate zone	24-hour-use buildings Hospitals, hotels, call centers, etc.		Daytime-use buildings Other building types	
	Maximum U-factor of the overall assembly	Minimum R-value of insulation alone	Maximum U-factor of the overall assembly	Minimum R-value of insulation alone
	(W/m^2-C)	(m^2-C/W)	(W/m^2-C)	(m^2-C/W)
Composite	U-0.261	R-3.5	U-0.409	R-2.1
Hot and dry	U-0.261	R-3.5	U-0.409	R-2.1
Warm and humid	U-0.261	R-3.5	U-0.409	R-2.1
Moderate	U-0.409	R-2.1	U-0.409	R-2.1
Cold	U-0.261	R-3.5	U-0.409	R-2.1

Source: *Energy Conservation Building Code (ECBC) 2006.* Bureau of Energy Efficiency, Ministry of Power, India.

Water Heating

Water heating for domestic use produces about 16% of all household-generated GHG emissions. The various sources of hot water requirements are shown in the following Figure 3-5. As can be seen, about 30% of related GHG emissions are caused by heat loss from water heater tanks and pipes, which is the second-highest consumer of energy in the home after bathing (45%).

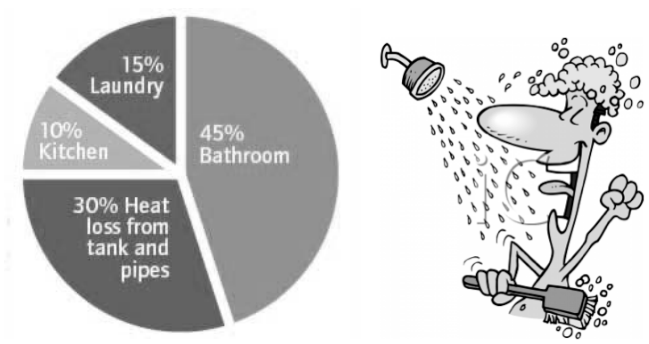


Figure 3-5. Greenhouse gas emissions from electric hot water system (140 liters usage daily)

Some Important GHG Mitigation Tips for Your Home:

- Showers squander the greatest amount of hot water in most homes, hence take shorter showers. By the act of turning off the shower, you can prevent the release of up to half a kilogram of GHGs every minute that the shower is needlessly kept on.
- Avoid rinsing dishes in running hot water. Avoid using even small amounts of hot water if cold water can do instead.
- Switch off your hot water system in case you are going away for a few days.

- Reduce heat loss from an electric- or gas-heated storage tank by wrapping the tank with extra insulation to cut energy bills and save up to half a ton of GHGs each year. An insulated outdoor unit will need to be protected from the weather.
- If the overflow pipe from a hot water service releases more than a bucket of water each day, call a plumber and prevent the release of hundreds of kilograms in GHG emissions each year.

Some Facts:

- An average household using electricity for water heating generates about 4 tons of greenhouse gas (GHG) each year while using natural gas generates about 1.5 tons.
- Every 15 liters of hot water from an electric heater generates about 1 kg of greenhouse gas.
- About 5 minutes less hot water rinsing every day can save a ton of GHG each year. Water-efficient taps can also save hot water and GHG: save up to a kilogram of GHG for every five minutes of tap use.
- Fix dripping hot taps: save up to 100 kg of GHG each year for each tap.

- If you have gas-heated water, you save about one-third of the amount of GHGs quoted above, which apply to electric hot water heaters. Solar water heating, of course, generates even lower greenhouse gas emissions.
- When installing a hot water system, position it so that pipes to outlets used the most are as short as possible. Long pipes can waste thousands of liters of hot water and half a ton of greenhouse gases each year.
- Avoid installing a continuously circulating hot water pipe loop. Such loops waste large amounts of heat and are expensive to use.
- Ensure that exposed hot water pipes are well insulated, with insulation at least 10 millimeters thick.

Source: *Global Warming Cool It: A Home Guide To Reducing Energy Costs and Greenhouse Gases*. Australian Greenhouse Office, Department of Environment and Water Resources, 2007.

Energy-Saving Tips

- Switch off all lights, appliances, and equipment when they're not needed.
- Divert garden and food wastes from landfill disposal to composting (either at home or through a local government scheme).

Some Important Tips:

- Install energy-efficient compact fluorescent lamps.
- Switch off your second fridge except when it's really needed.
- Use solar power – dry your clothes on the clothes line outside, not in a dryer.
- Select only energy-efficient devices.

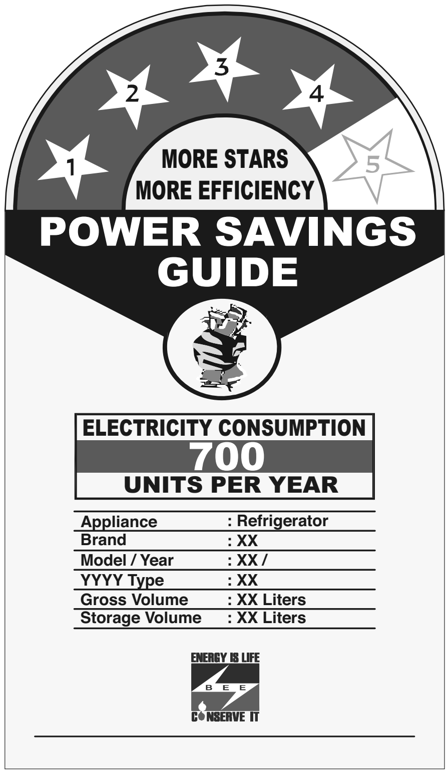
- Make your home more comfortable by insulating, draft-sealing, and shading windows in summer.
- Manage home heating and cooling by setting the thermostat appropriately, i.e., turn it up a couple of degrees in summer and down a couple of degrees in winter.
- Cut hot water usage by installing a water-efficient showerhead, taking shorter showers, and using cold water to wash household laundry.
- Switch to low greenhouse impact transport options such as a bicycle or public transport – or use the phone or email.
- Minimize waste of packaging and materials: Always remember the "Four R's": refuse, reduce, re-use, and recycle.

Many countries have introduced energy conservation bills to improve energy efficiency in facilities, public buildings, and residences. In India, for example, the government is promoting energy-efficient lighting not only in households but also for streetlights. In order to encourage local bodies, demonstration projects have been undertaken in various parts of the country by the Bureau of Energy Efficiency, Ministry of Power, India.

Refrigerators and Freezers

Some Important Tips & Facts:

- Use energy labels to choose your energy-efficient, greenhouse-friendly new fridge/freezer. Don't buy bigger than you need.
- Locate refrigerators and freezers in cool spots, out of the sun: save up to 100 kg of greenhouse gas each year.
- Small fridges and wine coolers without energy labels are very inefficient, and can generate up to 6 times as much GHG.
- Save up to 150 kg of greenhouse gas each year with good air circulation around the coils at the back of the refrigerator.
- To keep food safe and save energy, set the fridge temperature at 3–5°C. Setting it 1°C lower than necessary releases 15 to 50 kg more greenhouse gas each year.
- Continuous running of fridge or freezer motor will waste 20 kg of GHG every week.
- Switch off second fridge, if not used, and save up to one ton of GHG per year.
- Cooling a 2-liter drink from room temperature generates 10 times as much GHG as opening the refrigerator door.



Source: Bureau of Energy Efficiency, Ministry of Power, Government of India.

Figure 3-6. Energy label developed in India

Good Ideas About Lighting

Some Important Tips:

- Don't connect more than three lights to a single light switch – then you can leave lights switched off that you don't really need.
- Select light fittings with reflectors that direct light where you want it and do not absorb too much light – colored glass can halve light output, creating a need for higher wattage lamps.
- LED (light-emitting diode) lamps are beginning to appear for outdoor use and specialized applications like night-lights. These lamps are very long-lasting and efficient. We'll see a lot more of them in coming years. The Bureau of Energy Efficiency in India is promoting the use of LED lighting systems for street lighting.
- Traditional CFLs (compact fluorescent lights) deliver most of their light to the sides: an effective reflector may be needed to better direct the light. Corkscrew-shaped CFLs and CFLs enclosed in frosted plastic spheres distribute light in a pattern more like that of incandescent lamps.
- Just a few outdoor lights left on every evening can double a household's greenhouse gas emissions and lighting costs; switch them off if they are not needed.
- Install daylight and movement sensors so outdoor lights switch on only when they are needed, and don't waste electricity.
- Use natural light in commercial buildings by providing light wells to access sunlight as much as possible.
- Use daylight sensors that dim hallway lighting when sufficient daylight is present, and occupancy sensors to turn office lights off when rooms become vacant.

Some Facts:

- Over its life, a typical compact fluorescent lamp saves around a third of a ton of greenhouse gas.
- Fluorescent lamps cut greenhouse gas emissions and running costs by 75% while producing as much light. They come as circular or linear tubes, or as plug-in compact fluorescent lamps (CFLs).
- Low voltage halogen lamps are not low energy lamps: each one generates a kilogram of greenhouse gas every 15 hours—about the same as an ordinary 60 watt lamp, although it does produce a little more light. Halogens are not easily replaced by more efficient alternatives, so installing them locks you in to high lighting bills.

- Use low-emissivity (low-E) glass for windows and cover roofs with light-colored material that reflect the sun's heat.
- Install solar-powered garden lights and street lights within housing complexes.

- Turn off all unnecessary lights, including fluorescent lamps.
- Use natural light instead of artificial light – but don't overdo it: large windows and skylights add to summer heat and winter cold.
- Paint or wallpaper the walls of rooms with light colors. Dark colors absorb light, increasing the amount of lighting needed.
- Use desk lamps or standard lamps (with CFLs) where stronger light is needed, so less lighting is required in the rest of the room.
- Modern dimmer controls reduce greenhouse gas emissions as they reduce light output. They also extend lamp life. Dimmer controls can now also be used with some CFLs, but check the label first.
- Clean lamps and fittings regularly; over time, dirt build-up reduces light output.

Electronics

Important Tips to Save Electricity

- When appliances are switched off at the device, but left on at the wall switch, they may use some energy for standby power. Typically this is between 1 and 20 watts, with most appliances using less than 5 watts. This amount converts to about 45 kg of greenhouse gas each year for each item.
- Switch appliances off at the power point, not just at the device itself.
- When some appliances, such as VCRs, DVDs, and CD players are left on after use, they remain in active standby mode, often using more than twice as much energy as they do when switched off at the appliance

Some Important Facts:

- A large screen TV, used 6 hours a day, can generate around half a ton of greenhouse gas each year—more than a family fridge.
- Just turn it off if you aren't watching it!
- The most efficient conventional TVs around 76 cm generate a third as much greenhouse gas as big screen plasma and LCD TVs.
- DVDs, VCRs, TVs, packaged sound systems, computers and monitors, scanners, printers, and fax machines may carry an Energy Star label. This shows the product has much lower standby energy consumption than standard products.
- Many appliances use electricity even when they are not in use and kept on standby mode.
- When appliances are switched off at the power point, they don't use energy.
- Over the whole year, some microwave ovens generate more GHG running the digital clock than cooking food.

and in normal standby mode. Switch them off at the appliance to save some energy and switch them off at the power point to save even more!

Computers and laptops

- A laptop computer used 5 hours each day generates around 40 kg of greenhouse gas in one year. A desktop computer uses more power and can generate between 200 and 500 kg of GHG in a year. More than half of this is from the monitor.
- An LCD computer monitor generates around half as much greenhouse gas as older CRT monitors. Lowering display brightness on LCG screens can cut emissions to a quarter of the usual amount.
- Switch computers and equipment off when they're not in use. This cuts greenhouse gases, extends product life, and reduces fire hazards.

GHG REDUCTION TECHNOLOGIES FOR THE TRANSPORT SECTOR

If we look into the growth in GHG emissions and the use of energy, China leads with 6% annual growth in GHG emissions from the transport sector followed by India with 5% as compared to 1–2% a year in the developed world. Of this, about 96% of transport energy comes from oil with road vehicles contributing three-quarters of the total. If this trend continues, GHG emissions from transport will grow by 80% by 2030 compared to 2002. Freight transport is often ignored in analyses, but it constitutes 35% of transport emissions and is growing fast. Freight trucks now dominate energy use and GHG emissions; air freight is still small but growing quickly.

According to estimates by the World Resource Institute, the transport sector contributes about 14% to total global GHG emissions. Within this sector, road transport comprises about 72%, air transport 11%, and marine transport 8% (WRI, 2005). In view of this, it is especially important to concentrate on road travel. The CO_2 contribution according to type of fuel is presented in the following table.

Table 3-4. CO_2 emissions according to fuel type

Fuel	Emission/fuel type (CO_2/liter)
1. Petrol	0.00222
2. Diesel	0.00268
3. LPG	0.00165

Source: *CP-EE Tool Kit.* National Cleaner Production Centre / National Productivity Council (www.energyefficiencyasia.org).

With growing oil prices, alternative fuels will be promoted that will have great impact on GHG emissions. The alternative fuels will come from unconventional oil, coal, and natural gas. Bio-fuels newly introduced in the market can play a major role, with positive GHG emissions effects; however, it may have negative impacts on the environment and on food supplies. Further, some of the bio-fuels currently used are neither cost-effective nor especially climate-friendly. Development and rising income *will* bring motorization however, and to sustain development governments have to look into alternative transport sources. Reducing dependence on automobiles requires attention on expanded public transport, increased use of bicycles, improved public safety and infrastructure, and encouraging people to walk for short distances to conduct their daily activities, which ultimately requires careful urban planning.

Several low-cost or no-cost measures are listed in the following. Some of these measures involve related design or equipment changes. Most of the manufacturers are already continuously modifying engine technologies to improve fuel efficiency. The measures categorized by impact are:

- The engine compression ratio is increased from 9.0 to 10.5, as enabled by improved cooling. Fuel-air intake ports are cooled by an "air liner" invented by Chrysler engineers that insulates the ports from the rest of the cylinder head in a way that cools the charge at wide-open throttle. (The device also warms the charge at low power, improving cold start performance.) Furthermore, uniform cooling of cylinder walls enables lower average temperature and simultaneously enables more uniform dimensions and thus reduced friction.
- The efficiency of an IC engine is low at low engine speed and load, in part because of poor mixing of the fuel-air charge. This has been corrected in many engines by using two intake valves per cylinder and almost closing one of them to enhance swirl. Chrysler engineers invented a less costly approach by installing a baffle valve before each intake port to create turbulence. The baffle valve is kept out of the way at wide open throttle.
- In cold start, the cold engine and transmission are warmed up quickly using sophisticated coolant controls including electronic thermostat, electric water pump, transmission temperature management and a multi-mode temperature strategy. In addition, the warm engine is turned off when vehicle is stopped, and then restarted with windings acting both as a relatively efficient generator and a motor powerful enough to quickly restart the engine. This is more modest and lower cost than integrated starter-generators being adopted in many hybrids.
- Friction by moving parts is reduced by as much as 8%. More uniform cylinder wall temperatures are achieved in part by a short "coolant jacket" that enables reduced tension in the oil ring. An improved air/oil separator in the positive crankcase ventilation system permits lower-viscosity oil. An off-set crankshaft, as already adopted in some small Honda and Toyota engines, reduces the normal force in the power stroke, with a net reduction in the friction of cylinder walls.
- Electrification of accessories, or electrical control, means that accessory load can be sharply reduced when the function isn't needed. Reduction of the air drag coefficient by somewhat over 10% results in a 1% added fuel savings by redesigning the oil pump.

Table 3-5. Measures and their impact in reducing fuel consumption

Measures	Impacts				
	Increase CR w/o knock	Increase low-speed efficiency	Decrease cold start & idling penalties	Lower engine friction	Decrease accessory & air drag loads
Air liner at intake port	X		X		
Precision cooling	X			X	
On-demand piston oil squirters	X				

Table 3-5. Measures and their impact in reducing fuel consumption (continued)

Measures	Impacts				
	Increase CR w/o knock	Increase low-speed efficiency	Decrease cold start & idling penalties	Lower engine friction	Decrease accessory & air drag loads
Intake port baffle/valve		X			
Low oil (piston) ring tension				X	
Lower-viscosity oil				X	
Off-set crankshaft				X	
Advanced cooling system controls & water pump			X		X
12-V alternator/restarter			X		X
Electrically controlled power steering					X
Redesigned oil pump					X
Belly pan & automatic grille shutters					X
Fuel consumption reduction	3 to 4%	4%	5 to 6%	3 to 4%	4%

Source: *Low-Cost and Near-Term Greenhouse Gas Emission Reduction.* Marc Ross, Physics Dept, University of Michigan, USA, 2003.

Conventional Technologies to Reduce Vehicle-Caused Greenhouse Gases

Public and private vehicles are a major cause of global warming due to release of carbon dioxide from incomplete and improper combustion. Most of the carbon dioxide (CO_2) emissions in vehicles derive from the combustion of gasoline or diesel. These vehicles are also responsible for emissions of other potent greenhouse gases such as nitrous oxide (N_2O) and methane (CH_4). In addition, vehicle air conditioners can leak hydrofluorocarbon-134a (HFC-134a), a greenhouse gas that is 1,300 times more potent than CO_2.

Table 3-6. Technologies for engine modifications to reduce GHG emissions

Engine technologies		Vehicle models
VTEC		Most Honda vehicles
Variable valve timing		Most Toyota vehicles, Ford F-150 (5.4 L Triton)
Cylinder deactivation		Honda Accord (V6), GM Vortec V8 engine family
Throttleless engine		BMW 3 series
Transmission technologies	Continuously variable transmission	Nissan Murano, Mini Cooper, Saturn Ion, Saturn Vue, Toyota Prius, Honda Civic hybrid, Honda Civic CNG
	Six-speed automatic transmission	Jaguar S-Type and XK Series
	Dual-clutch transmission	Audi TT 3.2 quattro
Hybrid Electric Vehicles		Honda Civic, Honda Insight, Toyota Prius, Ford Escape, Toyota Camry

Source: http://www.ucsusa.org/

Some Facts:

- Automatic shift manual transmissions can reduce GHG emission by reducing the mechanical losses associated with transmission operation.
- Variable Valve Timing (VVT) or Variable Valve Lift and Timing (VVLT): By providing a better fuel/air mix and improved combustion.
- Improvements in catalyst technology can reduce N_2O and CH_4 emissions.
- Engine modifications can reduce GHG emissions through reduction in engine friction and/or improved combustion.
- Aerodynamic drag can be reduced through sleeker design.
- Leaks of refrigerant accounts for approx. 2% of the CO_2-equivalent GHG emissions released each mile.
- The use of low rolling resistance tires reduces friction between the vehicle and the road, and can result in a 3% reduction in greenhouse gas emissions.
- The use of a 42-volt electrical system can reduce the engine load created by vehicle systems or accessories such as power-steering pumps, air conditioners, or lubrication systems.
- Integrated starter generators or belt-driven starter generators allow a vehicle to turn off at idle and then quickly restart, thereby eliminating emissions while stopped.

Many vehicle technologies are now commercially available to reduce GHG emissions. Most of these technologies are already in use in some mass-market vehicles, or are proven technologies ready to be utilized in new car models, often at little or no additional cost. With the growing concern about the global warming potential of transport vehicles, manufacturers are continuously modifying their engines to improve the fuel efficiency to reduce the GHG emissions. Some of the technologies used are presented below.

Promising Technologies to Reduce GHG Emissions from Transport Sector

Electric car	Bio-fuel

Short-term Measures
The following can be adopted as short-term measures to help reduce GHG emissions.

- Registration and annual fees based on efficiency, power, engine size, etc.
- Fuel taxes to restrain demand, account for externalities
- Fee rebate systems to reward fuel-efficient vehicles, penalize inefficient vehicles
- Parking "cash back" and taxes/restrictions
- Road pricing and central city access fees
- Other transport demand management strategies
- Encouragement of eco-driving

In order to discourage the use of private vehicles, government has to strengthen public transport, and carry out infrastructure planning for walking and biking. Some successful examples with encouraging results are given below:

- Bus rapid transit in Curitiba, Bogota, Quito, Seoul, etc.
- Chinese cities combining pedestrian areas, restricted bus lanes, bikeways
- London's pricing experiment, which has been replicated many cities
- Car pooling that has been organized in many metro areas of India

Some Important Tips:

- Instead of driving, ride a bike, use public transport or walk – get fit, reduced driving stress and save money.
- Organize car-pooling and car-sharing programs to reduce fuel consumption and money, as well.
- Buy a fuel-efficient car which may save up to 20 tons of GHG in its life-time.
- Use your car efficiently by driving smoothly which can save GHG up to 30% and fuel cost as well. Also, maintaining recommended maximum tire pressure can save up to 100 kg of GHG each year.
- Remove unnecessary weight for your car: It may be noted that 50 kg weight cuts almost 2% of GHG.
- Switch fuels: Diesel can cut GHG by up to 20% relative to petrol.
- Use car air conditioner appropriately as it can increase fuel consumption and GHG emissions, as well.
- Every liter of fuel saved cuts GHG emissions by 2.8 kg.

Long-term Measures
In the long run, hydrogen fuel cells, plug-in hybrids, and advanced bio-fuels are promising. Their benefits will depend on details of the full fuel cycle and how the hydrogen is produced and how the electricity is generated. If we talk about GHG

emissions potential from bio-fuels, ethanol from sugar cane provides the strongest emission reduction while ethanol from corn has more modest reductions. However, one has to look carefully into the conflict between food and fuel.

Another area that is emerging is bio-fuels from cellulosic materials such as plastics that appear most promising. In developed countries like Australia and Europe, the technologies have been developed to produce diesel from plastic; however, it will require substantial R&D in developing nations.

Technology improvement is crucial in the transport sector for the reduction of GHG emissions. There is need for hybridization of urban delivery vehicles, improved diesel engines, better aerodynamics for long-haul trucks, etc. Advanced technologies are used in many transport vehicles with reduced energy loads from 0.22 aero drag coefficient, 0.006 rolling resistance coefficient (RRC), 20% weight reduction, and super-efficient accessories. High-efficiency drive trains with direct injection (DI) gasoline or diesel, hybridization, advanced transmissions, etc. have been introduced to improve the energy efficiency of vehicles.

Electric cars for short distances are being used in India and are becoming quite popular among the general public.

For air transport, blended-wing bodies, laminar flow control, advanced turbofan engines and advanced traffic control systems are the future. While in marine shipping, sails and solar panels, advanced hydrodynamic hulls, and bio-fuels may be considered as alternatives to conventional technologies.

GHG reduction strategies for the transport sector are complex and will depend upon local conditions. A host of technological solutions are available to all nations, however it depends greatly how we shape our cities and provide transport services to all citizens. Careful planning can provide solutions on the issue of GHG emissions to bring about its reduction in most of the South Asian countries with their growing populations.

ANNEX 1

CONVERSION TABLES

	To:				
	TJ	Gcal	Mtoe	MBtu	GWh
From:	multiply by:				
TJ	1	238.8	2.388×10^{-5}	947.8	0.2778
Gcal	4.1868×10^{-3}	1	10^{-7}	3.968	1.163×10^{-3}
Mtoe	4.1868×10^{4}	10^{7}	1	3.968×10^{7}	11630
MBtu	1.0551×10^{-3}	0.252	2.52×10^{-8}	1	2.931×10^{-4}
GWh	3.6	860	8.6×10^{-5}	3412	1

	To:					
	gal U.S.	gal U.K	bbl	ft^3	l	m^3
From:	multiply by					
U.S. Gallon (gal)	1	0.8327	0.02381	0.1337	3.785	0.0038
U.K. Gallon (gal)	1.201	1	0.02859	0.1605	4.546	0.0045
Barrel (bbl)	42.0	34.97	1	5.615	159.0	0.159
Cubic foot (ft^3)	7.48	6.229	0.1781	1	28.3	0.0283
Liter (l)	0.2642	0.220	0.0063	0.0353	1	0.001
Cubic meter (m^3)	264.2	220.0	6.289	35.3147	1000.0	1

Source: *CP-EE Tool Kit.* National Cleaner Production Centre / National Productivity Council. (www.energyefficiencyasia.org)

ANNEX 2

COUNTRY-SPECIFIC ENERGY FACTORS

COUNTRY	NCV T J/kiloton	CO_2EF (tons of CO_2/ton of coal used)	COUNTRY	NCV T J/kiloton	CO_2EF (tons of CO_2/ton of coal used)
Albania	18.284	1.70	Kuwait	17.710	1.65
Algeria	19.176	1.78	Kyrgyzstan	18.673	1.73
Argentina	17.585	1.63	Latvia	20.306	1.89
Armenia	18.673	1.73	Lebanon	18.003	1.67
Australia	21.227	1.97	Libya	17.710	1.65
Austria	22.944	2.13	Lithuania	17.208	1.60
Azerbaijan	18.673	1.73	Luxembourg	24.493	2.28
Bahrain	17.710	1.65	Malaysia	19.427	1.80
Bangladesh	16.329	1.52	Mexico	21.353	1.98
Belarus	18.945	1.76	Moldova	18.573	1.73
Belgium	24.995	2.32	Morocco	18.631	1.73
Bolivia	17.710	1.65	Nepal	17.543	1.63
Bosnia and Herzegovina	20.334	1.89	Netherlands	24.702	2.29
Brazil	25.874	2.40	New Zealand	23.781	2.21
Brunei	17.710	1.65	Norway	28.303	2.63
Bulgaria	18.663	1.73	Pakistan	15.701	1.46
Canada	22.944	2.13	Paraguay	17.710	1.65
Chile	21.143	1.96	Peru	23.572	2.19
China	16.370	1.52	Poland	0.000	0.00
Colombia	17.124	1.59	Portugal	25.581	2.38
Croatia	20.464	1.90	Romania	13.188	1.23
Cuba	17.710	1.65	Russia	18.573	1.73
Czech Republic	20.222	1.88	Singapore	13.105	1.22
Denmark	24.283	2.26	Slovak Republic	20.071	1.86
Ecuador	19.176	1.78	South Africa	19.739	1.83
Egypt	17.710	1.65	South Korea	19.176	1.78
Estonia	15.910	1.48	Spain	20.934	1.94
Finland	23.069	2.14	Sri Lanka	17.710	1.65
France	26.544	2.47	Sweden	23.404	2.17
FYROM	20.334	1.89	Switzerland	26.084	2.42
Georgia	18.673	1.73	Syria	17.710	1.65
Germany	23.739	2.21	Tajikistan	18.673	1.73
Greece	19.301	1.79	Thailand	19.887	1.85
Hungary	19.301	1.79	Tunisia	17.710	1.65
Iceland	27.591	2.56	Turkey	22.232	2.07
India	16.454	1.53	Turkmenistan	18.673	1.73
Iran	17.710	1.65	U K	27.005	2.51
Iraq	17.710	1.65	Ukraine	19.427	1.80
Ireland	24.367	2.26	United Arab Emirates	17.710	1.65
Israel	17.250	1.60	Uruguay	17.710	1.65
Italy	24.283	2.26	USA	23.530	2.19
Japan	27.758	2.58	Uzbekistan	18.673	1.73
Jordan	17.710	1.65	Venezuela	17.710	1.65
Kazakhstan	18.673	1.73	Default	19.841	1.84

Source: *CP-EE Tool Kit.* National Cleaner Production Centre / National Productivity Council. (www.energyefficiencyasia.org)

ANNEX 3

FUEL-SPECIFIC EMISSION FACTORS

Fuels	Carbon Emission Factor (tC/TJ)	CO_2EF (tons of CO_2/ton used)
Gasoline	18.9	3.07
Natural gas	15.3	2.93
Gas/diesel oil	20.2	3.19
Residual fuel oil	21.1	3.08
LPG	17.2	2.95
Jet kerosene	19.5	3.17
Ethane	16.8	2.90
Naphtha	20.0	3.27
Bitumen	22.0	3.21
Lubricants	20.0	2.92
Petroleum coke	27.5	3.09
Refinery feedstock	20.0	3.25
Shale oil	20.0	2.61
Refinery gas	18.2	2.92
Other oil products	20.0	2.92

Source: *CP-EE Tool Kit.* National Cleaner Production Centre / National Productivity Council (www.energyefficiencyasia.org).

EMISSION FACTORS FOR TRANSPORT VEHICLES

Transport	CO_2 Emission Factor	
	t CO_2 / kilometer	t CO_2 / mile
Average petrol car [5]	0.000185	0.000299
Average diesel car	0.000156	0.000251
HGV	0.000782	0.00126

Source: *CP-EE Tool Kit.* National Cleaner Production Centre / National Productivity Council (www.energyefficiencyasia.org).

ANNEX 4

EMBODIED ENERGY AND EMISSIONS OF GOODS

Estimated embodied energy and emissions of goods, annualized over an assumed lifetime

Item	Ref	Number of items	Annual embodied energy (MJ per item)	Annual embodied emissions (kg CO_2e per item)	Expected lifetime (years)
Bicycle	1	1	133	21	15
Fridge, freezer	1	1	280	44	20
Washing machine	1	1	347	55	15
Dish washer, clothes drier, air conditioner	1	1	267	42	15
Toaster, iron, camera, small appliance	1	1	27	4	15
TV (15" or smaller), video camera	1	1	240	38	15
VCR, sound system, microwave	1	1	133	21	15
Computer system (CPU + screen+ keyboard)	3	1	1733	274	6
Stove	1	1	160	25	30
Sewing machine or large power tool	1	1	120	19	20
Bed plus mattress	1	1	240	38	20
Jacket	1	1	88	14	10
Trouser	1	1	64	10	5
Sweater	1	1	80	13	5
Shirt, blouse, hat	1	1	48	8	5
Underwear (10 pieces)	1	1	80	13	4
Sets of bedding (doona+blanket)	1	1	80	13	10
Sheets set (2 sheets + pillow case)	1	1	50	8	8
Lawnmower / edger (petrol)	1	1	132	21	20
		KG WEIGHT			
Boat, trailer, caravan (per kg)	4	300	1220	193	30
Sporting equipment (kg)	1	6	528	83	10
Wood furniture (kg)	1	100	133	21	30
Metal furniture (kg)	4	100	400	63	30
Metal / plastic small items, tools (kg)	1	1	12	2	10
Electronic appliances (kg)	1	30	480	76	15
Books (kg)	1	50	280	44	20
		SQ. METERS			
Vinyl / lino floor covering (sq. m)	1	50	200	32	20
Carpet - synthetic light- med weight	5	50	200	32	20
High quality wool carpet (sq. m)	1	50	500	79	30

Source: *Carbon Neutral.* Australian Greenhouse Office, www.carbonneutral.com.au.

PER CAPITA EMISSION FACTORS OF AIRCRAFT AND TRAINS

Transport mode	Basis	Emission factor for carbon dioxide (1CO_2/P.km)
Air- short haul[7]	Person, kilometer	0.00018
Air- long haul[8]	Person, kilometer	0.00011
Train[9]	Person, kilometer	0.000034

Source: *CP-EE Tool Kit.* National Cleaner Production Centre / National Productivity Council. (www.energyefficiencyasia.org)

ANNEX 5

Some Facts and Figures on Fuel, Its Consumption Pattern, and GHG Emissions

Source: The data presented in the following Tables (A5-1 to A5-11) are compiled from *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy.* World Resources Institute, 2005.

Table A5-1. Data on GHG emissions according to economic status (with world average)

No.	Item	Developed nations	Developing nations	World average
1	GHG emissions – $MECO_2e$ – Percent of world GHG	17,355 52%	16,310 48%	– –
2	Per capita emissions, 2000 – GHG (tons CO_2e) – CO_2 only	14.1 3.3	11.4 2.1	5.6 4.0
3	Emission intensity levels and trends – GHG intensity, 2000 (tons CO_2e / $ mil GDP PPP) – Percent change, 1999–2002 (Intensity CO_2 only)	633 –23	888 –12	715 –15
4	Cumulative CO_2 emissions, 1850–2002 – Percent of world levels	76%	24%	–
5	Income per capita – 2002 $ PPP – Percent growth, 1980–2002 (annual average)	22,254 0.9%	3,806 1.9%	6,980 1.3%

Table A5-2. World primary energy consumption and GHG emissions (by fuel type)

No.	Parameter	Fuel	Consumption level (%)
1		– Coal – Biomass – Oil – Natural gas – Nuclear – Hydro – Other RE	24 11 35 21 7 2 1
2	GHG emissions	– Coal – Oil – Natural gas – Fugitive*	37 37 20 6

* Fugitive includes GHG emissions from oil and gas (CO_2, CH_4) drilling / refining and coal mining (CHG).

Table A5-3. Absolute emissions in this sector in 2000 were 5,743 mt CO_2 share by fuel type

No.	Fuel	Consumption	CO_2 emission
1	Oil	96	97
2	Gas	3.2	2.7
3	Coal	0.3	0.4
4	Biomass	0.5	–

Table A5-4. Carbon content of fossil fuels

No.	Fossil fuels	Tons of carbon per TJ energy
1	Coal	26.8
2	Oil	20.0
3	Gas	15.3

Table A5-5. Selected data on fossil fuels

No.	Type of fuel	Carbon content (per ton J energy)	Parameters Reserve to Production (R/P) ratio, 2004	Consumer 2004 (incl T of oil equ.)	Projected growth of energy demand 2002–2030 (%)	Shares of fuel graded (%)
1	Coal	26.8	164	2,778	51	17
2	Oil	20.0	41	3,767	57	60
3	Gas	15.3	67	2,422	89	25

Table A5-6. Fossil fuel consumption by sector, 2002

No.	Sector	Consumption by fuel type (%)		
		Coal	Oil	Gas
1	Electricity	68	9	38
2	Industry	13	18	27
3	Transport	–	52	3
4	Residential and Commercial	–	15	27
5	Others	18	7	5

Table A5-7. Electricity and heat (share by fuel type)

No.	Fuel	Electricity generation (%)	Heat output (%)	CO_2 emissions (%)
1	Coal	38	36	73
2	Oil	7	8	10
3	Gas	20	53	16
4	Nuclear	17	–	–
5	Hydro	16	–	–
6	Biomass	1	3	–
7	Other RE	1	3	–

Table A5-8. Transport sector – 14% of total global GHG

No.	Sector	Emissions share (%)
1	Road	72
2	Domestic Air	5
3	Industrial Air	6
4	Industrial Marine	8
5	Other	8

Table A5-9. Building use, 15% of total global of GHG emissions

No.	Energy source	CO_2 contribution (%)	
		Residential 65	Commercial 35
1	Public electricity	43	65
2	Dist. heat	12	4
3	Direct fuel combustion	45	31
4	All sources	65	35

Table A5-10. Industrial sector, 21% of total global GHG emissions

No.	Fuel type	GHG contribution (%)
1	Fossil fuel combustion (CO_2)	49
2	Electricity and heat (CO_2)	35
3	Process emissions (CO_2)	10
4	High GWP gases	6

Table A5-11. GHG emissions from industrial sector according to process

No.	Major sub-sector	GHG contribution (%)
1	Chemicals & Petrochemicals	23
	– Fuel combustion	51
	– Electricity and heat	29
	– Adipic and nitric acid (N_2O)	8
	– OD5 substitute (HFCs)	7
	– HCFC 22 production	5
2	Cement	18
	– Process emissions	52
	– Fuel combustion	43
	– Electricity and heat	5
3	Iron & Steel	15
	– Direct fuel combustion	70
	– Electricity and heat	30
4	Aluminum	4
	– CO_2 electricity	61
	– PTCs	20
	– CO_2 process emissions	12
	– CO_2 from fossil fuels	7

Source: Adapted from *Navigating the Numbers: Greenhouse Gas Data and International Climate Policy – Part II.* World Resource Institute, 2005.

ANNEX 6

GLOBAL WARMING POTENTIAL (GWP) FACTORS

Trace gas	GWP	Trace gas	GWP
Carbon dioxide (CO_2)	1	HFC-143a	3800
CCI 4	1300	HFC-152a	140
CFC-11	3400	HFC-227ea	2900
CFC-113	4500	HFC-23	9800
CFC-116	>6200	HFC-236fa	6300
CFC-12	7100	HFC-245ca	560
CFC-l 14	7000	HFC-32	650
CFC-l 15	7000	HFC-41	150
Chloroform	4	HFC-43-lOmee	1,300
HCFC-123	90	Methane	21
HCFC-124	430	Methylenechloride	9
HCFC-141b	580	Nitrous Oxide	310
HCFC-142b	1600	Perfluorobutane	7000
HCFC-22	1600	Perfluorocyclobutane	8700
HFC-125	2800	Perfluoroethane	9200
HFC-134	1,000	Sulfur hexafluoride	23900
HFC-134a	1300	Trifluoroiodomethane	<1
HFC-143	300		

Source: • IPCC 1990 and 1996.
• *The GHG Indicator.* UNEP (http://www.uneptie.org/energy/act/ef/GHGin/).

ANNEX 7

CONVERSION FACTORS

To convert from	To	Multiply by
grams (g)	metric tons (t)	1×10^{-6}
kilograms (kg)	metric tons (t)	1×10^{-3}
megagrams	metric tons (t)	1
gigagrams	metric tons (t)	1×10^{3}
pounds (lb)	metric tons (t)	4.5359×10^{-4}
tons (long)	metric tons (t)	1.016
tons (short)	metric tons (t)	0.9072
barrels (petroleum, U.S.)	cubic meters (m^3)	0.15898
cubic feet (ft^3)	cubic meters (m^3)	0.028317
liters	cubic meters (m^3)	1×10^{-3}
cubic yards	cubic meters (m^3)	0.76455
gallons (liquid, U.S.)	cubic meters (m^3)	3.7854×10^{-3}
Imperial gallon	cubic meters (m^3)	4.54626×10^{-3}
joule	gigajoules (GJ)	1×10^{-9}
kilojoule	gigajoules (GJ)	1×10^{-6}
megajoule	gigajoules (GJ)	1×10^{-3}
terajoule (TJ)	gigajoules (GJ)	1×10^{3}
Btu	gigajoules (GJ)	1.05506×10^{-6}
calories, kg (mean)	gigajoules (GJ)	4.187×10^{-6}
ton oil equivalent (toe)	gigajoules (GJ)	4.22887×10^{-3}
kWh	gigajoules (GJ)	3.6×10^{-3}
Btu/ft^3	GJ/m^3	3.72589×10^{-5}
Btu/lb	GJ/metric tons	2.326×10^{-3}
lb/ft^3	metric tons/m^3	1.60185×10^{-2}
Psi	bar	0.0689476
kgf/cm^3 (tech atm)	bar	0.980665
atm	bar	1.01325
mile (statute)	kilometer	1.6093
ton CH_4	ton CO_2 equivalent	21
ton N_2O	ton CO_2 equivalent	310
ton carbon	ton CO_2	3.664

Source: http://www.ghgprotocol.org/standard/tools.htm

ANNEX 8

CONVERSION BETWEEN GROSS AND NET CALORIFIC VALUES

Units:

- MJ/kg: megajoules per kilogram
- 1 MJ/kg = 1 gigajoule/ton (GJ/ton)

Gross CV (GCV) or "higher heating value" (HHV) is the calorific value under laboratory conditions.

Net CV (NCV) or "lower heating value" (LHV) is the useful calorific value in boiler plants. The difference is essentially the latent heat of the water vapor produced.

Conversions:

- Gross/net (per ISO, for as received figures) in MJ/kg:

Net CV Gross CV 0.212H 0.0245M 0.008Y

where M is percent moisture, H is percent hydrogen, Y is percent oxygen (from ultimate analysis that determines the amount of carbon, hydrogen, oxygen, nitrogen, and sulfur) as received (i.e., includes total moisture (TM)).

Source: World Coal Institute.
More details at: http://www.worldcoal.org/pages/content/index.asp?PageID=190

ANNEX 9

DEFAULT NET CALORIFIC VALUES (NCVS) AND LOWER AND UPPER LIMITS OF THE 95% CONFIDENCE INTERVALS[1]

Fuel type description		Net calorific value (TJ/Gg)	Lower	Upper
Crude Oil		42.3	40.1	44.8
Orimulsion		27.5	27.5	28.3
Natural Gas Liquids		44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
Jet Kerosene		44.1	42.0	45.0
Other Kerosene		43.8	42.4	45.2
Shale Oil		38.1	32.1	45.2
Gas/Diesel Oil		43.0	41.4	43.3
Residual Fuel Oil		40.4	39.8	41.7
Liquefied Petroleum Gases		47.3	44.8	52.2
Ethane		46.4	44.9	48.8
Naphtha		44.5	41.8	46.5
Bitumen		40.2	33.5	41.2
Lubricants		40.2	33.5	42.3
Petroleum Coke		32.5	29.7	41.9
Refinery Feedstocks		43.0	36.3	46.4
Other Oil	Refinery Gas [2]	49.5	47.5	50.6
	Paraffin Waxes	40.2	33.7	48.2
	White Spirit and SBP	40.2	33.7	48.2
	Other Petroleum Products	40.2	33.7	48.2
Anthracite		26.7	21.6	32.2
Coking Coal		28.2	24.0	31.0
Other Bituminous Coal		25.8	19.9	30.5
Sub-Bituminous Coal		18.9	11.5	26.0
Lignite		11.9	5.50	21.6
Oil Shale and Tar Sands		8.9	7.1	11.1
Brown Coal Briquettes		20.7	15.1	32.0
Patent Fuel		20.7	15.1	32.0
Coke	Coke Oven Coke and Lignite Coke	28.2	25.1	30.2
	Gas Coke	28.2	25.1	30.2
Coal Tar [3]		28.0	14.1	55.0
Derived Gases	Gas Works Gas [4]	38.7	19.6	77.0
	Coke Oven Gas [5]	38.7	19.6	77.0
	Blast Furnace Gas [6]	2.47	1.20	5.00
	Oxygen Steel Furnace Gas [7]	7.06	3.80	15.0
Natural Gas		48.0	46.5	50.4
Municipal Wastes (non-biomass fraction)		10	7	18
Industrial Wastes		NA	NA	NA
Waste Oil [8]		40.2	20.3	80.0
Peat		9.76	7.80	12.5

Annex 9 (Continued)

Fuel type description		**Net calorific value (TJ/Gg)**	**Lower**	**Upper**
Solid Biofuels	Wood/Wood Waste [9]	15.6	7.90	31.0
	Sulphite lyes (black liquor) [10]	11.8	5.90	23.0
	Other Primary Solid Biomass [11]	11.6	5.90	23.0
	Charcoal [12]	29.5	14.9	58.0
Liquid Biofuels	Biogasoline [13]	27.0	13.6	54.0
	Biodiesels [14]	27.0	13.6	54.0
	Other Liquid Biofuels [15]	27.4	13.8	54.0
Gas Biomass	Landfill Gas [16]	50.4	25.4	100
	Sludge Gas [17]	50.4	25.4	100
	Other Biogas [18]	50.4	25.4	100
Other non-fossil fuels	Municipal Wastes (biomass fraction)	11.6	6.80	18.0

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5.

[2] Japanese data; uncertainty range: expert judgement

[3] EFDB; uncertainty range: expert judgement

[4] Coke Oven Gas; uncertainty range: expert judgement

[5-7] Japan and UK small number data; uncertainty range: expert judgement

[8] For waste oils the values of "Lubricants" are taken

[9] EFDB; uncertainty range: expert judgement

[10] Japanese data ; uncertainty range: expert judgement

[11] Solid Biomass; uncertainty range: expert judgement

[12] EFDB; uncertainty range: expert judgement

[13-14] Ethanol theoretical number; uncertainty range: expert judgement;

[15] Liquid Biomass; uncertainty range: expert judgement

[16-18] Methane theoretical number uncertainty range: expert judgement;

Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 2, Energy.* IPCC National Greenhouse Gas Inventories Program.

ANNEX 10

DEFAULT VALUES OF CARBON CONTENT

Fuel type description	Default carbon content [1] (kg/GJ)	Lower	Upper
Crude Oil	20.0	19.4	20.6
Orimulsion	21.0	18.9	23.3
Natural Gas Liquids	17.5	15.9	19.2
Motor Gasoline	18.9	18.4	19.9
Aviation Gasoline	19.1	18.4	19.9
Jet Gasoline	19.1	18.4	19.9
Jet Kerosene	19.5	19	20.3
Other Kerosene	19.6	19.3	20.1
Shale Oil	20.0	18.5	21.6
Gas/Diesel Oil	20.2	19.8	20.4
Residual Fuel Oil	21.1	20.6	21.5
Liquefied Petroleum Gases	17.2	16.8	17.9
Ethane	16.8	15.4	18.7
Naphtha	20.0	18.9	20.8
Bitumen	22.0	19.9	24.5
Lubricants	20.0	19.6	20.5
Petroleum Coke	26.6	22.6	31.3
Refinery Feedstocks	20.0	18.8	20.9
Refinery Gas [2]	15.7	13.3	19.0
Paraffin Waxes	20.0	19.7	20.3
White Spirit & SBP	20.0	19.7	20.3
Other Petroleum Products	20.0	19.7	20.3
Anthracite	26.8	25.8	27.5
Coking Coal	25.8	23.8	27.6
Other Bituminous Coal	25.8	24.4	27.2
Sub-Bituminous Coal	26.2	25.3	27.3
Lignite	27.6	24.8	31.3
Oil Shale and Tar Sands	29.1	24.6	34
Brown Coal Briquettes	26.6	23.8	29.6
Patent Fuel	26.6	23.8	29.6
Coke Oven Coke and Lignite Coke	29.2	26.1	32.4
Gas Coke	29.2	26.1	32.4
Coal Tar [3]	22.0	18.6	26.0
Gas Works Gas [4]	12.1	10.3	15.0
Coke Oven Gas [5]	12.1	10.3	15.0
Blast Furnace Gas [6]	70.8	59.7	84.0
Oxygen Steel Furnace Gas [7]	49.6	39.5	55.0
Natural Gas	15.3	14.8	15.9

Annex 10 (Continued)

Fuel type description	Default carbon content [1] (kg/GJ)	Lower	Upper
Municipal Wastes (non-biomass fraction)[8]	25.0	20.0	33.0
Industrial Wastes	39.0	30.0	50.0
Waste Oils [9]	20.0	19.7	20.3
Peat	28.9	28.4	29.5
Wood/Wood Waste [10]	30.5	25.9	36.0
Sulphite lyes (black liquor) [11]	26.0	22.0	30.0
Other Primary Solid Biomass [12]	27.3	23.1	32.0
Charcoal [13]	30.5	25.9	36.0
Biogasoline [14]	19.3	16.3	23.0
Biodiesels [15]	19.3	16.3	23.0
Other Liquid Biofuels [16]	21.7	18.3	26.0
Landfill Gas [17]	14.9	12.6	18.0
Sludge Gas [18]	14.9	12.6	18.0
Other Biogas [19]	14.9	12.6	18.0
Municipal Wastes (biomass fraction) [20]	27.3	23.1	32.0

Notes:

[1] The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

[2] Japanese data; uncertainty range: expert judgement;

[3] EFDB; uncertainty range: expert judgement

[4] Coke Oven Gas; uncertainty range: expert judgement

[5] Japan & UK small number data; uncertainty range: expert judgement

[6] 7. Japan & UK small number data; uncertainty range: expert judgement

[8] Solid Biomass; uncertainty range: expert judgement

[9] Lubricants ; uncertainty range: expert judgement

[10] EFDB; uncertainty range: expert judgement

[11] Japanese data; uncertainty range: expert judgement

[12] Solid Biomass; uncertainty range: expert judgement

[13] EFDB; uncertainty range: expert judgement

[14] Ethanol theoretical number; uncertainty range: expert judgement

[15] Ethanol theoretical number; uncertainty range: expert judgement

[16] Liquid Biomass; uncertainty range: expert judgement

[17-19] Methane theoretical number; uncertainty range: expert judgement

[20] Solid Biomass; uncertainty range: expert judgement

ANNEX 11

DEFAULT CO_2 EMISSION FACTORS FOR COMBUSTION[1]

Fuel type description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/12*1000	Lower	Upper
Crude Oil		20.0	1	73 300	71 100	75 500
Orimulsion		21.0	1	77 000	69 300	85 400
Natural Gas Liquids		17.5	1	64 200	58 300	70 400
Gasoline	Motor Gasoline	18.9	1	69 300	67 500	73 000
Gasoline	Aviation Gasoline	19.1	1	70 000	67 500	73 000
Gasoline	Jet Gasoline	19.1	1	70 000	67 500	73 000
Jet Kerosene		19.5	1	71 500	69 700	74 400
Other Kerosene		19.6	1	71 900	70 800	73 700
Shale Oil		20.0	1	73 300	67 800	79 200
Gas/Diesel Oil		20.2	1	74 100	72 600	74 800
Residual Fuel Oil		21.1	1	77 400	75 500	78 800
Liquefied Petroleum Gases		17.2	1	63 100	61 600	65 600
Ethane		16.8	1	61 600	56 500	68 600
Naphtha		20.0	1	73 300	69 300	76 300
Bitumen		22.0	1	80 700	73 000	89 900
Lubricants		20.0	1	73 300	71 900	75 200
Petroleum Coke		26.6	1	97 500	82 900	115 000
Refinery Feedstocks		20.0	1	73 300	68 900	76 600
Other Oil	Refinery Gas	15.7	1	57 600	48 200	69 000
Other Oil	Paraffin Waxes	20.0	1	73 300	72 200	74 400
Other Oil	White Spirit & SBP	20.0	1	73 300	72 200	74 400
Other Petroleum Products		20.0	1	73 300	72 200	74 400
Anthracite		26.8	1	98 300	94 600	101 000
Coking Coal		25.8	1	94 600	87 300	101 000
Other Bituminous Coal		25.8	1	94 600	89 500	99 700
Sub-Bituminous Coal		26.2	1	96 100	92 800	100 000
Lignite		27.6	1	101 000	90 900	115 000
Oil Shale and Tar Sands		29.1	1	107 000	90 200	125 000
Brown Coal Briquettes		26.6	1	97 500	87 300	109 000
Patent Fuel		26.6	1	97 500	87 300	109 000
Coke	Coke oven coke and lignite Coke	29.2	1	107 000	95 700	119 000
Coke	Gas Coke	29.2	1	107 000	95 700	119 000
Coal Tar		22.0	1	80 700	68 200	95 300
Derived Gases	Gas Works Gas	12.1	1	44 400	37 300	54 100
Derived Gases	Coke Oven Gas	12.1	1	44 400	37 300	54 100
Derived Gases	Blast Furnace Gas [4]	70.8	1	260 000	219 000	308 000
Derived Gases	Oxygen Steel Furnace Gas [5]	49.6	1	182 000	145 000	202 000

Annex 11 (Continued)

Fuel type description		Default carbon content (kg/GJ)	Default carbon oxidation Factor	Effective CO_2 emission factor (kg/TJ) [2]		
				Default value	95% confidence interval	
		A	B	C=A*B*44/ 12*1000	Lower	Upper
Natural Gas		15.3	1	56 100	54 300	58 300
Municipal Wastes (non-biomass fraction)		25.0	1	91 700	73 300	121 000
Industrial Wastes		39.0	1	143 000	110 000	183 000
Waste Oil		20.0	1	73 300	72 200	74 400
Peat		28.9	1	106 000	100 000	108 000
Solid Biofuels	Wood/Wood Waste	30.5	1	112 000	95 000	132 000
	Sulphite lyes (black liquor)[5]	26.0	1	95 300	80 700	110 000
	Other Primary Solid Biomass	27.3	1	100 000	84 700	117 000
	Charcoal	30.5	1	112 000	95 000	132 000
Liquid Biofuels	Biogasoline	19.3	1	70 800	59 800	84 300
	Biodiesels	19.3	1	70 800	59 800	84 300
	Other Liquid Biofuels	21.7	1	79 600	67 100	95 300
Gas biomass	Landfill Gas	14.9	1	54 600	46 200	66 000
	Sludge Gas	14.9	1	54 600	46 200	66 000
	Other Biogas	14.9	1	54 600	46 200	66 000
Other non-fossil fuels	Municipal Wastes (biomass fraction)	27.3	1	100 000	84 700	117 000

Notes:

1 The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5

2 TJ = 1000GJ

3 The emission factor values for BFG includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas.

4 The emission factor values for OSF includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas

5 Includes the biomass-derived CO_2 emitted from the black liquor combustion unit and the biomass-derived CO_2 emitted from the kraft mill lime kiln.

Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 2 Energy.* IPCC National Greenhouse Gas Inventories Programme.

ANNEX 12

IP TABLE CONVERSION

Table A12-1: Roof U-factor Requirements (U-factor in Btu/h-ft^2-°F)

Climate Zone	24-Hour	Daytime
Composite	0.046	0.072
Hot and dry	0.046	0.072
Warm and humid	0.046	0.072
Moderate	0.072	0.072
Cold	0.046	0.072

Table A12-2: Wall U-factor Requirements (U-factor in Btu/h-ft^2)

Climate Zone	24-Hour	Daytime
Composite	0.062	0.062
Hot and dry	0.065	0.062
Warm and humid	0.062	0.062
Moderate	0.076	0.070
Cold	0.065	0.062

Table A12-3: Fenestration U-factor Requirements (U-factor in Btu/h-ft^2)

Climate	U-factor	SHGC
Composite	0.56	0.25
Hot and dry	0.56	0.25
Warm and humid	0.56	0.25
Moderate	1.22	0.40
Cold	0.72	0.51

Source: *Energy Conservation Building Code (ECBC) 2006.* Bureau of Energy Efficiency of India.

Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 2 Energy.* IPCC National Greenhouse Gas Inventories Program.

ANNEX 13

GUIDELINES FOR GREENHOUSE GAS INVENTORIES

Sector	Energy				
Category	Reference Approach (Auxiliary Worksheet 1-1: Estimating Excluded Carbon)				
Category Code	1A				
Sheet	1 of 1 Auxiliary Worksheet 1-1: Estimating Excluded Carbon				
	A Estimated Fuel Quantities	B Conversion Factor (TJ/Unit)	C Estimated Fuel Quantities (TJ)	D Carbon content (t C/TJ)	E Excluded Carbon (Gg C)
Fuel Types			C=A*B		E=C*D/1000
LPG(a)					
Ethane(a)					
Naphtha(a)					
Refinery Gas(a) (b)					
Gas/Diesel Oil(a)					
Other Kerosene(a)					
Bitumen(c)					
Lubricants(c)					
Paraffin Waxes(b)					
White Spirit(b) (c)					
Petroleum Coke(c)					
Coke Oven Coke(d)					
Coal Tar (light oils					
Coal Tar (coal)					
Natural Gas(g)					
Other fuels(h)					
Other fuels(h)					
Other fuels(h)					

Notes: Deliveries refers to the total amount of fuel delivered and is not the same thing as apparent consumption (where the production of secondary fuels is excluded).
- Enter the amount of fuel delivered to petrochemical feedstocks.
- Refinery gas, paraffin waxes and while spirit are included in “other oil”.
- Total deliveries.
- Deliveries to the iron and steel and non-ferrous metals industries.
- Deliveries to chemical industry.
- Deliveries to chemical industry and construction.
- Deliveries to petrochemical feedstocks and blast furnaces.
- Use the Other fuels rows to enter any other products in which carbon may be stored. These should correspond to the products shown in Table 1-1.

Source: *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 2 Energy.* IPCC National Greenhouse Gas Inventories Program.

GHG GLOSSARY

Activity data
Data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time. In the energy sector, for example, the annual activity data for fuel combustion sources are the total amounts of fuel burned. Annual activity data for methane emissions from enteric fermentation are the total number of animals being raised, by species.

Anthropogenic
Man-made, resulting from human activities. In the *Guidelines*, *anthropogenic* emissions are distinguished from *natural* emissions. Many of the greenhouse gases are emitted naturally. It is only the man-made increments over natural emissions which may be perturbing natural balances.

Base year
The year for which a GHG inventory is to be taken. This is currently 1990. In some cases (such as estimating CH_4 from rice production) the base year is simply the middle of a three-year period over which an average must be taken.

Calorific value
The calorific value of a fuel is a measure of its value for heating purposes. It is expressed in terms of the heat released from a specified unit quantity under defined conditions of complete combustion. The calorific value is sometimes referred to as the heating value of the fuel.

Two measures of calorific value are possible and are referred to as the net (NCV) and gross (GCV) calorific values. Also termed the lower (LHV) and higher (HHV) heating values.

The GCV is the total quantity of heat released during combustion when all water formed by the combustion reaction is returned to the liquid state.

The NCV is the total quantity of heat released during combustion when all water formed by the combustion reaction remains in the vapor state.

The NCV is therefore less than the GCV. For natural gas this difference is approximately 9–10% while for oils and coals the difference is approximately 5%.

Net calorific values are used and expressed in SI units, for example TJ/kt. The term *conversion factor* has two uses. First, as net calorific value, to convert quantities expressed in natural units to energy units and, secondly as a scaling factor to convert one form of energy unit to another (e.g., Btu to GJ).

Carbon dioxide equivalent
This is a metric measure used to compare the emissions from various GHGs based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents ($MMTCO_2E$)." The carbon dioxide equivalent for a gas is derived by multiplying the tons of gas by the associated GWP.

$MMTCO_2e$ = (million metric ton of gas) x (GWP of the gas)

CFCs
See Chlorofluorocarbons.

Chlorofluorocarbons (CFCs)
Hydrocarbon derivatives consist of carbon, chlorine, and fluorine, in which chlorine and fluorine partly or completely replace the hydrogen. Chlorofluorocarbons are chemical substances that have been used in refrigeration, foam blowing, etc. CFCs contribute to the depletion of the earth's ozone layer in the upper atmosphere. Although they are greenhouse gases, they are not included in the *Guidelines* because they are already being regulated under the Montreal Protocol.

Conversion factor
See Calorific value.

Emission factor
This is a coefficient that relates activity data to the amount of the chemical compound that is the source of later GHG emissions. Emission factors are often based on a sample of measurement data that is averaged to develop a representative rate of emission for a given activity level under a given set of operating conditions.

Fossil fuels
Fossil fuels comprise combustible fuels formed from organic matter within the Earth's crust over geological time scales and products manufactured from them. The fuels extracted from the Earth and prepared for market are termed "primary fuels" (e.g., coal, natural gas, crude oil, lignite) and fuel products manufactured from them are termed "secondary fuels" (e.g., coke, blast furnace gas, gas/diesel oil).

Fugitive emissions
Fugitive emissions are intentional or unintentional releases of gases from anthropogenic activities. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not support a productive activity (e.g., flaring of natural gases at oil and gas production facilities).

Gas/diesel oil
Gas/diesel oil is a medium distillate oil primarily distilling between 180° and 380°C. Several grades are available depending on use:

- diesel oil for diesel compression ignition (cars, trucks, marine, etc.);
- light heating oil for industrial and commercial use;
- other gas oil, including heavy gas oils that distil between 380° and 540°C, and which are used as petrochemical feed stocks.

Gasoline
Gasoline includes the following products:

Aviation gasoline
This is motor spirit prepared especially for aviation piston engines, with an octane number suited to the engine, a freezing point of –60°C and a distillation range usually within the limits of 30°C and 180°C.

Jet gasoline (naphtha-type jet fuel or JPA)
A light hydrocarbon oil distilling between 100°C and 250°C for use in aviation turbine power units. It is obtained by blending kerosenes and gasoline or naphthas in such a way that the aromatic content does not exceed 25% in volume, and the vapor pressure is between 13.7 kPa and 20.6 kPa.

Motor gasoline
Motor gasoline consists of a mixture of light hydrocarbons distilling between 35° and 215°C. It is used as a fuel for land-based spark ignition engines. Motor gasoline may include additives, oxygenates, and octane enhancers, including lead compounds such as TEL (tetraethyl lead) and TML (tetramethyl lead).

Global warming potential (GWP)
GWP is defined as the cumulative radiative forcing effects of a gas over a specified time horizon resulting from the emission of a unit mass of gas relative to a reference gas. The reference gas is considered as carbon dioxide. The molecular weight of carbon is 12, and that of oxygen is 16; therefore the molecular weight of carbon dioxide is 44 (12 + [16 x 2]), as compared to 12 for carbon alone. Thus carbon comprises 12/44ths of carbon dioxide by weight.

Greenhouse gases
The current IPCC inventory includes six major greenhouse gases.

Three direct greenhouse gases are included: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O); and three precursor gases are included: carbon monoxide (CO), oxides of nitrogen (NOx), and non-methane volatile organic compounds (NMVOCs).

Other gases that also contribute to the greenhouse effect are being considered for inclusion in future versions of the *Guidelines*.

HFCs
See Hydrofluorocarbons.

Hydrofluorocarbons (HCFC)
Hyrocarbon derivatives consisting of one or more halogens that partly replace the hydrogen. The abbreviation HCFC followed by a number designates a chemical product of the chlorofluorocarbon (CFC) family.

IPCC
The Intergovernmental Panel on Climate Change, which is a special intergovernmental body established by UNEP and the WMO to provide assessments of the results of climate change research to policy makers. The *Greenhouse Gas Inventory Guidelines* are being developed under the auspices of the IPCC and will be recommended for use by parties to the Framework Convention on Climate Change (FCCC).

LULUCF
Land use, land-use change, and forestry.

Montreal Protocol
This is the international agreement that requires signatories to control and report emissions of CFCs and related chemical substances that deplete the Earth's ozone layer. The Montreal Protocol was signed in 1987 in accordance with the broad principles for protection of the ozone layer agreed in the Vienna Convention (1985). The Protocol came into force in 1989 and established specific reporting and control requirements for ozone-depleting substances.

OECD
The Organization for Economic Co-operation and Development, which is a regional organization of free-market democracies in North America, Europe, and the Pacific.

Process emissions
Emissions from industrial processes involving chemical transformations other than combustion.

UNFCCC
United Nations Framework Convention on Climate Change

U.S. EPA
United States Environmental Protection Agency

FURTHER READING

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IMPORTANT WEBSITES

http://www.carbonmcgroup.com/

http://www.ucsusa.org/

http://buildlca.rmit.edu.au/

http://www.worldenergy.org